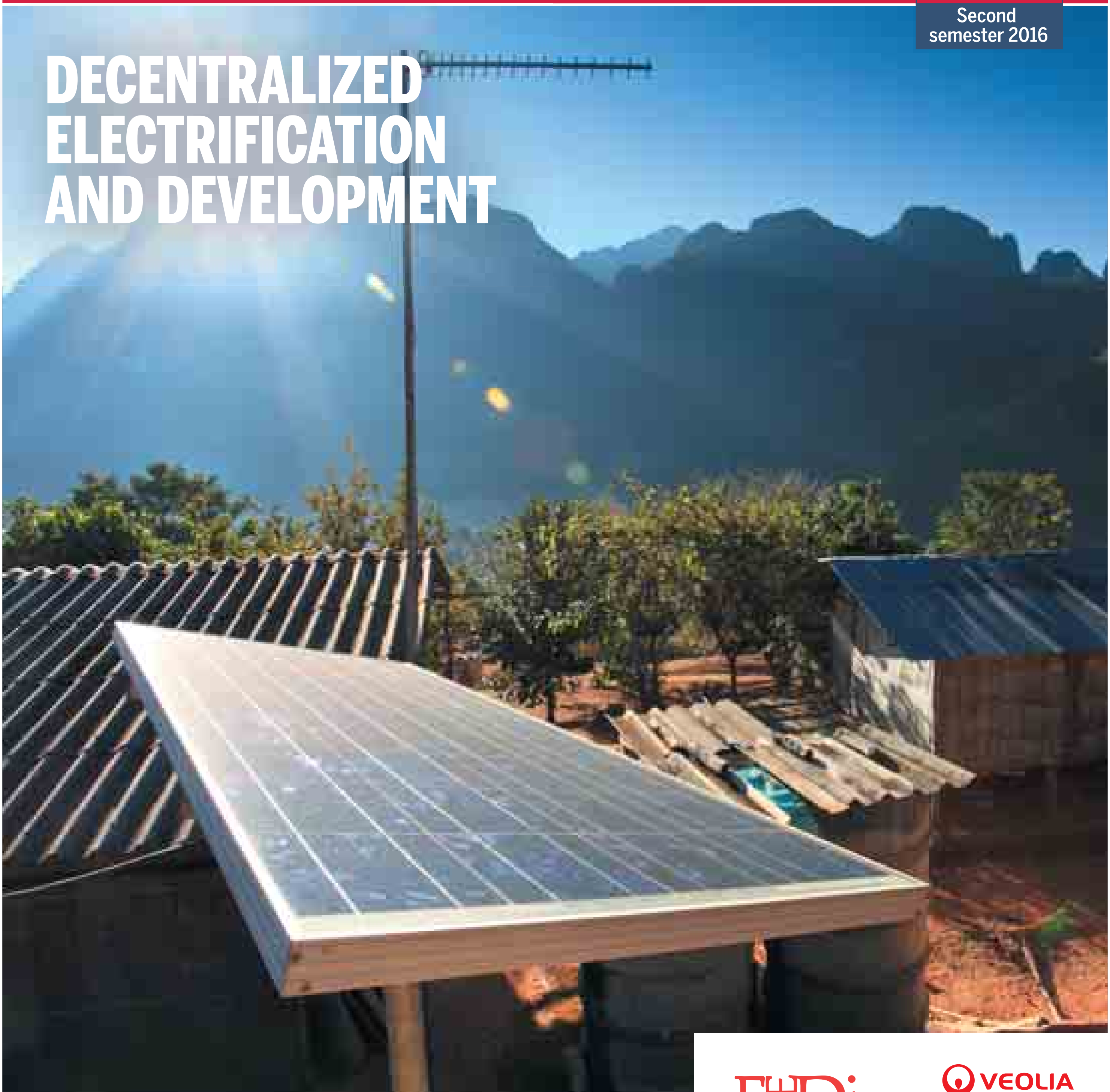
FIELD ACTIONS SCIENCE REPORTS

FACTS REPORTS

Second semester 2016

DECENTRALIZED ELECTRIFICATION AND DEVELOPMENT



Coordinated by **J-C. BERTHÉLEMY and V. BÉGUERIE**

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is published by
VEOLIA INSTITUTE
15 rue des Sablons
75016 Paris, France
www.institut.veolia.org/en

ABOUT FACTS REPORTS

AIM AND SCOPE

FACTS Reports is an international, peer-reviewed journal, devoted to promoting field-based activities in developing and developed countries and is open access for both readers and authors. Created in 2007, FACTS provides a unique forum for the expression and exchange of ideas in various fields, including economy and development, cities and urban services, health, education, environment, and agriculture.

Articles are subjected to peer review by field practitioners or academics. The main criteria for publication are that the articles describe actions that are both useful and reproducible. Editorials and Commentaries are also published, allowing experts from diverse fields to contribute critical analysis, and encouraging cooperation among authors.

OBJECTIVES

The principal objective of FACTS Reports is to help field practitioners, international organisations, national agencies and policy-makers communicate best practices and lessons learned through the implementation of their programmes. Many field practitioners implement projects in developing countries to address issues related to economics, health, the environment, agriculture, education and development in general. There are many opportunities to learn from the outcomes of these projects.

The journal is a unique international initiative and, moreover, the first of its type in the world. It provides an independent platform for key players in development to share best practices, to express their views and opinions, to share their experiences and to cooperate with other international development actors from around the world.

http://factsreports.revues.org/

Issuing Body
Field Actions Science Reports (FACTS)
is published by the Veolia Institute.
EISSN: 1867-8561

Contact:
facts-reports.ve@institut.veolia.org

Graphic Design
INCREA

Printed in France
with vegetable-based inks by an environmental printer (a member of Imprim'vert) on chlorine-free paper from well-managed forests and other controlled sources, certified in accordance with the standards of the Forest Stewardship Council.

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We gratefully thank Olivier Santoni (Geomatics specialist at FERDI) for his precious work on the maps of this special issue.

This special issue of FACTS Reports benefited from the financial support of the program "Investissements d'Avenir" (reference ANR-10-LABX-14-01) of the French government.

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PREFACE

"The initiatives discussed in this issue of FACTS are not only new economic models, but also new social models."

Jean-Michel Severino
CEO, Investisseurs & Partenaires

"This issue of FACTS deals with a social and technological revolution that is still in its early days: decentralized energy in developing countries."

The full impact of this revolution is yet to be determined, but it is sure to be profound. In a conservative scenario, which would already represent a great success, this revolution would be a phase of acceleration towards the centralized model of industrial countries. In a more optimistic scenario, the revolution would create (notably in Africa, which is the ideal region for such) a new energetic model that is the complete opposite of centralized models. And taking the scenario to its extreme, the revolution would spread to industrialised countries, thus becoming a new example of "reverse innovation".

It is still too soon to judge. Evolutions in technology, among many other factors, will decide the outcome. It is nevertheless already probable that, over the next two or three decades, hundreds of millions of households in Africa, Asia and Latin America will see their quality of life transformed: which is no small achievement.

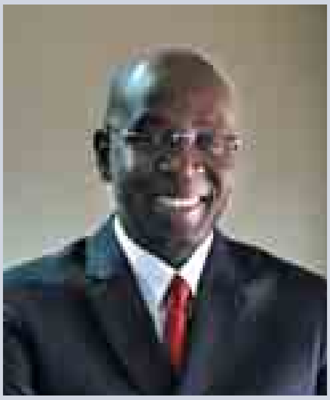
But the story doesn't stop there. The initiatives discussed in this issue of FACTS are not only new economic models, but also new social models. Applications of decentralized energy include provision of solar lamps, individual solar systems, kiosks, and mini-grids. The first three of these — which are also the most important quantitatively — have the common defining characteristic of connecting the consumer directly to the manufacturer or service provider. In these energy models, there is no energy producer, only suppliers of solutions. This is what allows new businesses, whether for profit or not-for-profit, to escape the constraints of energy sector regulations that render the sector incapable of providing energy to poor populations, as is the case with the often ineffective and inefficient national energy utilities. Households or small businesses, currently mostly rural or peri-urban, are no longer beholden to an inexistent or patchy public service, and become customers, beneficiaries of a growing number of competitive offers. Anyone who understands the energy industry will immediately see the important political and institutional consequences of this shift.

It's also an exciting tale of innovation. Take individual solar systems, for example ; their novelty derives from the combination of three great recent innovations: the mobile telephone, photovoltaic energy, and microfinancing. This story is ongoing, because the technological solutions in question will continue to evolve, as will economic models: how far, for example, will production and storage capacities of individual systems continue to grow, and could they eventually be connected into a grid, thus reversing the manner in which mini-grids are currently conceived? As for economic models, there are two competing business models for decentralized individual systems: mini-utilities, which effectively supply current, and mini-leasers, which effectively supply equipment. Which model will come out on top? One of them, or both of them?

Finally, this sector has seen the birth of businesses that are entirely African-owned, even if their creators are not always African. It is practically a certainty that in the next thirty years, some of these businesses will be among the top players in the African market. Indeed, the economic growth of the sector is very important, driven by both the socio-economic performance of the proposed solutions, and the mobilisation of international funding to support it. Despite the importance of social actors in this field, it is not only NGOs that are investing in it: investment funds—primarily from North America (but there are French ones too...!), multinationals from the energy sector and telecommunications companies are becoming increasingly involved in securing the financial success of what is considered to be the next big industry.

When I began my career in development thirty years ago, I thought with sadness that of all the major challenges associated with the fight against poverty, "last mile access" to energy would be the most difficult to overcome, and I was sure that I would never see it in my lifetime. The revolution of decentralized energy in Africa is both humbling and exciting: because in its most ambitious version, in countries where centralized structures are particularly lacking, the "last mile" will perhaps be crossed before the first, and it would seem that a great part of this rural energy battle may be won in the next thirty years... with the immense impact on poverty and development that one might expect. Bravo Africa!

FOREWORD



"The development of renewables-based off-grid electrification solutions would appear to be the only viable solution in the near to medium term if electricity is to gradually stop being an often unaffordable luxury for African consumers."

Thierno Bocar Tall
Chairman and CEO, African Biofuel and Renewable Energy Company (ABREC)

"We will make electricity so cheap that only the rich will burn candles."

Although Thomas Edison's famous 1887 boast turned out to be prophetic for the western world, there is no avoiding the fact that it still does not apply to developing countries, most notably in sub-Saharan Africa. Here, access to electricity is a luxury, with an overall penetration rate of 32%, falling to just 17% in rural areas, and electricity prices are often very high. In the face of the twin barriers of cost and availability, most households still rely on energy solutions such as firewood, candles, kerosene lanterns and battery lanterns that are time-consuming in terms of gathering fuel, unreliable, and destructive for the environment and users' health.

Ambitious projects to extend national utility grids all the way out to rural areas will have zero impact on this reality for the foreseeable future. Furthermore, a feature of these projects is an energy mix that relies heavily on fossil fuels, which rules them out as a solution for Africa's energy future. On the contrary, the development of renewables-based off-grid electrification solutions would appear to be the only viable solution in the near to medium term if electricity is to gradually stop being an often unaffordable luxury for African consumers.

Recent technological advances that give us access to solutions for the production of electricity from renewable sources at ever lower prices and using equipment that is relatively quick and simple to install, without the need for any megaprojects, represent a historic opportunity. This is the process the African Biofuel and Renewable Energy Company (ABREC) has been working on since 2009.

Africa has rich renewable energy resources and it is high time they were put to use. The goal must be to massively increase renewables' share of the energy mix and the capacity and reliability of utility grids, and to reduce the energy gap, primarily through rural electrification, in regions where utility grids will never reach.

The sheer number of private and public actors engaged in setting up off-grid renewable solutions for access to electricity makes it hard to get a clear idea of how the sector is developing and the trends affecting it, both in sub-Saharan Africa and everywhere else where access to electricity remains a challenge.

This issue of FACTS Reports takes us on a journey from Laos to Rwanda, India to Madagascar and Uganda to Brazil, looking at real-life applications and offering us a geographical and technological overview of the solutions that are beginning to spread across areas of the developing world that still lack electricity.

This issue lays the groundwork for identifying best practices: choice of technologies, organizational structure, funding method, and so on. This is a process that depends on increasing assessments of field experiences and understanding and comparing the various barriers and opportunities that characterize every situation. Identifying best practices is a necessary precondition to the transition to renewable energy sources that the whole world is demanding, for our energy future depends on such a transition — nowhere more so than in Africa.

INTRODUCTION

Decentralized electrification and development: initial assessment of recent projects

Jean-Claude Berthélemy and Victor Béguerie - Coordinators

Jean-Claude Berthélemy is Professor of Economics at Paris 1 Pantheon-Sorbonne University and former Dean of its School of Economics, and is co-director of the school's "sustainable development economics" research area. He is also Senior Fellow of the FERDI, where he heads research on access to electricity as part of the "Environment, climate and development" program, and a corresponding member of the Academy of Moral and Political Sciences (ASMP) of the Institut de France.

Victor Béguerie is research officer of the program "Environment, climate and development" at FERDI. His work focuses on access to modern energy and electricity, on their impacts on household living conditions and on their reliability. He holds a PhD in development economics of CERDI – Université d'Auvergne. His PhD brought him to Burkina Faso to analyze the impact of the Multifunctional Platform program on woman and child living conditions.

Recent years have seen the development of a great many initiatives to increase access to electricity in under-served regions. And yet, despite these actions and a growing awareness in the international community of the important part access to electricity can play in driving down poverty (DFID, 2002; ECOWAS and UEMOA, 2006), much work remains to be done if we are to meet Sustainable Development Goal 7: ensure access to affordable, reliable, sustainable and modern energy for all. Some 1.2 billion people remain without electricity (IEA, 2015), i.e. 17% of the global population. Of these people, 97% live in sub-Saharan Africa or developing Asian countries (Ibid.). There are significant regional disparities in electrification rates. The goal of universal electricity access is close to achievement in North Africa, the Middle-East and South America, where electrification rates are 99%, 92% and 95% respectively (Ibid.). Most of the problems in access to electricity are concentrated in rural areas of sub-Saharan Africa and developing Asian countries, where rural electrification rates are 17% and 78% respectively, as illustrated in Figure 1.

EXTENDING UTILITY GRIDS AND DECENTRALIZED ELECTRIFICATION: TWO COMPLEMENTARY APPROACHES

Until recently, initiatives looking to drive up access to electricity were focused on the major utility grids, which also dovetailed with in-house expertise at the major development financing institutions. But some of the more recent initiatives (Power Africa and New Deal on Energy for Africa in particular) also include off-grid electrification projects. Many NGOs of all sizes and companies from the private sector have been involved in off-grid projects for a number of years.

There are several reasons that argue in favor of this heightened interest in decentralized solutions, at least for areas of the world where electrification rates lag, i.e., sub-Saharan African and South-East Asia.

Extending major utility grids is extremely expensive as inhabitants are spread out over vast distances and transmitting electricity over long distances is very costly. As an example, in 2015 the Association for the Development of Energy in Africa (ADEA) costed at USD 884 billion Jean-Louis Borloo's plan for universal electrification across Africa by 2040. The plan is essentially based on upgrading the generating and distribution capacities of major utility grids, with over half the total amount corresponding to electricity transmission and distribution infrastructure.

CHRONOLOGY OF THE MAIN RECENT INITIATIVES TO PROMOTE ELECTRIFICATION

2016
- Electrification Financing Initiative (European Commission)
- Africa Power Vision (African Union Commission, New Partnership for Africa's Development, Nigerian ministry of finance, United Nations Economic Commission for Africa, African Development Bank)

2015
- New Deal on Energy for Africa (African Development Bank)
- Energy Africa campaign (DFID)
- African Energy Leaders Group (Heads of State and business leaders)
- Energy Access Ventures Fund (Schneider Electric, CDC Group, DFID, European Investment Bank, FISEA, PROPARCO, OFID and AFD-FFEM)
- Énergies pour l'Afrique (Jean-Louis Borloo)

2013
- Power Africa (Obama presidency)

2012
- Sustainable Energy Fund for Africa (African Development Bank)
- Access to Energy Initiative (World Business Council for Sustainable Development)
- Global Electricity Initiative (initiative supported by the World Energy Council)
- Global Lighting and Energy Access Partnership (inter-governmental initiative)

2011
- Sustainable Energy for All (United Nations)

2008
- Africa Electrification Initiative (World Bank)

2007
- Lighting Africa (World Bank)

It is interesting to note that even where potential customers live close to a utility grid ("under grid") they do not always connect to it. Lee et al. (2014) used Kenyan data to show that half of all households not connected to the grid live less than 200 meters from a low voltage power line. Connection costs account for part of this phenomenon, but to understand its true significance it is important to remember how unreliable electrical grids are in regions where electricity supply remains under-developed.

Decentralized solutions, whether individual or collective (micro-grids and kiosks) offer a partial response to the challenges posed by the very high cost and poor reliability of the major utility grids. This phenomenon has long been observed among industrial users in sub-Saharan Africa, where most companies whose output relies on electricity use standalone generators to compensate for outages in the utility grid supply, which they are also connected to, even though using generators to produce electricity is expensive.

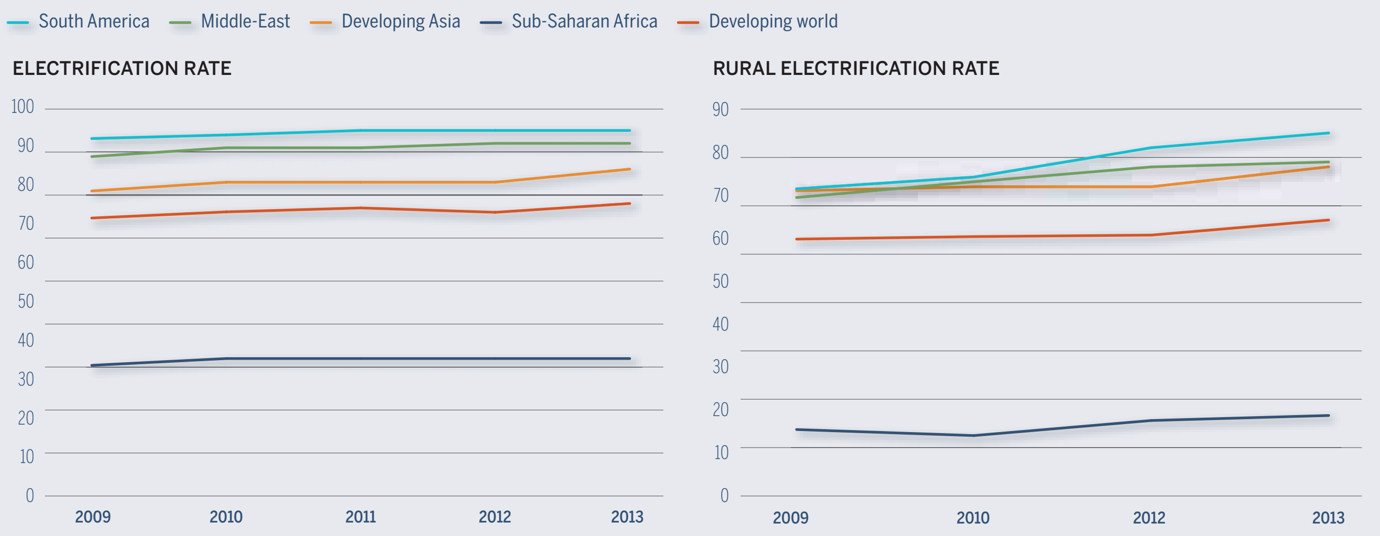
Decentralized solutions for access to electricity offer more limited supplies of electricity than would be available from a utility grid, particularly in terms of the amount of power available. However, none of the farming and small-scale service or craft activities that could develop in these rural areas (lighting, refrigeration, irrigation and use of small electrical tools) require a high-power electrical supply. Furthermore, according to the World Bank (2014), these are some of the types of activity that have had the biggest impact in driving down poverty in sub-Saharan Africa. So, the development of decentralized electrification might be a realistic option as part of a development policy focused on poverty eradication.

The quest for renewable energy sources (mainly solar, but also wind, hydro, biomass and geothermal) is fully compatible with off-grid projects. In the current context, where sustainable development and climate change are central to the challenges facing our planet, it is vital that efforts to close the energy gap focus on mechanisms that are sustainable and environmentally friendly. This is something that can be achieved with decentralized solutions that rely wholly or partially on renewables. Technical solutions employing renewable energy exist and have already proved their worth, such as micro-hydroelectric, solar, wind and hybrid power plants, kiosks, solar kits and lamps. In addition, with prices for solar panels falling by as much as 67% between 2011 and 2020, the cost of PV-generated electricity will by then be comparable to the cost of electricity from conventional sources (de la Tour et al., 2014).

The many initiatives and the lack of coordination between them make it impossible to identify and evaluate the many decentralized electrification solutions that have recently been developed or are emerging. This makes it impossible to have a clear vision of the respective merits of the various solutions on offer, which may also be wholly dependent on the geographical and institutional contexts that they are deployed in.

"EXTENDING MAJOR UTILITY GRIDS IS EXTREMELY EXPENSIVE AS INHABITANTS ARE SPREAD OUT OVER VAST DISTANCES AND TRANSMITTING ELECTRICITY OVER LONG DISTANCES IS VERY COSTLY."

Rate of electrification in the developing world



Source: IEA, World Energy Outlook annual reports

Figure 1

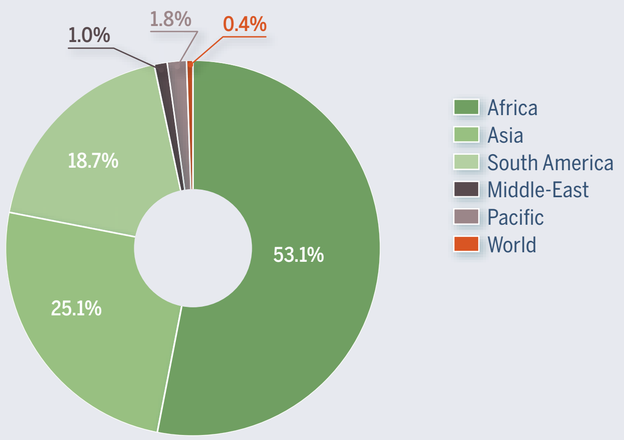
OVERVIEW OF RECENT PROJECTS

The only initiative we are aware of to gather data on these energy access initiatives is the database developed by World Access to Modern Energy (WAME) & EXPO 2015 . WAME & EXPO 2015 is a non-profit created by eight major European energy companies (A2A, Edison, Enel, Eni, Eon, Gas Natural Italia, Engie and Tenaris) in collaboration with the organizers of World Expo 2015 in Milan, Italy. The idea is to raise public awareness about the issues and consequences of the lack of access to modern energy sources facing a large percentage of the global population. The organization exists to help eradicate the "modern energy gap" by supporting, developing and multiplying actions in the field that help to tackle this issue. WAME's database lists energy access projects, policies, case studies and publications that have helped to increase access to energy services for households, collective bodies and businesses, almost exclusively in Asia, Africa and South America. The initiatives listed in the database are often, but not always, focused on renewable sources and cover a very broad range of participants (bilateral and multilateral donors, public institutions, governments, NGOs, private businesses and charitable foundations). Even though it is not exhaustive, using this database does provide us with an initial overview of the current status of decentralized electrification projects.

By concentrating on data on accurately documented projects (location, year, energy source and technology used), 606 electrification projects and case studies carried out between 2000 and 2015 were identified. Of these projects, 481 (79.4%) were off-grid electrification initiatives, 99 (16.3%) were on-grid electrification initiatives, and 26 (4.3%) were electrification initiatives that combined densifying or extending the national utility grid with deploying off-grid systems.

The geographic spread of decentralized electrification projects, or projects with dual centralized and decentralized dimensions, is as follows:

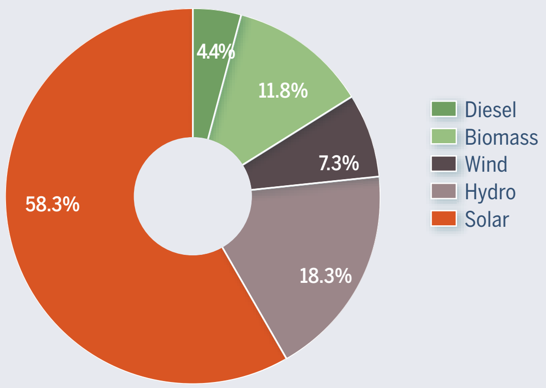
Geographic distribution of projects identified



Source: WAME modified by the authors

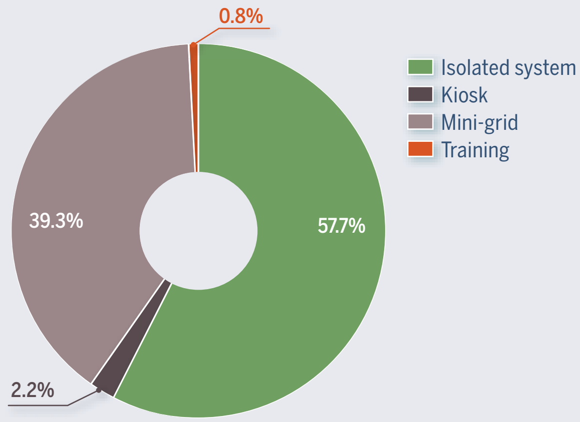
Figure 2

Breakdown of energy sources



Source: WAME modified by the authors *Figure 3*

Breakdown of the different solutions offered



Source: WAME modified by the authors *Figure 4*

Unsurprisingly, Africa and Asia are home to almost 80% of electrification projects identified in the database between 2000 and 2015.

These decentralized electrification projects use a very varied range of energy sources: fossil, solar, hydro, wind and biomass. A total of 15.9% of initiatives identified directly involve several energy sources, and 4% of them combine energy sources via a range of hybrid technologies, from basic solar-fossil power plants to more complex solutions combining solar, wind and diesel, for example. Solar is the most widely used energy source, used in close to 60% of the off-grid electrification projects identified.

Three major families of technical solutions can be identified:

- mini-grids powered by electricity generating plants (fossil, solar, hydro, hybrid, etc.);
- energy kiosks offering a range of energy services to communities;
- isolated systems that provide access to electricity for households and collective structures (schools, health centers, water pumps, etc.). These technical solutions may take the form of solar lanterns, solar kits, pico turbines, pico wind turbines, home biodigesters, etc.

In total, 20.6% of projects identified concern several families of technical solutions.

Most of the projects identified include a capacity-building dimension. A minority provide training only.

The large majority of decentralized electrification initiatives identified in the database concern isolated systems (57.7%) and mini-grids (39.3%).

EXPECTED EFFECTS OF DECENTRALIZED ELECTRIFICATION PROJECTS

It is impossible to assess the actual effects of these initiatives from the WAME database. At best, it provides information on the expected effects, which are wholly dependent on the nature of the solutions deployed.

Low-power individual installations provide lighting and can be used to recharge mobile phones. We have no data on the impacts on people's well-being and so we can only conjecture: lighting in the evening should help children to improve their schoolwork; the ability to recharge a mobile phone saves time that could be used for productive activities. However, timesaving in these ways remains a potential effect. We can add to this the fact that people living without electric lighting use primary energy sources that damage their health and the environment as well as being expensive (kerosene, candles and wood), or else they use a number of individual solutions that pollute over the long term (small battery-powered torches and lanterns), but the harmful health effects of these traditional solutions are not generally measured.

Installations offering greater amounts of power can help to trigger a process of development through contributing to the economic transformation of the communities concerned, the creation of new small-scale businesses and

"THE SUCCESSFUL DEPLOYMENT OF A MINI-GRID DEPENDS ON THE GRID'S QUALITY OF GOVERNANCE."

the use of water pumps for irrigation. They can also contribute to improving vital public services such as dispensaries and schools. Mini-grids have to be designed, scaled and organized (sharing the resource, bill payment methods) in ways that promote the development of these enterprising uses of electricity.

Constraints relating to the intermittent nature of the primary sources used for renewable production (wind and solar) impose additional constraints on the structures of mini-grids, which are all the more severe in cases where users require a set amount of power. This means that the successful deployment of a mini-grid depends on the grid's quality of governance. Compared with major interconnected utility grids, which in developing countries suffer from chronic outages related to the inability of the grid operators to meet demand, local governance of mini-grids is potentially more efficient. Elinor Ostrom (1999) suggests this in her work on local governance rules for coping with the tragedy of commons.

CONTEXTUALIZED FEEDBACK

This special issue of FACTS Reports does not claim to answer every question. Instead, it showcases a few real-life examples of decentralized electrification and suggests a few initial conclusions. The case studies are presented by the project leaders themselves. There are already a number of encouraging responses to questions of how to evaluate the impact of these field actions, although they remain mostly highly qualitative. Looking in detail at some of these experiments also highlights several key factors for the success of these endeavors. Identifying the technology most appropriate to the circumstances is far from the only factor and many other questions arise, such as prior identification of local people's needs and requirements, alterations to the institutional and legislative framework, deployment of innovative finance and payment solutions for users (pay-as-you-go, microcredit), and the need to train the energy entrepreneurs who will carry out the installation and then provide maintenance and after-sales services. Mini-grids require a mode of governance, for what is a local public good, that is appropriate to the context and enables collective maintenance management and conflict resolution in the event of disputes about how this common resource is to be shared.

This special issue features presentations of experiments from the field, arranged into the three categories described above (mini-grids, kiosks, individual solutions), that correspond to the varying degrees of ambition for the development of decentralized electricity offerings. These different solutions cannot be assessed according to a single set of criteria, but they must all, in one way or another, meet the needs of the communities concerned.

The first section looks at mini-grids. In areas without access to an interconnected national utility grid, mini-grids can provide electricity to households, small businesses and public services (schools, dispensaries, etc.). In some cases, mini-grids constitute a viable alternative to electrification by extending major interconnected grids, providing comparable services to those offered by major utility grids, particularly in terms of matching available power to demand. We examine four mini-grid experiments:

- hybrid mini-grids in Mauritania, a delegated public service managed by CDS (article from David Munnich);
- mini-grids in Mali, built as part of a rural electrification program supported by GERES (interview with Benjamin Pallière);
- a project in Laos to develop pico turbines, run by Électriciens sans frontières (article from Gérard Descotte);
- the Rhyviere rural electrification project in Madagascar, developed by GRET (article from Julien Cerqueira).

The first section also contains two articles examining electrification via the national utility grid, but are of particular interest for the governance and management of mini-grids:

- an article on Light Recicla, a social scheme in Brazil that helps with access to electricity in poor neighborhoods (article from Eleanor Mitch and Fernanda Mayrink);
- an article on the constraints limiting the inclusion of intermittent energy sources within the electricity grid on the Seychelles, as identified by Energynautics (article from Tom Brown, Nis Martensen and Thomas Ackermann).

The second section looks at energy kiosks, which offer local people services that require a source of electricity (solar in these cases) rather than access to an electrical connection. For outlying or poor villages where it would not be economically viable to build a mini-grid, these solutions can bring the first benefits from modernizing economic and social life specifically provided by electricity, such as refrigeration or the use of modern computer and communication technologies:

- the development of solar kiosks in Madagascar by HERi, a social enterprise (article from Louis Tavernier and Samy Rakotoniaina);
- the development by the SELCO Foundation of integrated energy centers for people living in informal settlements in Karnataka, India (article from Adritha Subbiah, Sahar Mansoor, Rachita Misra, Huda Jaffer and Raunak Tiwary).

The third section examines individual solar solutions. Often limited to providing a low-power supply for lighting and recharging mobile phones, individual solutions are nonetheless very popular in developing countries thanks to their ease of deployment and the emergence of appropriate financing solutions (pay-as-you-go). Such is the extent of their popularity that today their spread is increasingly the work of private commercial initiatives rather than of projects funded by NGOs or aid agencies. However, the maturity of the market for individual solutions remains conditioned by the existence of market infrastructure, particularly distribution and maintenance networks and specific financing solutions such as microfinance institutions, which are still largely dependent on collective initiatives. Several articles examine these issues:

- two articles illustrate the spread of purchases using pay-as-you-go financing. One describes the experiences of Azuri Technologies, which sells home solar installations in Rwanda with the backing of USAID (article from Simon Collings and Anicet Munyehirwe); the other looks at lessons learned by Village Power's Light Lwengo project in Uganda (article from Annie von Hülsen, Thomas Huth and Simon Koch);
- two articles explore microcredit for financing the purchase of individual solar solutions, one on the work done by Fondation Energies pour le Monde in Burkina Faso (article from Sarah Holt), and the other on the partnerships PAMIGA has built with local microfinance institutions in Cameroon, Ethiopia and Kenya (article from Marion Allet);
- an article describing PAMIGA's experience of training energy entrepreneurs to help grow the energy solutions market in Cameroon and Ethiopia (another article from Marion Allet).

Lastly, the final section features two articles summing up the current situation, setting out a few initial conclusions drawn from recent experiments in decentralized electrification. As the large majority of initiatives use off-grid solar equipments as their energy source, these last two articles concentrate on this type of solution. These are:

- an article that looks at lessons learned from projects that have won an Ashden Award for their work to develop access to sustainable electricity (article from Anne Wheldon, Chhavi Sharma and Ellen Dobbs);
- an article setting out recent trends in the market for solar products in Africa (article from Jörg Peters and Michael Grimm).

"THE ARRIVAL OF ELECTRICITY MUST HAVE A TRULY TRANSFORMING EFFECT ON BEHAVIORS AND PRODUCTION METHODS."

CONCLUSION

This special issue of FACTS Reports on decentralized electrification does not claim to offer any definitive answers to the – perfectly legitimate – questions of the appropriateness of developing decentralized electrification projects. It does, however, show that many solutions have emerged that are capable of tackling the problems encountered, particularly for increasing uptake of individual solar solutions, but also for setting up more ambitious projects such as mini-grids. There are still many practical obstacles to overcome, technical and economic, financial and organizational, and this is something that the growing volume of experience feedback, such as presented here, should help to resolve. Other questions remain to be explored regarding the reality of the social and economic impacts. Although impacts are sometimes verified, impact assessment methods are far from systematic. In the future, better assessments must be made of the economic, social and environmental impacts of these types of projects. In conclusion, we submit that, in order to bring about significant impacts on development, the arrival of electricity must, whatever the geographical or economic conditions and whatever the profile of the target groups, have a truly transforming effect on behaviors and production methods.

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Source: EOSOL Madagascar

1. MINI-GRIDS: IT IS ESSENTIAL TO ADAPT TO LOCAL TECHNICAL AND ECONOMIC CONSTRAINTS

CDS:
A CASE OF AUTONOMOUS WATER AND ENERGY NETWORKS

David Munnich
Chief Operations officer for the IPDEV2 Fund, Investisseurs & Partenaires
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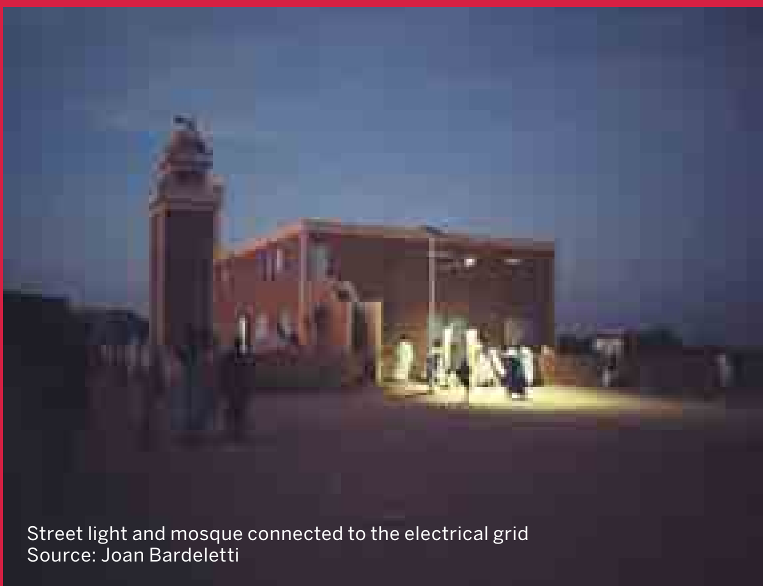
For almost ten years, CDS has been operating water and electricity off-grid networks in remote villages in Mauritania. Chosen by the authorities through several calls for tender, CDS operates and maintains the infrastructure, as well as invoicing and collection from customers. This approach will make it possible to foster rigorous and experienced national operators liable to play a growing role in the professionalization of the sector.



Street light and mosque connected to the electrical grid
Source: Joan Bardeletti

I&P is a group of impact investment funds dedicated to African SMEs. I&P supports and funds entrepreneurs and growing companies with the double aim of having a social and environmental impact and reaching financial profitability. I&P helped CDS structure from 2011, allowing it to double in size since then. Within I&P, David Munnich, in charge of the CDS project with Jérémy Hajdenberg, is the Chief Operations officer for the IPDEV2 Fund.

KEYWORDS
- ACCESS TO ELECTRICITY
- ACCESS TO WATER
- UTILITY OUTSOURCING
- AUTONOMOUS NETWORKS

INTRODUCTION

Mauritania is vast but has a low population density, whose inhabitants live for the most part in remote villages. Giving access to essential services to Mauritanian citizens is a huge challenge for this country lying at the crossroads of the Maghreb region with sub-Saharan Africa. Access to water and electricity there are very limited: only 50% of inhabitants have access to safe drinking water (AFD, 2011) and the rate of electrification is 34% nationwide (IRENA, 2015), with strong geographical disparities. Only 3% of the rural population has access to electricity. The infrastructure deficit is such that several hundred villages are as yet unequipped. The context is all the more conducive to the development of a private offer, because the country's great potential for renewable energies is just beginning to be exploited. Mauritania has one of the planet's highest amounts of sunshine[1] (UNECA, 2012) and it has been identified as one of the 15 countries with the best wind resources in Africa[2] (UNECA, 2012).

1 Mauritania receives more than 3,000 hours of sunshine per year. Direct solar radiation for the entire country is estimated at 78%. The potential is estimated at 4-6.5 $kWh/m^2/day$ with 8 hours of sunshine on average per day. Peaks have been recorded of 9.3 $kWh/m^2/day$ in the north (Bir Moghrein) and 7.9 $kWh/m^2/day$ in the south (Rosso).

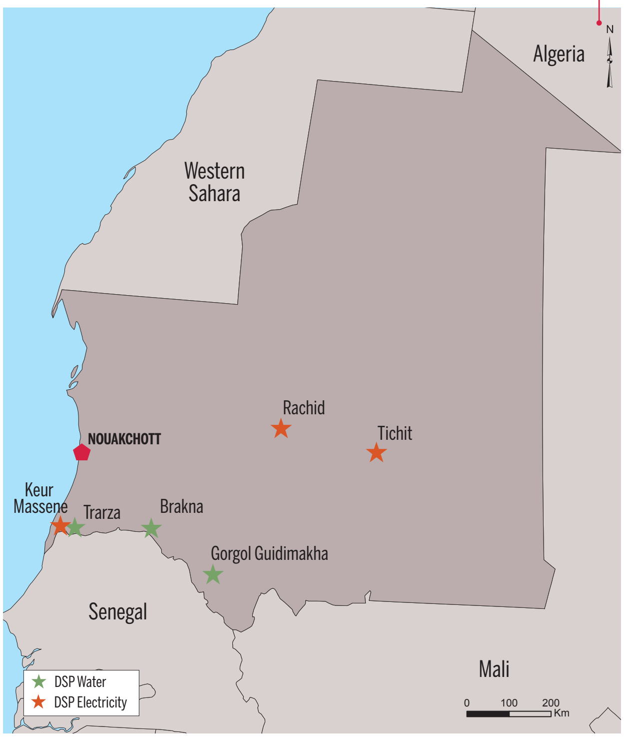
2 By Helimax, a Canadian wind energy consultant: "With winds of 5-6 m/s in most regions, lower speeds of 4-5 m/s in the north-east and parts of the south, and a significant potential of 6-7 m/s on the west Atlantic coast."

1. THE POLITICAL CONTEXT OF MAURITANIA

For over a decade, the Mauritanian authorities have been committed to an ambitious policy of reform of the water and electricity sectors with a view to combating poverty. A legal and regulatory framework favorable to the private sector has been in place since the end of the nineties, which governs the "outsourcing of public utilities management" for electricity[3] since 2001, and for water[4] since 2005, under the responsibility and supervision of the Regulatory Authority (ARE)[5]. The Mauritanian State aims in particular to give Mauritanian companies the operation and maintenance of infrastructure that it funds in the villages, since these private operators do not bear the cost of investing in the infrastructure itself. These companies are selected through calls for tenders. The selection criteria focus on the technical quality of the tenders and the soundness of the bidding companies, and not on the energy sale price, set by the State, which subsidizes if necessary part of the cost in order to cover the expenses of the delegatee business while keeping prices affordable for the users. Several backers have assisted this policy by setting up funding to support the reform of the water and electricity sectors[6].

"WATER OR ENERGY ARE AVAILABLE 24H A DAY."

Figure 1. Location of DSPs - Source: FERDI



2. CDS, A PRIVATE COMPANY SEEKING TO GIVE ACCESS TO ENERGY TO ALL

Entrepreneur Sidi Khalifou
Source: David Munnich

Sidi Khalifou is a Mauritanian engineer and entrepreneur trained in France. At the end of several entrepreneurial trials, in particular design offices and NGOs, Sidi Khalifou took over CDS, a family business, and developed it, focusing its activity on access for all to water and energy, particularly from renewable sources.

A strong entrepreneurial vision structures the business strategy of CDS[7]. It is possible to provide villages with a sustainable, high-quality electricity and water supply as long as three conditions are met: rigorous management, affordable pricing for the customers and the initial investment in the infrastructure covered by the authorities.

Since 2007 CDS has won several calls for tender for the outsourcing of public utilities management ("*Délégation de Service Public*", DSP) organized by ARE. CDS has thus become a "delegatee", i.e. operator of electricity or water miniature networks in isolated areas. CDS is in charge of the operation and maintenance of the network and of the miniature plant, as well as of invoicing and collection from customers.

In the water sector, CDS has won 3 calls for tender (in the south, in the regions of Trarza, Brakna and Gorgol Guidimakha), covering some fifteen villages, approximately 20,000 people. In these "water" DSPs, a treatment station and a small water tower are used to store water need energy to operate and supply the network. The energy used is either thermal or hybrid (solar, with thermal taking over when necessary). These 3 contracts have been renewed and are still ongoing. CDS has recently been awarded a fourth contract in the same area. In the energy sector, CDS has won 4 calls for tender, covering 4 villages (Tichitt, Rachid, Keur Massene, El Kaira), and has installed an off-grid network on own funds in a municipality (Blawack) near the capital Nouakchott. In these "electricity" DSPs, the authorities have chosen a thermal energy source (diesel) because of the power requested by customers. For several years CDS has thus assumed responsibility for access to energy in these municipalities. This represents approximately 1,000 households, or nearly 10,000 people, who have thus been given access to a professional electricity utility. These 4- to 8-year management contracts have now ended. After gaining nearly 10 years' experience as DSP, and having served almost 30,000 customers

3 In particular, Law 2001-19 of 25 January 2001 relating to the Electricity Code

4 Law 2005-030 establishing the Water Code

5 Law 2001-18 of 25 January 2001 creating the Regulatory Authority (ARE), reporting to the Prime Minister, responsible for regulating activities in the water, electricity, telecommunications, and mail sectors.

6 For example: Project to support restructuring of the water, sanitation and energy sector (PARSEAE) funded by IDA (International Development Association); Water Priority Solidarity Fund (PSF), funded by France; support of the EIB for the Félou hydroelectric development project.

7 http://www.cds.mr/

for water and energy, CDS can make a first assessment of the operation of this mechanism.

In addition, since 2011, CDS has been backed and funded by Investors & Partners[8] (I&P), capital investor specializing in funding African SMEs, as well as by the Lundin Foundation and other Mauritanian entrepreneurs. The arrival of these new shareholders has also helped to strengthen the company strategy and governance, develop its skills and therefore accelerate its growth. The company was given structure, for instance implementing analytical accounting, an IT system, and a sales division. Today CDS has become a reference in Mauritania in the area of access to energy, both conventional and renewable, as well as to water. I&P has contributed to conduct a study of the impact on the activity of CDS, conducted by CDS and the Photographer Joan Bardeletti, the results of which are available on the website Small is powerful[9] and have also been reported by the newspaper Le Monde and in a web-documentary[10]. CDS received an award from the Poweo Foundation[11] in 2009 and signed a partnership with Kiva in 2014.

Maintenance by the local team
Source: Joan Bardeletti

3. ENERGY AND WATER SUPPLY BY CDS

The villages where CDS supplies the electricity or water service are small, usually 2,000 to 5,000 inhabitants. In these villages, the infrastructure is comprised of a network supplying a few hundred meters in the village, and an energy source: a heat engine for an electricity DSP, and a hybrid device (solar/thermal) for a water DSP requiring lower power. Several neighboring villages are sometimes connected to the same central infrastructure (water tower or energy source). This off-grid network is autonomous: geographically remote, it is not connected to the national grid. The cost of a connection at a distance of several tens or hundreds of kilometers would be very high. To date, this village infrastructure is systematically funded on subsidy by the State or donors (for an amount estimated at approximately EUR 100,000 to 300,000, depending on the village size and extension). The delegatee operator of the infrastructure would not have the financial capacity required for this investment. The prospects for profitability of such an infrastructure in a small village are too remote to be covered by a private operator without a subsidy.

However, contracting all or part of the creation of the infrastructure and network to the company to which it will ultimately be outsourced, whenever possible and if the operator has the necessary skills, is a good practice because it empowers the operator. It also gives the operator a thorough knowledge of the facility it will be managing. In addition, this gives it the incentive to choose its equipment wisely in order to avoid the future outages, instead of minimizing costs to increase its profit on the construction itself. Put briefly, the "vertical" integration of the activity incites to do things properly during construction to facilitate future management. But this method is still rare in Mauritania. CDS has not yet created the entire infrastructure but has chosen, purchased and installed the electromechanical part and the meters of a water DSP.

For both water and electricity, ARE picks the operator through a call for tender for a 5- to 10-year period, usually in order to (i) operate the network, service and maintain the infrastructure, and (ii) read the meters, invoice and collect payment from customers. For water, the tender mechanism is a reverse auction on the price of the m^3 of water charged to the customer. For energy, the bidding is based on the profit and loss forecast describing the various expenditure headings. The price of the kWh is in fact set by ARE *ex ante*. In both cases, ARE's assessment of the offers focuses on (i) the soundness of the bidding company, its experience and skills, (ii) an estimate of expenditures necessary to the activity. This mechanism aims to analyze the applicant's ability to implement the water and energy provision service in a competitive, continuous manner, "accepting" the price set by ARE for energy or the price proposed by the bidder for water. The operator's capability to ensure proper management and cost control is therefore decisive in this business.

However, in the energy sector, the subscribers' consumption at the price set *ex ante* by ARE does not allow the operator to

8 http://www.ietp.com
9 http://www.smallispowerful.fr/cds-mauritania/
10 http:lesgrandsmoyens.org
11 http://www.ivva.org/lend/691566

generate sufficient turnover to cover the operational expenses of the activity. A balancing subsidy is then provided, according to the amount of energy produced and invoiced, to allow the operator to cover its expenses. This subsidy is paid directly by ARE from a dedicated fund, supplied by Mauritanian mobile and telecoms operators through a specific tax. This fund is not managed by the State budget but directly by ARE. In 8 years, CDS has practically never experienced a delay or difficulty in receiving this subsidy, which is in itself an achievement. Depending on the villages, the year and the consumption, the subsidy may rise from EUR 20,000 to 40,000 per year and per village. This balancing subsidy may in the end fund up to 50% or even 66% of the actual cost of energy. Without these subsidies, the activity would not be possible.

By contrast, the subsidy is not necessary in the water sector. The income derived from invoicing is sufficient to cover expenses. Indeed, water requires less energy, i.e. less diesel. But on the other hand, the price charged by the delegatee must help ensure the long-term sustainability and quality of the service.

Table 1. Recap of energy consumption costs for the customer (EUR 1 = MRO 360)

Quantity of energy consumed	Fixed subscription	Variable billing	Total cost for the customer	i.e. in Euros	Type of customer
Cat. 1: 0 to 25 kWh / month	MRO 600	MRO 51 / kWh	MRO 1,875	€ 5	Family
Cat. 2: 25 to 120 kWh / month	MRO 1,700	MRO 81 / kWh	MRO 11,420	€ 32	Family +++
Cat. 3: From 120 kWh / month	MRO 7,500	MRO 90 / kWh	-	-	Business

Table 2. Recap of data of the 3 main Electricity outsourcing contracts managed by CDS

Electricity outsourcing	Keur Massene	Tichitt	Rachid
Year started	2008	2007	2007
Contract duration	4.5 years	5.5 years	8 years
Type of energy	Thermal	Thermal	Thermal
Installed power	2x65 kVA	60 kVA	60 kVA
Number of Inhabitants	2,000	3,500	2,500
Number of meters	147	205	245
Average consumption /meter	65 kWh / month	17 kWh / month	29 kWh / month
Average annual subsidy	€ 36,000	€ 21,000	€ 27,000
Nbr Cat. 1 subscribers (at end period)	117	176	205
Nbr Cat. 2 subscribers (at end period)	26	26	37
Nbr Cat. 3 subscribers (at end period)	4	3	3

Electricity DSP mini-plant at Keur Massene
Source: Joan Bardeletti

For a customer, the payment of the electricity service is very simple: one buys his meter on first connecting to the grid for about EUR 40. It is often paid in installments, and in some villages, development programs cover this initial cost. A fixed monthly subscription is then chosen: there are 3 types of subscription according to the amount of energy the customer needs. If the ceiling set for the chosen subscription category is overshot, the customer is automatically switched to the next subscription package. Finally, variable billing depends on the subscription and the consumption registered by the meter. It may vary from to EUR 30 per meter and per month on average (between EUR 0.15 and 0.25 per kWh). The chosen pricing system is intended to make energy accessible to smaller consumers (families) and a little more expensive for the bigger consumers (businesses, professional activities, etc).

Payment for the water service works in a similar way: a meter is purchased on connection for some EUR 40, which is sometimes covered by development programs. In the case of water, the sole subscription package costs EUR 1.5 per month, with an added variable billing according to the amount of water consumed. The price per liter depends on the operating costs of each DSP (linked to remoteness, etc). For instance, a family of 10 consuming approximately 100L of water per day (which is low, for all purposes) will pay a water bill of approximately EUR 4.5 per month.

Table 3. Recap of data of the 3 main Water outsourcing contracts managed by CDS

Water outsourcing contract	Gorgol Guidimakha	Brakna	Trarza
Year started	2008	2009	2010
Contract duration	10 years	10 years	10 years
Type of energy	Hybrid	Hybrid	Thermal
Installed thermal power	20 kVA	10 kVA	20 kVA
Installed solar power	1,480-4,000 Wp	500-1,440 Wp	N/A
Maximum water flow	11m^3/hour	8m^3/hour	12m^3/hour
Number of Inhabitants	15,600	7,500	5,000
Number of meters	757	200	254
Average consumption /meter	10m^3/month	9m^3/month	5m^3/month
Cost of the liter of water	MRO 250/m^3	MRO 250/m^3	MRO 350/m^3
Monthly subscription	MRO 550	MRO 550	MRO 550

In the villages it manages, CDS usually employs two to three people full-time responsible for all tasks related to the operation of the autonomous mini-network:

- Light maintenance and servicing of machinery, starting up or shutting down the infrastructure,
- Procurement of spare parts, and diesel oil if applicable,
- Reading customer meters, invoicing, collection.

This on-site team, selected among the village inhabitants, is trained and supported by the central CDS team. It plays a strategic role in the proper provision of the service, both as regards management (use of business software) and technical aspects and first level maintenance. CDS annually gathers its field teams for training, technical upskilling and sharing experience. In addition, the central technical team travels from the CDS head office regularly to visit the various sites in order to perform routine inspections or when complex maintenance is necessary. It is not uncommon for a technical team of 3 or 4 people to have to drive 7 or 8 hours to perform a routine inspection or do repair work which will take a few hours.

The quality of the organization and management of the technical teams is the main factor in the success or failure of this activity. As in other "last mile" issues, cost control is decisive in this low-revenue business. It is what makes it possible to ensure the sustainability and quality of the energy and water provision service.

Another solution implemented by CDS is to try to make the best use of its local base and travel: around the DSPs it operates and in the big cities (Nouakchott, Nouadhibou, Kaédi), CDS started in 2011 a solar kit distribution activity with a dozen points of sale, for customers not connected to the grid or too far from the DSP network, or to supplement the installed meter. The commercial organization of this activity is based in part on the presence of the on-site DSP team, allowing them to deploy this sales activity at a lower cost. Travel between the head office and the DSPs also provide the opportunity to restock the kits and distribute them. Within a few years, CDS identified a few flagship products, purchased from major international producers (Sunking, Bbox, d.light, Barefoot) matching the population's needs: mini-kits (EUR 15, Barefoot Firefly individual lamp with mini-panel and integrated battery, 36 lumens, or stronger from SunKing), TV kits (EUR 150, more powerful solar panel - 100 to 290W and 24V), solar batteries and inverters. Solar refrigerators (130 to 225L) and solar water heaters (150 to 200L) are also distributed sometimes. As they are more expensive, they are intended for a more urban client base with more resources. In these cases, the CDS team must perform a specific installation when they travel. The development of the solar kits activity is promising and makes it possible to capitalize on the presence of CDS in remote areas. Today its sales are comparable to the DSP activity (however, with a significant part of sales made in the capital, Nouakchott). The mini-kits account for three quarters of sales volume, with approximately one thousand products sold in 2015, but they represent much less in value. The solar refrigerators, solar water heaters, TV kits and batteries account for the majority of sales by value. This product mix is necessary to ensure the profitability of a low-margin activity, specifically when the products must be routed to remote areas of the country.

4. ACHIEVEMENTS OF THIS ENERGY AND WATER ACCESS POLICY

At the end of eight years of experience, several lessons can be drawn from the operational experience of CDS in the provision of an energy and water service through autonomous networks.

In the villages where it operates, CDS has proved that the service works: energy and water are available round the clock. The current supplied conforms to the specifications requested by ARE and the water quality, audited regularly, is good. As regards electricity, the rate of outages is lower than the ceiling imposed by ARE in its Specifications: on average 20 hours of interruption of the current per year and village, in tranches of a few hours, often due to minor failures or maintenance. Keur Massene village initially experienced a few more service interruptions due to faulty equipment installed at the start (subsequently replaced). By contrast, the other villages (including Rachid) have experienced several years without interruptions. In most villages there is a secondary plant which is used during failures or maintenance. As regards water, there are one to two failures per year in each DSP, half of them requiring intervention from the head office. Overall, the service interruption rate is around 1%. The installed equipment proved to be appropriate for its use and CDS has not experience serious malfunction of the infrastructure.

The professionalization of the delegatee activity is also a key achievement: CDS and a few other DSP operators are gradually expanding their skills in the management and maintenance of these facilities. The little institutional or external support they have received mainly concerns the management of the DSPs (software, rules and good practices, etc). On a technical plane, they have gained experience and learned on their own by grappling with the technical challenges of their activity daily.

These delegatees are also grouped together at national level in an operators' association, in order to communicate more effectively with the authorities and develop common practices. This association is promising and could become a platform for support and development. Those operators who achieve a sufficient structure will truly become the strategic players of the energy sector of the future in their countries.

Finally, the balancing subsidy that the authorities were committed to pay to the electricity DSP has always been settled in accordance with the stated provisions. The reliability of this compensation mechanism is also a condition for the success of this energy access policy. The vitality and the high profitability of the mobile and telecom sectors in Africa, including in Mauritania, suggest that these subsidy amounts will be permanently available and could fund access to energy in other villages.

The quality and sustainability of this water and electricity access service is based on a strict operational requirement: long-term cost control and rigorous management. Because the delegatees are all small SMEs, they are forced to control their expenditures very closely in order to survive. For Sidi Khalifou, CDS CEO, "This is a service requiring skills and regularity, and we know that this can be difficult for our States, our communities or the large public undertakings. A small private business like CDS can manage this, even if this is not always easy."

Utility consumption by the customers confirms that the offer matches a need. The quality of collection (95% on average, sometimes 100%) demonstrates customers' ability to pay and the appropriateness of the billing method and rates. If at the start of a DSP only 70 to 80% of the inhabitants are indeed connected (mainly due to costs), subsequently CDS observed a gradual increase in the number of meters, by approximately 5% per year, as well as an increase in households' consumption, approximately 5 to 7% per year on average for all DSPs. To date, apart from a few specific events, there has been no case of interruption of subscription to the utility. CDS has managed to ensure a quality service, maintaining its costs and achieving a true financial balance, although the margin is very narrow.

In the villages managed by CDS, approximately 10,000 people have benefited from access to professional and sustainable energy and approximately 20,000 people have benefited from access to water. A qualitative assessment of the impact of the supply of water and energy in the villages served by the DSP, carried out on the basis of internal CDS data, has helped to identify three main avenues for social and sanitary progress that the service has generated, and which in turn have many and successive impacts on the economy and society in general.

First, the quantity of water consumed has increased, from an average of 100L of water per family and per day previously, to 200L/day/family today (increase not due to waste but to new uses, particularly economic). In addition, water quality improved with CDS: in several villages, the inhabitants had previously used river or well water, which caused many diseases. According to Mr. Bamba, CDS DSP Manager, "Some populations directly took water from the river or surrounding backwaters, it was too polluted and had so many microbes that it caused diarrhea and diseases of all kinds. The populations' situation improved with CDS's management." According to the elder of Dioullom village, 15km northwest of Boghé, mostly composed of livestock and crop farmers, "Tap water is healthier than the well water."

In the villages served by an electricity DSP, the use of refrigeration makes it possible to keep food longer and reduces the risk of consumption of spoilt food, which is very frequent. Ms. Zenob Mint Mohamed said as much, "during hot weather, meat did not keep very well. Now, when a villager kills a sheep, he can keep it in the freezer."

In addition, other small-scale and "professional" uses appear: the energy supply powers small mills, welding stations, bread ovens, or telecom shops: it is no longer necessary to travel several kilometers

"30,000 PEOPLE WERE GIVEN ACCESS TO WATER OR ENERGY IN THIS WAY."

to recharge a mobile phone. Far from being simply an expenditure, energy is an opportunity for the creation of additional revenue within the village economy. The refrigerator is also a source of additional activity for the storekeepers, who sell ice and cold drinks in Mauritania's very warm climate.

Table 4. Economic activities supplied with power in the 3 villages

Keur Massene	Mills, tailors, electric well pumps
Tichitt	3 mills, 1 gas station, several welding stations, tire inflation stations, hair salons, tailors, telephone recharging
Rachid	Electrical well pumps, refrigerators/ ice sellers, welding stations and tire inflation stations, telephone recharging

Several public or social services are also routinely connected to the energy or water network: health clinic, school, administrative services, and... the cemetery, as Sidi Khalifou explains: "In our traditions, the dead must be buried straight away and often they die at night. Before, people were afraid to go to the cemetery at night. Now, they are more comfortable during evening burials and this also gives a spiritual weight to the cemetery. "

Table 5. Public or collective services supplied with electricity and water

Keur Massene (electricity)	Police, town hall, clinic, prefecture, cemetery
Tichitt (electricity)	Elementary and middle school, town hall, clinic, radio transmitter
Rachid (electricity)	School, town hall, clinic, prefecture
Gorgol Guidimakha (water)	Four elementary schools, two middle schools, a high school, a town hall, two clinics, two prefectures, a police station, two cemeteries
Brakna (water)	School and clinic
Trarza (water)	Clinic

5. CHALLENGES AND DIFFICULTIES OF THIS APPROACH

CDS's experience also serves to identify the major challenges of this energy and water access policy that must be resolved in order to scale up and achieve a real impact on development for the inhabitants of Mauritania.

The main disadvantage of the government strategy of outsourcing management is the absence of a consistent geographical approach. The successive invitations to tender are distributed all over the country, from the south (river valley) to the east (the two Hods), and from the center to the north. The same operator may therefore find himself delegatee for 5 sites several thousands of kilometers apart from each other. Yet one of the key parameters of service quality is the distance between the delegatee site and the operator's resources such as: skilled maintenance teams, spare parts stocks, etc. It is obviously impossible for an operator to mobilize all those skills and all those stocks for each delegation, because this would make the cost price of energy unaffordable. By contrast, mobilizing skills or stocks only a few tens of kilometers apart makes it possible to significantly reduce management costs, the operational complexity of the activity (delays, travel), as well as the loss of income related to the any service interruptions. Geographical consistency of the delegations awarded would solve this difficulty by giving the same operator several neighboring sites, or even a region.

This issue can in effect be addressed by proposing delegations of a sufficient "size", i.e. commercially viable for the operator. Supply electricity or water for a very small village of a few hundred people, several thousands of kilometers away from the operator's head office (in Nouakchott, the capital) is far more expensive, and therefore far less profitable, than to do so for a larger village (several thousands of inhabitants) just three or four hours by road from the capital. This is why for a long time CDS has been pushing the Mauritanian authorities to adopt a consistent and ambitious geographical approach to the outsourcing of utilities, as is the case in neighboring countries such as Senegal.

Such an approach of course is only meaningful for delegatees that are sufficiently competent and capable of managing relatively vast areas. Strengthening delegatee skills is another crucial issue for the success or failure of this energy and water access policy. In several DSPs, ARE has had to renew the call for tenders to change operators due to poor service rates, limited maintenance skills and, ultimately, an inadequate performance from the operator chosen initially. This is hardly surprising since there was initially no professional operator in this sector, which only arose recently. A few years therefore had to pass for specialized players to emerge and structure their business.

In addition, the geographical consistency of the awarded DSPs also collides with the constancy of the Mauritanian public authorities, whose vision for the sector has sometimes varied. The frequency of calls for tender is changeable and does not match an established and published timetable. Sometimes, for contingent political reasons, a DSP may be withdrawn from a delegatee and handed to the public electricity utility, whose rates are lower, despite (or because of!) very good operating results and an increase in demand. This has already happened with some electricity DSPs managed by CDS. However, the public electricity utility is unable to operate these DSP in a sustainable and profitable manner: its cost structure is very high, its management quality is less good and income is lower. These factors often lead to a gradual degradation of service quality (frequent outages, delayed maintenance, dropping service rates) and, simultaneously, to a far greater "subsidizing" than in the DSP program, since the considerably loss-making public utility is regularly bailed out by the authorities.

In addition to geographical consistency, consistency as regards duration is also required in this approach to utility outsourcing in order to produce experienced operators and a stable and high quality service.

6. CDS INNOVATES TO GROW AND TAKE ON THESE CHALLENGES

Faced with these difficulties, CDS has implemented several concrete solutions.

CDS is trying to concentrate its activities in the south of the country, a more densely inhabited area that still has little service. Mr. Khalifou's goal is to base as many operational team assets as possible equidistant to the various DSPs which CDS operates. The closer the team to the maintenance site, the faster and more inexpensive the maintenance will be.

CDS proposes to authorities to carry out as much as possible a part of the infrastructure installation (the electrical or electromechanical part) in order to install reliable, quality hardware subject to limited failures. CDS wishes to encourage the authorities to move towards a "concession" approach where part of the infrastructure investment is borne by the concessionaire.

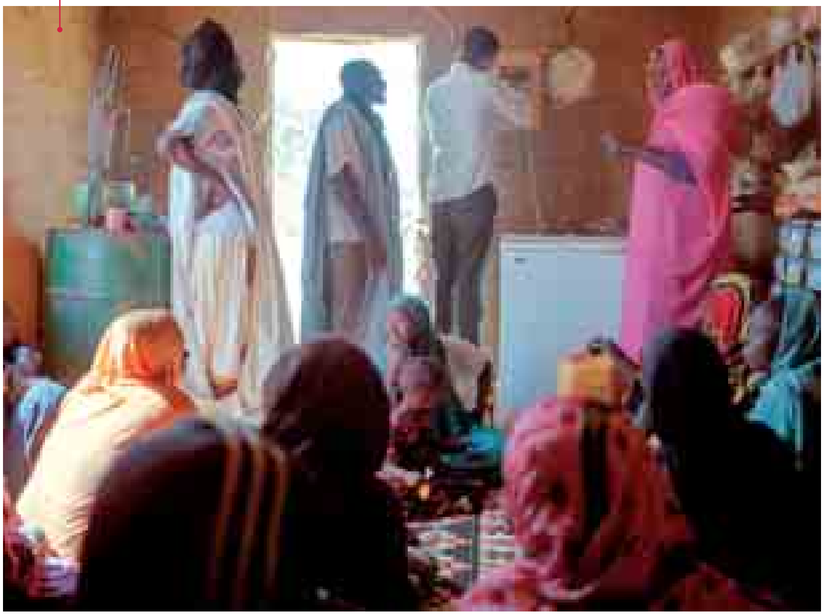
CDS is trying to increase network density: even restricted extensions can make it possible to reach another village or a part of the village is not served by the infrastructure. Whether this extension is funded by CDS alone or shared with the authorities, commercially and technically it represents a natural avenue for growth: without increasing operating expenses, the same equipment can often serve a greater number of people. This would help spread the fixed charges over a greater income, reduce the operating subsidy and improve the activity's sustainability.

Finally, CDS as far as possible endeavors to promote renewable energy production methods, mainly hybrid ones (solar combined with thermal). In addition to the environmental impact and the reduction of pollution (noise or air), these solutions are also economically virtuous: (i) they reduce the influence of the variation of the price of diesel on the profit and loss account, (ii) they fail less often and significantly reduce maintenance requirements (longer intervals between two technical inspections), (iii) over the long term, they reduce the cost of water or energy for customers. If the CDS case shows that it is not yet feasible to aim for renewable energy alone, the fact nevertheless remains that decisive progress can be made by promoting these energy sources. CDS has already managed to switch several water DSPs to a hybrid power source.

Over all of these challenges, the authorities must be lobbied in order to design together the best energy and water access solutions for these villages.

"COST CONTROL AND RIGOROUS MANAGEMENT ARE KEY OPERATING REQUIREMENTS."

A refrigerator installed in a shop
Source: Joan Bardeletti



CONCLUSION

More widely, professionalizing and developing the delegatees, as well as optimizing energy production through the use of renewable sources and increasing the density of DSP sites, will be decisive to replicate and scale up the DSP approach: decentralized electrification will be a solution for access (even partial) to energy and will be repeated only if the need for subsidized funding is limited to a minimum. If the dedicated fund supported by the mobile operators does not seem likely to dry up in the immediate future, it will not cover the financing of expensive infrastructure, often several hundreds of thousands of euros for each installation. Even on the road to a concession approach, the public authorities and donors will need to cover a part of the investment needs sustainably, and associate the DSP approach to other initiatives in order to overcome the difficulties of access to energy and water.

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CAN RURAL ELECTRIFICATION STIMULATE THE LOCAL ECONOMY?

Constraints and prospects in south-east Mali

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Batteries of the power plant in Koury
Source: GERES

Protecting the environment and limiting climate change and its consequences while also improving living conditions for the poorest: these are the challenges that GERES seeks to tackle through development engineering and specialist technical expertise. Energy efficiency, renewable energy and local economic development are at the heart of its activities.

Providing rural electrification with solar solution to small businesses requires a specific design adapted towards their equipment and the impact of the use of their equipment on an isolated mini-grid has to be diagnosed and assessed before providing a localized solution to meet their consumption needs. Therefore, the need for an Electrified Activities Zone (ZAE) that is complimentary to the existing solution for household electrification.

KEYWORDS
- RURAL ELECTRIFICATION
- BUSINESSES
- SOLAR
- MINI-GRID
- ACTIVITIES ZONE

Victor Béguerie: GERES is actively involved with rural electrification projects in Mali. Can you start by describing the rural electrification situation there?

Benjamin Pallière: To improve access to electricity in rural areas, the Malian government has decided to turn to structures such as private businesses, economic interest groups and non-profit organizations that are independent from the incumbent electricity company that operates decentralized power plants used to supply mini-grids. These structures are almost exclusively businesses that are regulated by the Malian Agency for the Development of Household Energy and Rural Electrification (AMADER). They operate in areas not served by the national utility company, Electricité Du Mali (EDM). At present, these companies operate under renewable 15-year licenses, and the State generally co-funds a portion of the initial investment costs. They are free to define their own business models, although operators that receive State funding have their tariffs set by AMADER. This strategy was adopted around the turn of the millennium and has increased the rate of rural electrification from 1% in 2006 to 11.9% in 2012[1] and 18% in 2014[2]. During the first decade the focus was on diesel-fired solutions but the second phase, post-2010, saw these solutions hybridized with the arrival of photovoltaic panels (PV). GERES works with one of the private rural electrification operators, Yeelen Kura. This Malian decentralized services company was founded in 2001 and, by 2015, was operating decentralized power plants in 10 locations in south-east Mali, nine of them hybrid solar-fossil fuel.

V.B.: One of these 10 locations is the town of Koury, a place where GERES has been operating for almost a decade and where Yeelen Kura operates the local mini-grid and hybrid solar-fossil fuel power plant. What are the key features of Koury?

B.P.: Koury is the main town in the Sikasso region, with a population of 14,915 in 2009[3]. It is accessible via a paved road (1 hour 15 minutes, 110 km) from Koutiala, Mali's second largest manufacturing city and the capital of its cotton industry. Koury borders Burkina Faso and is the second most important crossing point between the two countries. Koury is the largest town in the Yorosso Cercle, which had a population of 211,000 in 2009. Its location in Mali's cotton-growing region makes it a particularly dynamic place.

V.B.: What's your assessment of the economic impact of AMADER's actions?

B.P.: Mali's rural electrification program aims at several targets: households, street lighting, businesses and community facilities. Productive use of electricity is supposed to generate revenues that will improve people's living conditions. Among other things, these revenues should enable people to afford electricity for home

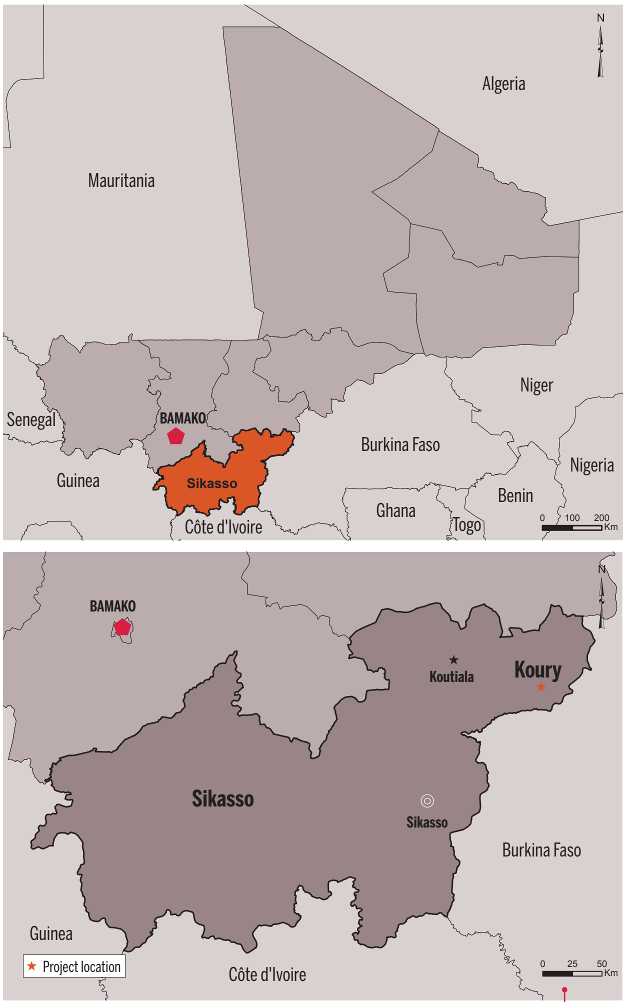

Figure 1. Project location - Source: FERDI

comforts. But feedback from the field shows that the reality fails to match these assumptions. Although encouraging progress has been made in terms of household use of electricity, street lighting and electrification of community facilities, electrification has not had much of an impact on the growth of micro-businesses[4,5]: households' electricity bills are not being financed by these new activities, and electricity suppliers are not finding a decisive income stream from producer customers. Productive uses of electricity appear limited, or even impossible for certain types of activity, since they lead to outages or deterioration in the quality of supply from the mini-grid. In 2014, in three of the areas where Yeelen Kura operates that have a sustained business environment (Bla, Koury and Yorosso), only 10% of electricity generated was used by producer customers.

1 World Bank (2015), Databank, http://data.worldbank.org/country/mali

2 Toure, H. (2014), Malian presentation at the Regional Discussion and Capacity-Building Workshop for the Program for Energy Access in Africa, AMADER

3 INSTAT (2013), 4th General Population and Housing Census

4 Mayer-Tasch, L., Mukherjee, M., Reiche K. (2013), *Measuring Impacts of Electrification on Small and Micro-Enterprises in sub-Saharan Africa, GIZ*

5 Shanker, A. (2012), *Accès à électricité en Afrique subsaharienne : retours d'expérience et approches innovantes [Access to electricity in sub-Saharan Africa: feedback and innovative approaches]*, Agence Française de Développement working document.

V.B.: To help us better understand the divide that exists between the technical and economic solutions introduced and the actual needs of producer customers, can you talk us through the technical and economic solutions that Yeelen Kura runs in Koury, as an example.

B.P.: Koury has a hybrid solar-fossil fuel power plant (100 kWp of PV and a 275 kVA generator unit) and a decentralized mini-grid that is not connected to the sub-regional interconnection and operates daily from 4 pm to 1 am. The tariff per kWh is FCFA 250, equivalent to EUR 0.38/kWh, to which are added fixed charges for meter hire and a contribution to the cost of street lighting. Once these charges are factored in, the cost is FCFA 335/kWh (EUR 0.51/kWh). In 2013, the 20.5 km low voltage mini-grid covered 31% of the inhabited area of the town of Koury. Every customer has the choice between single- or three-phase supply, but high power (several kW) is not available.

To guarantee a good quality electricity supply you need a suitable power plant, but you also have to have a suitable distribution grid. In a newly electrified area experiencing strong demographic growth, grid maintenance demands that adjustments are made from time to time, both to limit distribution losses and to ensure a quality electricity supply. This was something that Yeelen Kura did in 2014.

However, because the power plant and mini-grid were designed with household customers in mind, the work done on the mini-grid was not necessarily enough for all its customers, particularly potential business customers.

V.B.: What are the main economic constraints facing a rural electrification operator running a hybrid solar-fossil fuel power plant?

B.P.: The constraints relate to each energy source: solar PV on the one hand, the fossil-fired generator on the other. The advantage of hybrid solutions generally relates to profiting from the strengths of each technology, but only if you also avoid their weaknesses.

Solar PV has become highly competitive for what's known as direct injection. This refers to electricity that is used directly rather than stored. Because although the price of PV panels has fallen enormously, batteries remain expensive. Allowing for the fall-off in battery performance once temperatures exceed 25 °C, storage costs in Mali are from FCFA 150 to 250/kWh. These costs have to be added to other production factors.

A fossil-fired generator unit works most efficiently at about 70% of its nominal operating load. Ignoring staff and equipment replacement costs, to produce 1 kWh in Mali under these conditions, with diesel or a substitute vegetable oil costing FCFA 660 per liter and remembering that generators require regular maintenance, costs a minimum of FCFA 246/kWh. This marginal cost represents the opportunity cost of using fossil to generate an additional 1 kWh.

These two factors lead or force operators to prefer operating during daylight hours and adapt use of their batteries to correspond to their generators. But this presupposes that customers want to consume during the day.

V.B.: What are the specific features of micro-businesses that lead to the mismatch between their needs and the technical and economic solutions implemented?

B.P.: There are two types of micro-businesses. There are those that provide services using equipment whose power or quality is no different to conventional household uses and that, apart possibly from their operating times, have no specific needs. These might be hairdressers, storekeepers or tailors. And then there are micro-businesses that produce goods, such as bakeries, carpentry workshops, engineering services and water supply, or services, like millers, computer centers and local radio stations. We're going to talk about this second category.

Micro-businesses need an electricity supply that provides them with enough power (from 1 to 5 kW) and that meets their quality requirements (no blackouts or brownouts or load-shedding) at the times they need: 24 hours a day for some of them, daytime only for others. The price of the electricity is not a major constraint. This is demonstrated by the fact that all businesses of this type equip themselves with alternative sources of energy to compensate for the weaknesses of the supply from Yeelen Kura.

It's very tough for a rural electrification operator to meet these needs, all the more so where its priority is to bring electricity to households (at least, that is what is expected of them). There are two problems that immediately arise: the operating times of the mini-grid and its sizing. Where power plants have only limited generating capacity, the situation will quickly arise that all electricity used comes from fossil-sourced electricity, which is more expensive. The second point is that the mini-grid has to be scaled to match demand. For large customers it is important to run cables with a greater section in order to reduce voltage drops and line losses, as well as on occasion fitting hardware to manage electrical disturbances. One issue here is reactive power caused by induction components in machinery that contributes to increasing the current transiting the grid. Reactive power can be reduced using a compensation capacitor bank. The second type of disturbance, rarer under normal circumstances, is the creation of harmonics, which are electrical signals with a frequency that is a multiple of 50 Hz. Harmonics disturb the sinusoidal shape of the electrical signal and can damage some types of equipment. They can be created by inverters and converters, and amplified by certain types of grid equipment. This makes it necessary to fit harmonic filters. However, a rural electrification operator, faced with a challenging business model and limited investment capacity, will prefer to focus its mini-grid on household customers, particularly in places where micro-businesses were not originally established.

However, and I'll end my answer with this, rural businesses may be ready to pay the real costs for their electricity. A bakery must have electricity to operate the kneader. Instead of being restricted to a few dozen loaves a day, it can make one or two thousand with a reliable power supply. At an all-in cost of FCFA 300/kWh, the electricity used to knead dough will represent just 3% of the bakery's revenue.

"THE SOLUTION COMPRISES GROUPING TOGETHER MICROBUSINESSES AND ARTISANS IN A LOCATION THAT OFFERS ACCESS TO ELECTRICITY THAT MEETS THEIR NEEDS AT SPECIFIC TIMES OF THE DAY AND UNDER CONDITIONS THAT VARY ACCORDING TO THE TYPE OF ACTIVITY."

V.B.: What solutions have GERES and Yeelen Kura developed to improve the productive use of electricity for micro-businesses?

B.P.: Developments in the power supply industry, particularly the arrival of hybrid solar-fossil fuel power plants, represent a great opportunity to reach out to this very distinct group of customers as soon as the process of sizing the grid technically and economically begins.

In the past, Malian rural electrification companies would have built and operated their grid with household customers in mind first and foremost. On top of taking notice of the needs of rural businesses in terms of power supply and of the disruptions that can be generated by their machines, there are three further key points that arise: operating hours, location and pricing.

The question of operating hours needs to be looked at in conjunction with solar generation. It takes a smaller investment to supply daytime customers than nighttime ones. The difference is significant. Increasing the daytime customer base will be one of the key factors for the future viability of decentralized hybrid solar-fossil generating systems, for although household customers cannot easily switch their energy use to daytime, it is naturally much easier for business customers.

The second issue is location. Taking on board the fact that two different types of grid are needed, it becomes clear that having rural businesses widely dispersed across the area will greatly increase the additional expenditure requirements. And a good many of these producer customers could relocate, and could well benefit from being located close together. Economies of scale achieved by grouping these customers close to one another lower the overall cost of establishing the mini-grid. This holds good not just for the grid operator but also for the municipality and all other stakeholders involved in a program to support the development of entrepreneurship.

The final point is pricing. Rural businesses understand that their service needs are different from those of households and that differential pricing may apply, so long as this is justified. This is absolutely not about getting businesses to pay more while offering them nothing in return.

If we incorporate new town planning techniques and zoning practices into the points cited above, a solution worth developing emerges quite naturally: the provision of an electricity supply suitable for micro-businesses in appropriately located and serviced areas. This solution comprises grouping together micro-businesses and artisans in a location that offers access to electricity that meets their needs at specific times of the day and under conditions that vary according to the type of activity. This is the thought process behind the idea of the Electrified Activities Zone (ZAE).

V.B.: Can you tell us a bit more about GERES' work in and around Koury that led you to introduce the Electrified Activities Zone (ZAE)?

B.P.: Setting up the ZAE project took place in two distinct phases, designed to clearly identify the constraints and problems to address and to build local partnerships for the future project.

- The first phase, from 2007 to 2011, focused on observation. It led to an understanding of which rural businesses had the possibility of connecting to the local electricity mini-grid and which of them were interested in doing so. This phase also helped us to understand how Yeelen Kura worked.
- The second phase was an opportunity to combine targeted actions with accurate measurements to create a precise picture of the needs and economic interactions between this type of customer and the electricity operator. This involved in-depth studies of the project's impacts on electrified micro-businesses and the electricity grid respectively, and setting up a center to demonstrate and train people in the use of electrical equipment.

By 2014, GERES and its partners had drawn conclusions from this two-stage analysis and together they proposed a program to develop an Electrified Activities Zone, a process that only really took off in 2016.

V.B.: Can you talk us through the two initial phases of the project, which focused on observation and analysis?

B.P.: The team used an energy assessment tool that combines energy metering with interviewing actors on both sides, electricity suppliers and users[6] (see Figure 2). Energy assessment is designed to provide a comprehensive picture at the level of a rural municipality or district, aiming to highlight the position of all energy consumers, the value chain they belong to and the barriers they face in moving toward sustainable, clean solutions. This tool, and its use in other districts, will generate technical information and development ideas for newly electrified areas.

An energy assessment is based on the principle of combining comprehensive mapping with an understanding of the target stakeholders, using energy metering and qualitative interviews. The team has a toolbox that includes metering equipment and comparative benchmarks, as well as surveys with model questionnaires and interview frameworks. For each assessment, only the most appropriate tools are retained. Having access to benchmarks from other locations is a key prerequisite for a successful assessment.

V.B.: Which stakeholders were involved in setting up the ZAE?

B.P.: Three major stakeholders were involved:

• The rural electrification operator

The key stakeholder in all this is the rural electrification operator, because rolling out the solutions requires the operator's agreement and support. But this does not necessarily mean that the electrification operator has to be the project's driver or promoter. In the Malian example, Yeelen Kura's role is to support the process for this pilot project by being wholly transparent about its strategy (and how this will evolve), its objectives and constraints, and by welcoming and assisting any surveys or other operations that may be needed. There are two reasons for this: (i) Yeelen Kura views itself as a development actor, and (ii) solving the electrification problems of micro-businesses will make its work easier at the same time as meeting donors' expectations.

6 GERES (2014), Rural energy assessment, http://www.geres.eu/images/publications/rural-energy-assessment-2.pdf

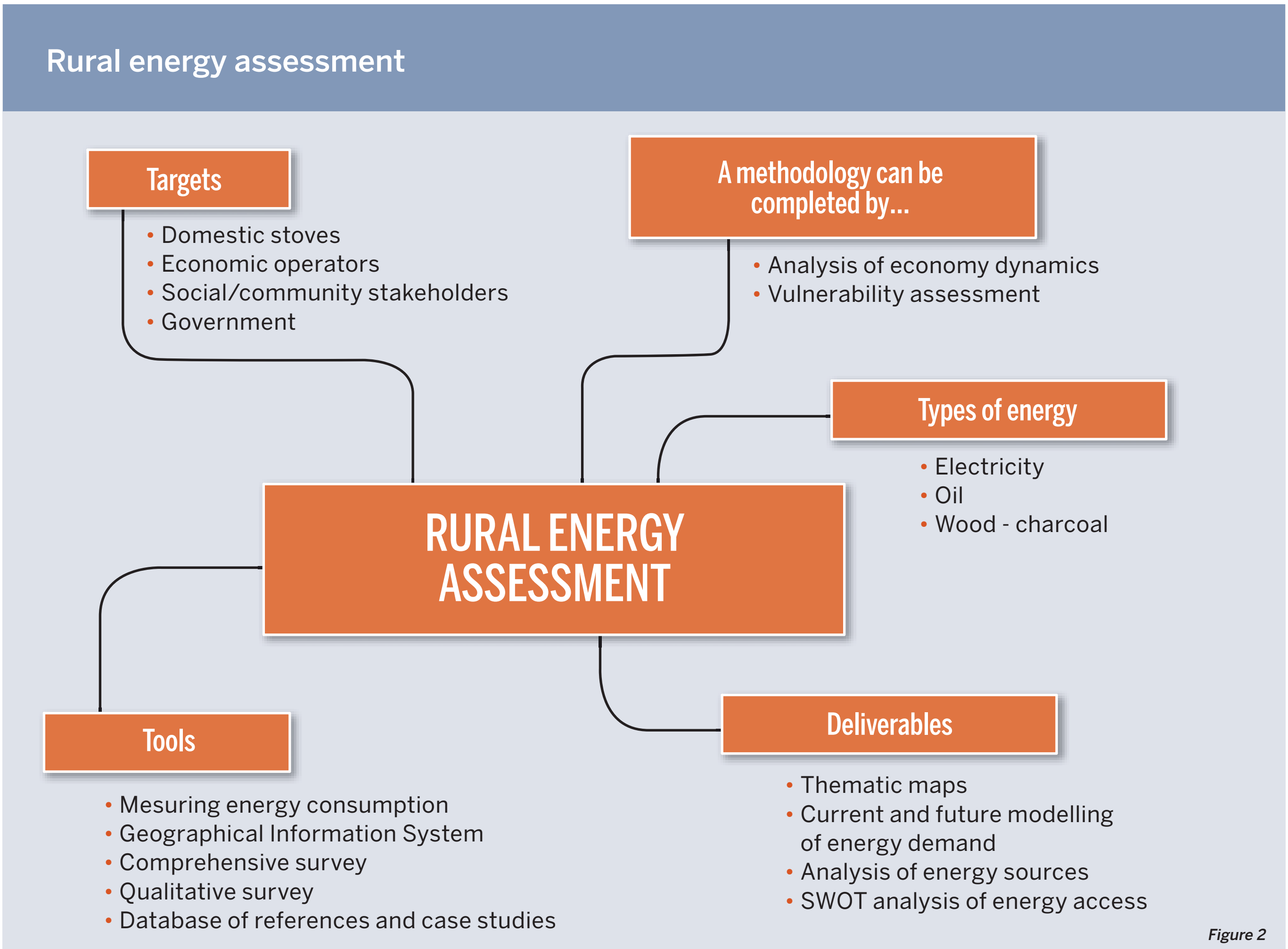

Figure 2

• **A body that unites and represents producer customers**

Micro-businesses are represented by an association of artisans (ASAOK). This long-established body was set up to facilitate discussions between businesses and artisans on specific themes (such as harmonized prices for milling cereals) and to act as a point of entry for various programs (such as training). GERES has worked with this association for a number of years at the municipal and Cercle levels. The ZAE may mean the association will have to adapt its mandate.

• **Decentralized state representatives (the mayor's office in this case)**

The mayor's office plays a pivotal role in the work in Koury, both through its role in driving and ensuring continuity and through its ability to provide locations and plots for this type of project. GERES was keen to find ways to increase the involvement of the mayor's office, particularly during the pre-project phase. A ZAE can also show a mayor's office how to take ownership of an issue, energy in this case, that was previously thought to be the sole responsibility of the national government in Bamako.

By the end of 2015, fund-raising was completed and work should be getting under way in mid or late 2016.

V.B.: What are the key components of this ZAE?

B.P.: The ZAE is intended to provide a quality electricity supply (energy component) in an environment designed for business activities (real estate component) and that provides non-financial support for the ZAE's micro-business customers (business support component). These three components are absolutely vital.

In practical terms, this means first of all adding an additional 25 kWp capacity to Yeelen Kura's mini-grid, running a direct feed from its power plant to the ZAE (so that the ZAE supply can be managed separately from the rest of the mini-grid) and, lastly, installing a storage battery bank at the ZAE. This solution means that Yeelen Kura's role will be limited to supplying daytime electricity, and the ZAE will be in charge of electricity storage and management of any disruptions to the supply. The additional costs of all this will be billed directly to the micro-businesses, which will pay different rates during the day than at nighttime. At the moment, the idea is to have a daytime rate of FCFA 250/kWh, and FCFA 400/kWh at night. Bear in mind, for example, that for a bakery with an electric kneader (the oven is wood-fired), these electricity costs represent 2% of the final sales price for a loaf. But a 24-hour electricity supply means it can bake more often.

The second key point is providing an environment where people and machines can work comfortably. In a country as hot as Mali, this means constructing bioclimatic buildings. GERES has partnered with a non-profit organization called Voute Nubienne for the construction component. Between 500 and 600 m² of floor area, just under a quarter of the total available, will be connected to the mini-grid. The cost of renting space is projected to be FCFA 500 per square meter. Management of the buildings, as well as the ultimate distribution of the electricity supply to the ZAE site, will be delegated, remembering that the land and buildings are, and will remain, the property of ASAOK, Koury's association of artisans that GERES has worked with for several years. All the prices will include an element to cover the costs of running the ZAE team (watchman and manager) and any minor maintenance and repairs, as well as an element designed to build up a fund for future major equipment overhauls or replacements. We already have a rough breakdown of the costs, and we will renegotiate some elements once the program is up and running. These prices and the cost breakdown both include allowances for annual inflation. The fact that there's now a bank and microfinance provider in place makes it much easier to maintain a measure of oversight over the delegated management.

The third point is fostering businesses. Although a handful of business people (the wealthiest and best-trained) do not need any support, others do. This is especially true of women, who are less practiced in setting up a business, and young people. This support covers both the preparation (thinking about the business model, helping to obtain a loan) and the operational stage (bookkeeping and business development, specialist training, such as hygiene and taxes). GERES does not want to become involved in financing equipment for projects of this nature.

V.B.: In more general terms, what do you think will be the future benefits of creating the ZAE in Koury?

B.P.: Ultimately, what's really interesting about it is how the question of energy acts as a facilitator. New arrangements and opportunities become possible thanks to the obligation micro-businesses have to group together spatially. I can give you three examples of the effects we hope to see, and that have been observed elsewhere. The dispersion of economic actors (not small traders) is frequently cited as a constraint for any microfinance institution. Having 5 to 10 micro-businesses gathered in a single location provides a new approach to how they can be managed. The second point is that the micro-businesses will naturally become each other's customers. Bakeries need ice while they are kneading their dough. Employees will be very happy to use a catering service. A radio station is a fabulous provider of cost-effective advertising. Lastly, success attracts success. Psychologically, it is easier to set up in a location where several businesses are already operating than somewhere empty and lifeless. And confidence is a key to success in business.

PICO HYDRO TURBINES FOR ELECTRICITY IN RURAL AREAS

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This article discusses the feedback and lessons learned, particularly from a survey carried out following the deployment program of a pico hydro power solution in a very isolated rural area in north Laos. This project is part of the strategic development for the rural electrification of Laos, in which pico hydro power facilities constitute the main avenue of progress for the electrification of isolated villages.

Theoretical training course
Source: Électriciens sans frontières

Électriciens sans frontières, a public interest international solidarity NGO, conducts electricity and water access projects to ensure the poorest populations in the world can enjoy sustainable access to energy that is reliable, affordable and as clean as possible. The skills and involvement of our 1,200 volunteers are harnessed to improve the living conditions of communities that are often rural and isolated.

KEYWORDS

- LAOS
- HYDROELECTRICITY
- PICO HYDRO TURBINE
- ELECTRIFICATION
- DEVELOPMENT

INTRODUCTION

Almost half the world's 1.2 billion people with no access to electricity live in South Asia (World Bank, 2013).

For the region, the consequences of this lack of access to clean, reliable energy are many and harmful. The absence of electricity is depriving the population of access to care and proper education conditions. It was observed that the rate of infant and maternal mortality drops with the rise of access to electricity (UNDP, 2009). Similarly, 50 per cent of primary schools in South Asia have no access to electricity, which affects the learning conditions of nearly 100 million students (Practical Action, 2014).

According to the context, the solutions are varied and assume different forms in urban areas, peri-urban areas, densely-populated rural areas or isolated rural areas. Beyond this first factor, adapting a solution to the local geographic, economic and social conditions is paramount. There is no single solution then, but a range of solutions to be applied depending on the situation.

In north Laos, many villages have no access to electricity. The population's dispersion and low density in this extremely rugged area make it unfeasible to consider expanding the national electricity grid. However, in Phôngsaly province, the local authorities identified the development of hydro power production as a strategic avenue of progress. They then appealed to Électriciens sans frontières to implement a deployment program of a pico hydro power solution.

1. GENESIS AND LOCAL CONTEXT OF THE PROJECT IN PHÔNGSALY PROVINCE IN 2006

Électriciens sans frontières has been present in Laos since 2003. In 2007, at the request of the provincial authorities, the NGO worked in partnership with the Comité de Développement Vietnam France (CODEV Vietphap) and EEP Mekong (Finnish cooperation) charities for the first time in Phôngsaly province, in the Nhot Ou and Phôngsaly districts. Originally the request focused on raising awareness of the villagers of electrical hazards and the transfer of competencies in the field of hydro power.

At the start of the project, Phôngsaly province had the lowest electrification rate in Laos, with only 13% households connected (Asian Development Bank, 2009).

The characteristics of this rugged area, which has many streams and rivers, is subject to monsoons and often covered in mists or fog, makes it natural to harness its potential for production of hydroelectric power. Thus the last decade has seen the emergence of the individual production of electricity using pico hydro turbines supplied by China. This production of electricity nevertheless remains quite random during monsoon flooding season, when keeping the pico hydro turbines in the water is difficult if not downright impossible.

In addition, only a very limited number of villagers are equipped with run of the river horizontal pico hydro turbines (0.3 to 0.6 kVA) placed in the watercourses near the villages. These few pico hydro turbines are installed in a very basic way by the villagers themselves. No installation has a voltage limiter and the lines, whose length is too often excessive, and poorly dimensioned and strongly degrade turbine electrical performance. The facilities are also often poorly protected and electrical accidents are therefore frequent.

In the face of this situation, the authorities and the Ministry of Energy (Electricity department) have informed us that the Électriciens sans frontières project was part of the strategic development for the rural electrification of Laos and that individual or collective pico hydro facilities represent the main avenue of progress for the electrification of isolated villages in Phôngsaly province.

The Lao Government also encourages all initiatives to reduce the poverty of the minorities in north Laos. Under this heading, Phôngsaly province has priority as regards national and international aid, and it has been the target of several programs of the European Union. The villages number 20 to 50 families on average from 30 different ethnic groups. One of the main sources of revenue (34% of revenue) is farming, with flocks composed 55% of chickens, 24% of pigs, and 7% of cattle. The second source of livelihood for the households is the sale of forest products not derived from wood (27%), followed by the planting of cereals (8%) and income from farm work (7%). The average annual income per household is USD 1,400, the lowest income being approximately USD 700 per annum. 94% of households lie below the poverty threshold set by national authorities (Coordination Sud, 2015).

After analyzing their expectations, we suggested the representatives of the provincial authorities accompany the rural populations of the province in a collective approach to access electricity. This approach is based primarily on the transfer of skills, through practical teaching sites and theoretical classes on the management of the resource and the control of electrical hazards, for 2 to 3 villagers selected by the local authorities on the basis of criteria set by Électriciens sans frontières. The selection criteria are relatively simple: young people with reading, writing and basic math skills, but mainly with spare time and an interest in the project.

WHAT IS A PICO HYDRO TURBINE?

1,000W pico hydro turbine
Source: Électriciens sans frontières

A pico-turbine is an assembly comprising a hydraulic turbine or propeller and a 220V single-phase alternator with a permanent magnet. The word "Pico" indicates the alternator's range of power. There are three types of hydraulic turbine: Run of the river Kaplan (vertical pico hydro turbine) or Francis turbine (horizontal pico hydro turbine), and Pelton waterwheel for the high heads ("seated" pico hydro turbine).

2. PRESENTATION AND ORGANIZATION OF PROJECTS ROLLED OUT BETWEEN 2007 AND 2012

The essential goal of these projects was to develop the villagers' capabilities to give them long-term, independent and safe collective access to electricity, relying on hydro power. The area concerned remained fairly localized, and if the operation could not be considered a large-scale rural electrification program, it was intended to reach out to several thousand beneficiaries and serve local authorities as a model for subsequent programs.

The approach therefore relied largely on a learning process intended to develop a sufficient mastery of technical operations and reflexes adapted specifically to pico hydro turbine technology. The

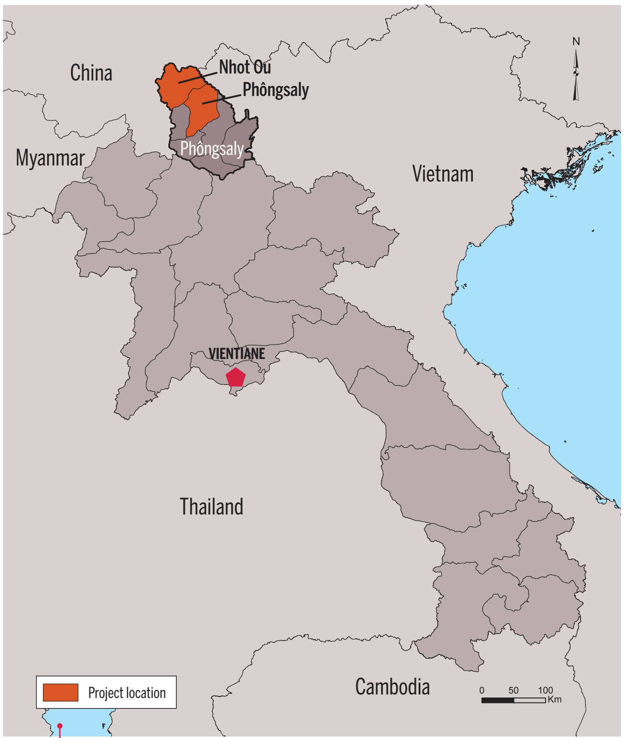


Figure 1. Project location - Source: FERDI

other component was to support the creation of a suitable organization and a favorable environment for the financial sustainability of the facilities (acceptability of fees, establishment of recognized management committees). Finally, all the actions carried out in this framework have been designed to ensure that everything that was transmitted or built could subsequently be reproduced.

Two districts were chosen for this action: Nhot Ou during 2007-2009, and Phôngsaly in 2009-2012. The operation concerned thirty-six villages. These villages were very isolated and excluded from any electrical distribution grid.

2.1. ECONOMIC MODEL AND ORGANIZATION

The project also promoted a collective approach to access electricity. The number of production sites being limited in the area, the solution was inevitably to share production, the rate ultimately retained being 1,000 W per 10 families. The installed pico hydro turbines were chosen according to the watercourse's characteristics and the exact needs of the village, pico hydro turbines of 250, 500, 600, 1,000 and 1,500 W being used. Where it was impossible to electrify all homes, the village governance bodies (village Chief, council of wise men, women's association and a young people's representative) decided on which dwellings to electrify with priority after an iteration process with all villagers. Since the choice was not based on objective criteria, in the event of disagreement between villagers and governance bodies, new meetings could be held until a consensus was reached. The villagers would then have to continue these actions in order to ensure all families of each village can enjoy access to electricity. After making an assessment of the proposed sites as regards hydraulic quality and reliability, Électriciens sans frontières let the village authorities decide the location of the program's pico hydro turbines among those sites with sufficient hydraulic quality. The project revealed some situations where a conflict arose between individual and general interest: in some villages, some families had usurped the right of ownership of the potential production sites on the watercourse by the village. The local authorities successfully ruled on these land problems, sometimes after agreeing on a compensation for the families in question. Similarly, the management principles down to the level of the fees and technicians' salaries were discussed collectively during the project and approved by the villagers.

In all of the villages, the project thus sought to substitute a purely individual energy management by a collective approach.

The management model set up is based on the creation of a village management committee, formed by the village Chief, 3 technicians, a village wise man, a representative of the women and a representative of the young (or a second wise person). This committee is responsible for collecting the fees from the households and relies on the technicians that it pays to carry out the maintenance operations. The fees are collected monthly, and the frequency of maintenance operations is set during the technicians' training period. Any surplus fees are set aside in a fund that can be used to purchase spare parts as required, or to enable the extension of the facilities (additional turbines, etc.) in the long term.

The economic model chosen for this project concentrates the efforts of the initial operator (Électriciens sans frontières) and its partners on the initial investment, while the contribution of the beneficiaries is focused on operating expenses. Électriciens sans frontières and its partners supplied all the equipment and tools, the beneficiaries paying a flat rate fee for access to electricity, used to finance spare parts procurement and maintenance.

The rates were set at the outset, at the outcome of the discussions within the villages, at a single flat rate of LAK 2,000 per month. To justify this single amount, voltage limiters were installed in order to avoid over-consumption by some families.

In terms of organization, the project was conducted collaboratively. The skills were transmitted and shared through teaching sites. In return, the project team relied on the irrigation skills and experience of many rice farmers in the region to reduce the construction costs of the hydraulic structures. The villagers helped build the hydraulic structures, the power lines and supplied all the available raw materials necessary for the works.

At an institutional level, the local authorities showed a strong involvement in the electrification programs. They became aware that sustainability issues were the most important and that installed systems should be based on the principles of sustainability and reliability. This project thus made it possible to encourage a true local institutional movement in Laos vis-a-vis isolated rural electrification, which echoes at small-scale the regional findings of the World Bank evaluation of electricity access programs

(Independent Evaluation Group, 2015)[1]. The involvement of the authorities in favor of electrification is strong at all levels and creates a favorable context not observed on other continents.

The choice of the trainees, training base villages, and villages to install the equipment was done directly by the Ministry of Energy and Mines, while the Department of Energy Policy and Planning managed the information to the various participants in the province concerned with the project and ensured compliance with the commitments of the local authorities and beneficiaries acting as the project steering committee. It is therefore tempting to extrapolate to isolated rural electrification the findings of the above report (Independent Evaluation Group, 2015)[2].

2.2. PRACTICAL ASPECTS

Young people were trained in both in the theory and the practice of pico hydro turbine selection and installation. Each training course included learning about several solutions, through the building of hydraulic works, installation of pico hydro turbines, construction of the electrical lines and creation of interior facilities.

At the end of the project, each village had a team of trained technicians capable of replicating the solutions best suited to the local context to ensure that the entire population could benefit from electricity. A management committee was set up in each village to manage and ensure the sustainability of the facilities and equipment.

The acquisition of general theoretical knowledge and practices required a 10- to 12-day course for a group of 12 to 18 technicians. Each session was organized in a "pilot" village. It was intended to provide the keys to understand the operation and use of hydroelectric installation and the practical knowledge necessary to run new installations or refurbish existing ones. This learning phase required concrete actions in the field, as well as an awareness-raising phase on the use of electricity for the families in the pilot village.

1 "South Asia can also largely eliminate its access (to electricity) deficit if it maintains the pace of new connections it implemented in recent years", p XIV.

2 "These experiences illustrate common underlying principles adapted by each country to its own institutional framework, broadly stated : adherence to a nationwide least-cost national access rollout plan using coordinated grid and off-grid delivery as appropriate to achieve universal access nationwide", p XIII.

Practical training: tests and measurements on an installed pico hydro turbine
Source: Électriciens sans frontières

Almost half the world's
1.2 BILLION PEOPLE
with no access to electricity live in South Asia

50%
of primary schools in South Asia have no access to electricity

Phôngsaly province had the lowest electrification rate in Laos, with only
13%
households connected

The consolidation and evaluation of the technicians' acquired knowledge were based on a full practical exercise: the trained technicians had to install at least two turbines per village. The works were then inspected by Électriciens sans frontières and corrected if necessary by the technicians.

Maintenance operations of several levels were carried out. They were acquired during a twelve-day course taught jointly by Électriciens sans frontières and instructors of the Lao-German Technical School of Vientiane. The exercises included replacing bearings, rewinding the alternator, balancing the machine's rotating part, redoing all seals, lubrication, etc.

Introducing electricity imposed some constraints and changes in behavior, regarding electricity as a hazard, energy saving, and rigorous use and sustainability of the facility. This public awareness issue was also addressed in training.

A little over 90 people were finally taught the techniques to create the facilities and some 20 were taught how to maintain them. The underlying idea was for villages to pool their resources in terms of tools and skills. Of the 36 villages, only 2 were equipped in the presence of Électriciens sans frontières. For the remaining 34, the trained technicians carried out the equipment's installation alone.

Between 1 and 5 variable power pico turbines were installed in each village at a rate of 1,000W per 10 families.

3. PROJECT PROGRESS

One of the characteristics of the NGO Électriciens sans frontières is that it is formed by volunteers who work in field operations. Generally, the operations for this project were carried out by teams of 2 to 3 volunteers, depending on the workload, over 5 week periods. Overall 18 operations were required to complete this project, a total of approximately 1,600 man days.

For the teaching activities in these communities it was necessary to create the training materials, translate them into Lao and convey all equipment and tools to the village. On site, the presence of a good interpreter was paramount to ensure the quality of the discussions.

All operations were covered by an agreement with the authorities, who supplied a transport vehicle, where tracks were available, as well as a guide who was also the district's representative of the Ministry of Energy and Mines. Each operation began with a working meeting with the Chief of the district, in the course of which the project advancement and the program of activities for the current mission were laid out. All operations concluded with a meeting to report to the Chief of the district.

The Ministry of Energy and Mines personnel of the province and districts took part in the training, with a view to acquiring the specific know-who and subsequently being able to provide advice and assistance to the villagers. In the framework of the project, Électriciens sans frontières equipped a small mechanical workshop in the premises Phôngsaly district.

In the villages, the volunteers were housed and fed by the population against payment, in view of the villagers' modest financial position. The contact in each village was the village Chief. It is he who organized the villagers' contribution for the work activities agreed on with the Électriciens sans frontières teams.

4. PROBLEMS ENCOUNTERED

Very quickly during the project's first year, the Chinese pico hydro turbines experienced operating failures. The poor quality of the ball bearings, their premature wear or rapid corrosion limit the bearing life to a few weeks. If unreplaced, off-centering of the rotating part causes friction which may result in the separation of the permanent magnets and block the machine. Other manufacturing anomalies were observed and the manufacturer provided no help. Given the widespread availability of this type of equipment in northern Laos and its low cost, it was decided to improve the reliability of the pico hydro turbines before use. This operation consisted in equipping the machine with quality waterproof bearings, rewinding the stator with copper, balancing the rotating part and redoing all seals. This significantly improved the pico hydro turbines' operating reliability.

36 VILLAGES
electrified between 2007 and 2012

18
field missions

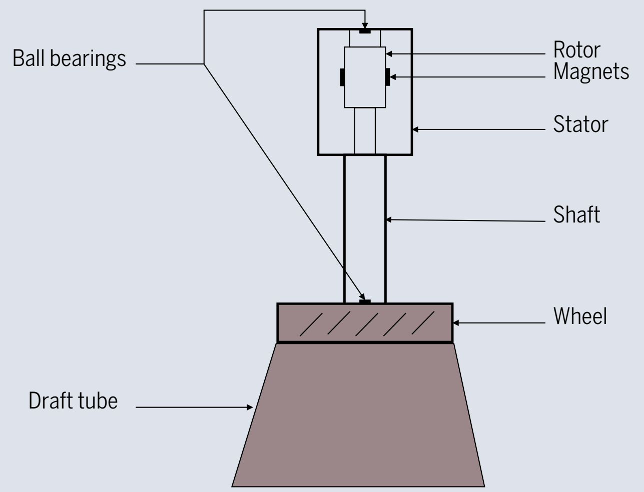
1,000 W
per 10 families

At the same time, Hydrotech pico hydro turbines manufactured in Vietnam were tested. They had the reputation of being the best products available on the Asian market. Despite the prior expert assessment of Hydrotech pico hydro turbines, which showed them to be correct before being procured, when they were put in service they quickly experienced repeated failures which made it necessary to drop this solution because they endangered the project on several counts: discouraging of population vis-à-vis maintenance, and a poor service quality which could encourage the beneficiaries not to pay the access to electricity fee.

These technical hazards, as well as the cost constraints, confirmed the need for the villagers to learn how to improve the reliability of the Chinese pico hydro turbines. Thus 30 Chinese pico hydro turbines, purchased from a local supplier at Phôngsaly, were made reliable during the training course on «maintenance for improved reliability of pico hydro turbines». This solution turned out to be the right one, because the technicians subsequently demonstrated that they master the process and have fully taken it on board.

Other constraints could also complicate the use of pico hydro turbines, such as variations in climate and the strong flooding caused by the monsoons. In anticipation of the risk of equipment damage, the facilities were designed so as to allow dismantling of the turbines in case of very high water.

Diagram of a pico hydro turbine and its components



Source: Électriciens sans frontières

Figure 2

Finally, in the matter of the transfer of skills, the selection of young people was the responsibility of the authorities, district Chief, village Chief, Ministry of Energy and Mines. But the observed low degree of instruction (linked to child work and the obstacle of different dialects) has considerably complicated the training courses and has required a lot of adaptation, including as regards the material used and its contents. The theoretical training part required the most in-depth change, undertaking first a practical approach followed by theory periods, and also limiting training to the essentials on the acquisition of basic knowledge.

5. IMPACTS OF THE PROJECT

On a societal plane, the project impacts were multiple.

In 2011, a study was conducted in 6 villages on the basis of interviews and site inspections, in order to make a mid-course review of the project. Of the 6 villages, only 5 were fully able to answer the questions of the investigators, since in the sixth village, the insufficient water flow in the turbine at the time had not allowed full use of the facilities.

The study covered the following areas:

- Analysis of the electrical consumption of the villagers
- Satisfaction of beneficiaries and impact on their daily lives
- Analysis of the running of the village committees
- Savings for the villagers
- Compliance with the rules for the use of electricity and the facilities
- Application of the maintenance protocol
- Verification of the condition of the facilities and equipment reliability
- Analysis of the operating procedures in the villages

Of the 177 families interviewed, the reported satisfaction rate was 100%.

In 3 of the 5 villages, all of the families were connected to the grid.

The villagers use first electricity to get light. On average they use the lights for 4 hours in the evening (from 6 p.m. to 10 p.m.) and 2 hours in the morning (5 a.m. to 7 a.m.). Families have between 1 and 3 light bulbs according to their standard of living. After that, almost all of the electrical devices in the villages with battery chargers are music devices. According to the villages Chiefs, half were purchased after the arrival of collective electricity.

Table 1. Results of the mid-course project evaluation

Village	Number of turbines	Installed power	Number of families connected to the grid	Number of devices	Percentage of families equipped	Connection rate	Collection rate
Hat Phay	1	1,000W	20	5	25%	100%	100%
Hat Ko	2	2,000W	45	13	29%	100%	100%
Phon Hom	3	3,100W	48	25	52%	100%	95%
Poussoumnea	2	2,000W	31	28	90%	68%	100%
Vanea	1	500W	33	16	48%	48%	100%

Source: Électriciens sans frontières

There are also a few fixed phones (1 or 2) per village.

During this survey, the main changes reported during the interviews were: the ease for performing some household tasks (meals), the improvement in working conditions in the evening for both men and women (repairing of fishing nets or farming instruments for men, sewing and repairing clothing for women), the improvement of social life (school work for children, listening to music CDs in a number of cases) and care conditions for the doctors who visit the families.

The impact of the program has been less in terms of the development of income-generating activities, because the electrification through low capacity hydroelectric production does not supply sufficient power. However, especially for the women who already carried out embroidery activities (local crafts), having quality lighting has allowed them to work in better conditions, even opening up a new field of activities for those wishing to do so.

A year after the project, computing the costs avoided and comparing with the expenditures generated by the arrival of electricity (fee) shows that families could save between 2 and 5 per cent of their annual income according to circumstance. The average cost of the previous energy system was LAK 25-30,000 per month on average for a family, against a monthly LAK 2,000 fee with the new system. The cost has therefore been divided by 10.

"A YEAR AFTER THE PROJECT, COMPUTING THE COSTS AVOIDED AND COMPARING WITH THE EXPENDITURES GENERATED BY THE ARRIVAL OF ELECTRICITY (FEE) SHOW THAT FAMILIES COULD SAVE BETWEEN 2 AND 5 PER CENT OF THEIR ANNUAL INCOME ACCORDING TO CIRCUMSTANCE."

Table 2 summarizes the savings in kips per family over 10 months in the villages. It must be remembered that these savings do not take into account the exceptional collections, which are hard to quantify.

Table 2. Savings per family over 10 months (in kips)

	Hat Phay	Hat Ko	Phon Hom	Poussoumnea	Vanea	Total average
Family 1	210,000	107,000	544,000	550,000	42,000	
Family 2	184,000	182,000	436,000	512,000	382,000	
Family 3	954,000	330,000	306,000	962,000	181,000	
Family 4	416,000	215,000	64,000			
Family 5			-31,000			
Average	**441,000**	**208,500**	**263,800**	**674,700**	**201,700**	**357,500**

Source: Électriciens sans frontières

The new system is more expensive than the previous one only for a very poor family. This family used almost no oil and has had to change its light bulbs several times.

In a few cases, it was also found that access to electricity was accompanied by work to improve the home, which could extend to a permanent construction. This phenomenon remains marginal (3 to 4 houses in a village of 50 families), but reflects the emergence of a new and encouraging movement. During the various site inspections, and particularly during the survey conducted at the end of one year in the 6 villages, no problems of breakdown or malfunction of the distribution network and of the internal installations were observed. This means, in particular, that the maintenance of the network surroundings is satisfactory. As regards internal installations, a few connections made by the households themselves have been observed, but they remain marginal and have not altered the safety conditions of the facilities nor apparently caused any incidents. The danger actually remains limited insofar as the connection facilities (units, wiring, etc.) have been placed high enough to put them out of reach of young children.

From a technical viewpoint, it would appear that the technicians are capable of replicating what they have learned, and that the necessary parts for basic maintenance are easily accessible and stocked. In each village, trained technicians quickly put into practice their skills since the facilities require a daily maintenance, a monthly lubrication for pico hydro turbines equipped with greasing nipples, and bearing replacement and lubrication every 2 to 6 months. In practice, the various inspections carried out showed that beyond the differences observed between villages, the larger pico hydro turbines were very well maintained, while the less powerful turbines supplying fewer homes were not always well maintained. The size of the sample considered for this project, however, makes it impossible to draw general conclusions on this point.

In all the villages visited during the various missions, or during the survey carried out after one year, it was found that the management model put in place allowed the financial and organizational sustainability of the operation in the medium term.

A village was able to install an additional pico hydro turbine, together with a distribution network, and to supply new families thanks to the savings achieved. These installations carried out by the villagers themselves under the supervision of the technicians, were operational during subsequent visits. It is the only example observed to date of replication of a collective installation. In another village, the villagers replaced a turbine that had a serious breakdown. In all cases, the modification of the Chinese turbines had been carried out satisfactorily. The technicians thus demonstrated their ability to set up new installations.

The only brake to explain the limits of the replication of facilities lies in the cost of the fee. This had been set rather low, taking into account the low incomes of some families, and it appears that it results in a collection rate that is very encouraging for the project's sustainability, but it does not allow investment in new installations (excepting the exceptional effort of the inhabitants of one village).

Several villages have thus had to conduct "exceptional collections" of a further LAK 2,000 to 10,000 per month. The management committees therefore considered raising the rates at the end of a year, but preferred to stay on current pricing levels. Thus, the savings are reflected more in an improvement in the financial situation of the households that by a significant deployment of new turbines (see Figure 3).

Figure 3 and Table 3 were made from the impact assessment carried out in 2015 by the Commission Climat Développement de Coordination Sud of 6 access to energy projects[3], including the Laos project of Électriciens sans frontières. Figure 3 serves to measure project efficiency by quantifying the main benefits of the project broken down to one unit of investment made on the one hand by the lender, and on the other hand by the users (the unit being USD 10). In the case of the Phôngsaly province project, the profits in question are the savings of the households and the economic gain for the sector's stakeholders (the technicians trained to maintain the installations):

3 http://www.coordinationsud.org/wp-content/uploads/2015_EtudeCCD_Acc--s----l--nergie_FR.pdf

Project efficiency

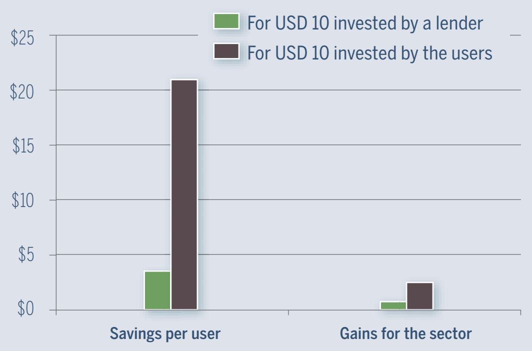


Figure 3

The main lesson drawn from this graph is that the impact of the project is clearly in favor of the direct users (households).

By contrast, the benefits for the economic stakeholders, the technicians, are much lower, as evidenced by the result of the economic impact study below. The study aims to emphasize the long-term impact of the project as a whole taking into account three criteria: the savings made through the project (substitution of energy sources), the savings made by the sector, and the jobs generated by the activities related to the monitoring and maintenance of the technology. The study of the savings was based on internal data, after analysis of savings on the purchase of fuel, and on the basis of a survey of 20 households in 4 villages. The evaluation of jobs created corresponds to the analysis done by the project team and shared with local stakeholders, of the hourly charge for maintenance over a year (a full-time job for a year corresponds to 1,600 hours/year).

Table 3. Results of the economic impact study

	USD saved	USD earned in the sector	Full-time jobs created in the sector
Construction		29,187	9.225
Year 1	58,438	1,235.43	0.97619
Year 2	55,655	1,176.60	0.929705
Year 3	53,005	1,120.57	0.885434
Year 4	40,385	853.77	0.674616
Year 5	33,654	711.47	0.56218
Year 6	32,051	677.59	0.53541
Year 7	30,525	645.33	0.509914
Year 8	29,072	614.60	0.485632
Year 9	27,687	585.33	0.462507
Year 10	26,369	557.46	0.440483

The low level of the single fee makes it impossible to set aside significant revenues for the sustainable development of an activity beyond mere maintenance (for instance, installing new turbines). This led to a revision of pricing levels for the continuation of the program, with several rates.

It was also noted that efficiency is higher from the user's viewpoint than from the lender's, which is typical of an electricity access project with a significant initial investment in capital.

CONCLUSION

The aim of the project in Nhot Ou and Phôngsaly districts between 2007 and 2012 was to give poor populations in 36 very isolated villages access to a minimum of electricity using of pico hydro power production means.

The skills transfer has enabled a standalone but partial deployment of the mini hydro power for the populations, safely. At the end of the project, the trained technicians proved in two villages that they were capable of replicating or replacing the installations, which was essential to the project.

Several avenue of progress have been identified and taken into account in the continuation program initiated in 2014 with a view to electrifying a dozen other villages in Phôngsaly province by 2017:

- *the sustainability of hydraulic works and the associated construction quality,*
  Proposed solution: *in the continuation of the project, the presence of a local hydraulic structures engineering consultant made it possible to work further on this issue and improve the robustness of the works, thus reducing the burden of maintenance.*
- *institutionalization of the management committees and the still partial involvement of women.*
  Proposed solution: *these issues continue to be worked on with the support of local consultants in social engineering with good knowledge of the north Laos region.*
- *the absence of watercourses or sufficient flow in some villages,*
  Proposed solution: *the current project provides for different hydro power or photovoltaic solutions for the electricity production according to the locally available resources.*
- *a single pricing rate linked to the lowest incomes, is sufficient to maintain the facilities but insufficient to allow for their replication,*
  Proposed solution: *a multi-level pricing grid matching the household incomes makes it possible to generate sufficient revenue to consider a wider deployment of the program.*

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WHAT COALITIONS OF STAKEHOLDERS TO ELECTRIFY MADAGASCAR?

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Dam construction in Sahasinaka site
Source : GRET

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KEYWORDS

- ACCESS TO ENERGY
- COALITION OF STAKEHOLDERS
- RURAL ELECTRIFICATION
- PUBLIC-PRIVATE PARTNERSHIP
- PUBLIC SERVICE

This article analyzes the successes and limits of the Rhyviere hydro power project in Madagascar and raises questions about the role of stakeholders in building an effective and sustainable rural electrification model. By promoting a delegation model based on strong institutions capable of playing their part, this experience demonstrates that civil society organizations have a role to play in building fair and balanced coalitions of stakeholders.

INTRODUCTION

With an electricity access rate only reaching 12.3% in 2010, Madagascar is one of Africa's least electrified countries. The situation, common in sub-Saharan Africa, is characterized by a very strong dichotomy of access between urban environments (39% access rate) and rural areas (4.8%). This means that close to 14 million rural people are still living in the dark, without modern energy services (Instat, 2011).

While 77% of the country's population lives in extreme poverty, access to a modern energy source seems the prerequisite to increase the means of production and thereby economic development. Improving access to electricity for these rural households is therefore an important stake for economic development and improvement in living conditions.

The purpose of this article is to present and examine the results of the Rhyviere rural electrification project[1] carried out by GRET in Madagascar between 2008 and 2015. This project, which benefited to nearly 2,000 households on three electrical grids, encourages upscaling to meet the challenge of electrification of the whole country. It has helped to demonstrate that hydro power constitutes a viable technical solution for electrifying small urban centers, at a tariff both suited to the population's capacity to pay and providing a revenue incentive for the service delegatee.

In a context where practical implementation of a relatively stabilized sectoral framework in Madagascar is somewhat random, GRET focuses on structuring and strengthening a balanced coalition of stakeholders. By standardizing the sharing of responsibilities between national institutions, private businesses, local authorities and civil society organizations, the project has helped to stabilize the public-private partnership to achieve sustainable service for rural populations.

1 Village hydro power grids, energy and respect for the environment

1. CONTEXT: AN ELECTRICITY REFORM INCAPABLE OF LIMITING ELECTRICITY ACCESS INEQUALITY IN MADAGASCAR

1.1. PROGRESS AND LIMITATIONS OF THE ELECTRICITY SECTOR REFORM IN MADAGASCAR

Aware of the country's weak electrification strategy and of the need to increase energy access for rural populations, in 1998 the Malagasy State started to reform the sector, through several key measures:

- Liberalizing the electricity sector to give new operators the opportunity to step in. Breaking the monopoly of Jirama, the State company, allowing the electrical energy production, transportation and distribution activities to be provided by private companies, selected through call for tender[2].
- The Agency for the Regulation of Electricity (ORE) was created as an autonomous regulation body. It acts as the usual regulator of the sector, setting tariffs, ensuring compliance with standards and legal and regulatory provisions, promoting competition and the participation of the private sector, while protecting the interests of consumers.
- Establishing financial incentives to fund rural electrification through the creation of the National Electricity Fund (FNE). The FNE may subsidize up to 70% of the cost of the rural electrical infrastructure installed by delegatees[3], making it possible to lower prices to within the consumers' capacity to pay.
- Taking into account the needs of rural populations through the creation of the Agency for the Development of Rural Electrification (Ader). Ader operates under the Ministry of Energy, with a view to increasing the rate of access to electricity of rural populations; it promotes and develops new projects, while monitoring autonomous centers with installed power under 250 kW[4].

Nearly 15 years after the sector's reforms were adopted, the outcome in terms of access to energy remains nevertheless incomplete. The reform's main success is that it has significantly helped increase the private sector's participation. Although Jirama remains the country's main electricity supplier, private operators now generate nearly a quarter of the country's overall production, almost 300 GWh in 2011 (WWF, 2012). Rural communities are the main beneficiaries of the reform since all rural sites are supplied by private operators. However, the sustainability of the infrastructure put in place by these operators is quite random: of the 94 rural networks run by operators[5], 41 grids were not functional at end 2014. Private companies have the worst results, since one rural network managed by a delegatee out of two is non-functional.

In addition, the reform did not help attract investors to the rural electrification sector. Between 2000 and May 2014, only USD 18.2M[6] were invested to develop new projects in total by the State, private delegatees or donors, i.e. barely over USD 1M per year. This degree of funding is therefore particularly low although the financial incentives are significant, especially for renewable energies.

Figure 1. Project location - Source: FERDI

1.2. THE RHYVIERE PROJECT DESIGNED TO MEET THE SECTOR'S WEAKNESSES

In this context, since 2008 GRET, an international development NGO, has been implementing the Rhyviere project which aims to design, test, and popularize mechanisms for the development of self-sufficient small hydro power networks adapted to the rural context of Madagascar. This project is intended to demonstrate the development potential of hydro power grids in rural areas by creating the conditions to entice private operators. Funded by the European Union (Energy Facility), Ader and private operators, this project has enabled the creation of three electrical grids serving approximately 10,000 people across 5 municipalities in the country.

Designed to mitigate the weaknesses identified in the rural electrification sector, the project met

2 Authorizing municipalities or associations of users to ensure the provision of the service. This possibility was granted through a dispensation procedure requiring no competitive process.

3 In this article we use the term "delegatee" to designate the company to which the State outsources the construction, management and maintenance of the service. Malagasy law speaks of "licensee" or "concessionaire", depending on the installed power threshold of the contract.

4 In actual fact, this power limit is not applied. Any autonomous center not supplied by Jirama when the Act was passed is placed under the responsibility of Ader.

5 This is inferred from figures provided by ORE on 31/12/2014. At that time there were seven grids operated by associations or cooperatives, eight by the municipalities and 79 by private companies.

6 Source: Ader, from interviews carried out by GRET in 2015.

with a triple challenge: (i) to develop technical models in line with the local context to reduce the cost of rural electrification, (ii) to develop a methodology to analyze and select the delegatees that renders a utility concession attractive for private companies, and (iii) to accompany the sector's stakeholders, and in particular the grid construction and operation companies, through technical support and capacity-building.

The project implementation was considerably delayed primarily because of the political crisis of 2009 which led to the exile of President Marc Ravalomanana and the establishment of a transition regime. The national institutions and local authorities progressively collapsed until the end of 2013, which delayed implementation of several project activities, in particular those regarding the selection and acknowledgment by the State of the delegatees who would be providing the electrical service. In addition the work has been delayed due to various problems - administrative issues (delay in issuing the environmental permit, sale of an equipment container by the port, etc.), the weather (cyclone washing away part of a dam under construction) and financial issues (delays in payment of Ader's subsidy, bank credit turned down, etc.). Despite these problems, the three hydro power grids were completed by the end of the project:

- The Tolongoina site serving one municipality started operating in June 2013;
- The Sahasinaka site serving three municipalities started operating in December 2015;
- The Ampasimbe site serving one municipality started operating in January 2016.

"THE SEGMENTATION OF A "TYPICAL PROJECT" CLEARLY STATES THE RESPONSIBILITIES OF EACH STAKEHOLDER AND STRUCTURES AN IMPLEMENTATION METHODOLOGY THAT HAD HITHERTO NEVER BEEN REALLY FORMALIZED."

2. INNOVATION TO STRUCTURE THE HYDRO POWER SECTOR

2.1. A METHODOLOGY OF ACTION THAT STRUCTURES ALL STAKEHOLDERS

The project's first innovation consisted in designing an operating methodology making it possible to structure projects through the development of standardized procedures and tools that the stakeholders could use when carrying out their duties. Implementation of a hydro power project was divided into five phases:

- **Phase 1 - Study:** identification of potential sites, reconnaissance survey and preliminary design (PD). Once the PD findings have been approved by the local authorities, the project is officially included in the Rhyviere program;
- **Phase 2 - Fund:** selection of the delegatee through call for tender and signing of a financing agreement to formalize allocation of the investment between the delegatee, Ader, the municipality / intermunicipal group and GRET;
- **Phase 3 - Design:** detailed design (DD) study to validate the final technical sizing of the project. This DD includes, if necessary, an environmental impact assessment;
- **Phase 4 - Build:** construction, by the delegatee or subcontractors, of the electrical and civil engineering infrastructures, disbursement of subsidies by tranche and network compliance certified by ORE;
- **Phase 5 - Operate:** training of and support to the delegatee's activities of technical monitoring and commercial management of the service, the municipality / intermunicipal grouping and users through their association.

Structuring these activities has the advantage of defining the role of each stakeholder in the operation, and thus helping each stakeholder learn its responsibilities in the electricity service. The segmentation of a "typical project" clearly states the responsibilities of each stakeholder and structures an implementation methodology that had hitherto never been really formalized.

In addition, this approach has formalized the role of the municipalities, which was previously limited to obtaining the property rights and easements for the delegatee. In the framework of the Rhyviere project, the municipalities now take part firstly in the project activities implementation phase (identification of potential hydro power sites, presentation and approval of the service sizing, participation in delegatee selection, involvement in monitoring the works, etc.), and later as local project manager for the service, in charge of monitoring and controlling the service operation. A concession contract between the municipality and the delegatee, appended to the concession award decree, formalizes the municipality's role.

This integration of the municipalities is reflected financially by a tax on each kWh consumed added to the electricity rate to fund public lighting and the cost of electricity of municipal public services. This tax, returned to the municipality, can also be used to help fund grid extensions to new neighborhoods or new connection subsidies.

Role of stakeholders in service implementation and monitoring

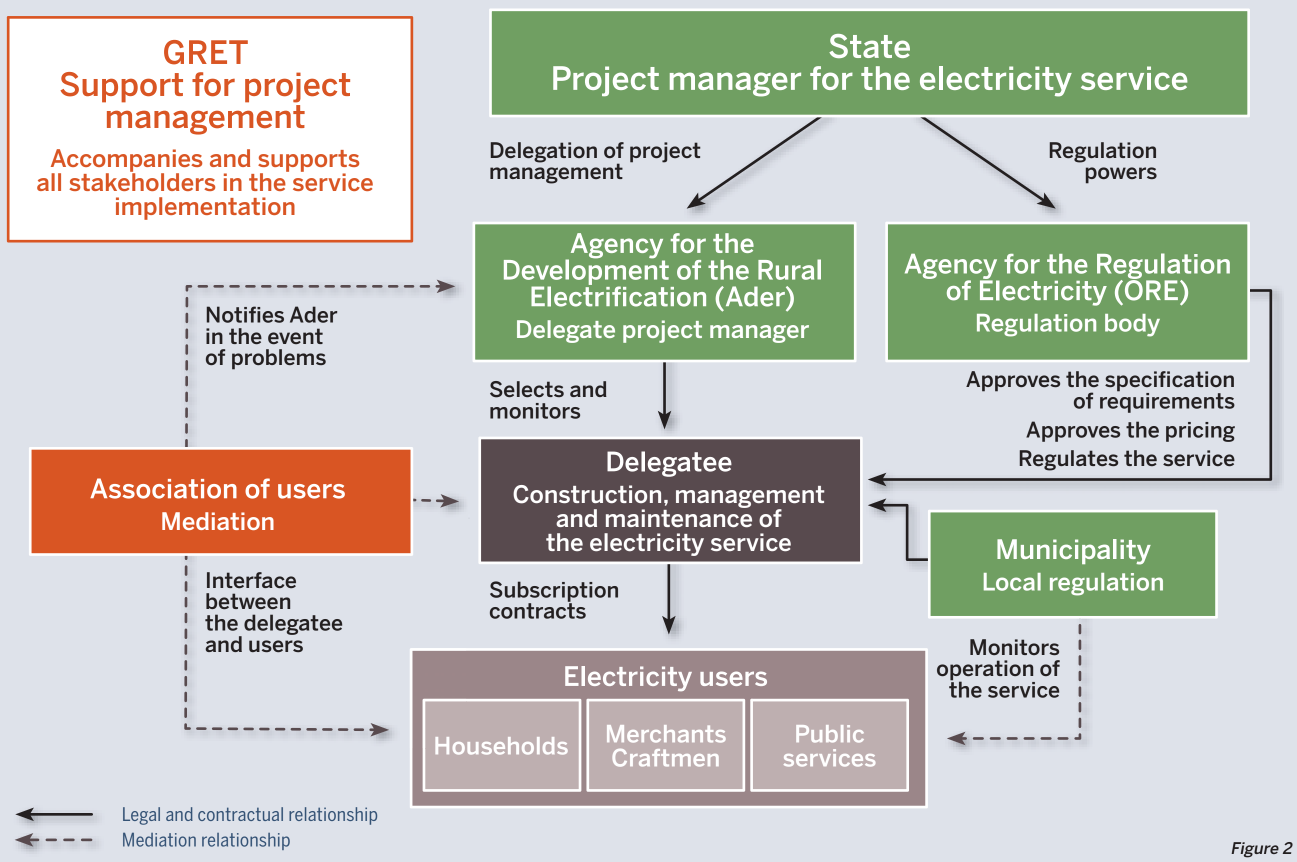

Figure 2

2.2. CO-DESIGNING TECHNICAL STANDARDS TO REDUCE COSTS

Another contribution of this methodological improvement work is the optimization of technical standards for electrical grids in rural areas. The standards used in Madagascar, formerly based on old decrees (1960 to 1964), often taken from urbanized countries, were unsuitable for rural electrification. It would entail an overinvestment in electrical infrastructure and a reduced profitability of rural networks. Defining standards adapted to rural electrification and, more particularly, to micro hydro power, was one of the program's areas requiring work to improve the sector's development. This was all the more relevant because in Madagascar there is no real technological constraint for hydro power in particular, and for rural electrification in general: skills in electricity, hydrology and electro-mechanics are available and a few international turbine manufacturers have local agents. The challenge was therefore to reduce costs to facilitate the implementation of electrification projects.

The GRET team carried out a technical standards optimization process together with Ader and ORE in order to define requirement levels suited to the local context, without sacrificing the required safety of these infrastructures. After working several months with the competent authorities, two guides were designed:

- *Specifications for the design of hydro power networks in rural areas:* it provides lighter design standards for the construction of micro hydro power stations and electrical rural grids and recommends the methodology to carry out studies and choose financing: orchestrating investments to avoid overinvestment at the project launch, contents of the preliminary design studies, recommendations for the sizing of the infrastructure according to the context, templates for works drawings, etc.;
- *Specifications for the operation and maintenance of hydro power networks in rural areas:* it specifies the standards to adopt in order to ensure a high service quality in compliance with the regulations in force and to maximize the service life of each network component. It details the activities required to operate, maintain, and service a rural electrical network, by equipment type (dam, civil engineering works, turbine, grid, etc.) and provides recommendations on the necessary skills and personnel.

12.3%
of the population is electrified in Madagascar

14 MILLION PEOPLE
are living in the dark in rural areas

77% OF THE POPULATION
lives in extreme poverty

Water sharing and deforestation in the watershed - Source: GRET

These two documents are designed as proper guides to support the implementation of investment, by either the delegatee or projects sponsors (donors, NGOs, etc.). They have not yet legally replaced previous regulations, but they have been used since their inception as a required part of Ader's calls for tender for rural networks.

2.3. THE ENVIRONMENT-ENERGY CONNECTION: AN ORIGINAL APPROACH FOR RESOURCE SUSTAINABILITY

The project tested on one of the sites integrating an environmental protection component with a view to achieving sustainability of the water resource, resulting in a mechanism of Payment of Environmental Services (PES)[7]. The watershed whose point of concentration is a waterfall used by the Tolongoina project mainly consists of a protected forest area. The agricultural activities in this basin pose two major risks for the preservation of the water resource: (i) a decline in water quality through increased erosion, which may silt up the facilities and damage the turbine blades by abrasion from sand; (ii) an irregular river flow, with a decrease during low water periods and an increased risk of flooding during rains.

The Tolongoina site, with a small watershed (6 km²) limiting the number of stakeholders involved, was the perfect place to conduct an experiment on a PES mechanism. In the past, conflicts had arisen because the municipality banned slash-and-burn practices, so it seemed relevant to begin negotiations to recognize and reward the services rendered by watershed users in maintaining and developing agricultural practices compatible with the provision of water services. The PES mechanism was all the more relevant because the farmers in the watershed were not going to benefit from the village electrification project.

The originality of IRD's approach was based on the co-construction of knowledge concerning the hydrological services, in order to formalize with the populations of the watershed a shared understanding of both the hydrological services and the perceptions of compatible activities and those that pose a risk to these services. Interviews with farmers and electricity users led to a consensus on the fact that certain agricultural activities threatened the quantity and quality of the water resource.

On the basis of this consensus, new discussions were carried out to convince the electricity users of the need to set up a compensation mechanism for the service suppliers to adapt their practices in order to ensure the sustainability of the water resource. The PES mechanism is therefore built around a contribution from the service beneficiaries (users through their association, municipality, delegatee) paid to the suppliers of the environmental service to compensate them. This contribution is considered "voluntary" because all service beneficiaries have voluntarily decided on the principle of contribution and its amount. The payback for this compensation is the adoption or strengthening of practices conducive to the preservation of the water resource.

7 This work was carried out together with a team from the Institut de Recherche pour le Développement (IRD) working on environmental services, within the framework of the SERENA program dealing with issues related to the emergence and implementation of the notion of "environmental service" in the field of public policies for rural areas. SERENA is a research project carried by IRD, CIRAD and IRSTEA between 2009 and 2013. It brought together some 30 researchers.

Organization of the PES mechanism in Tolongoina (Toillier, 2011)

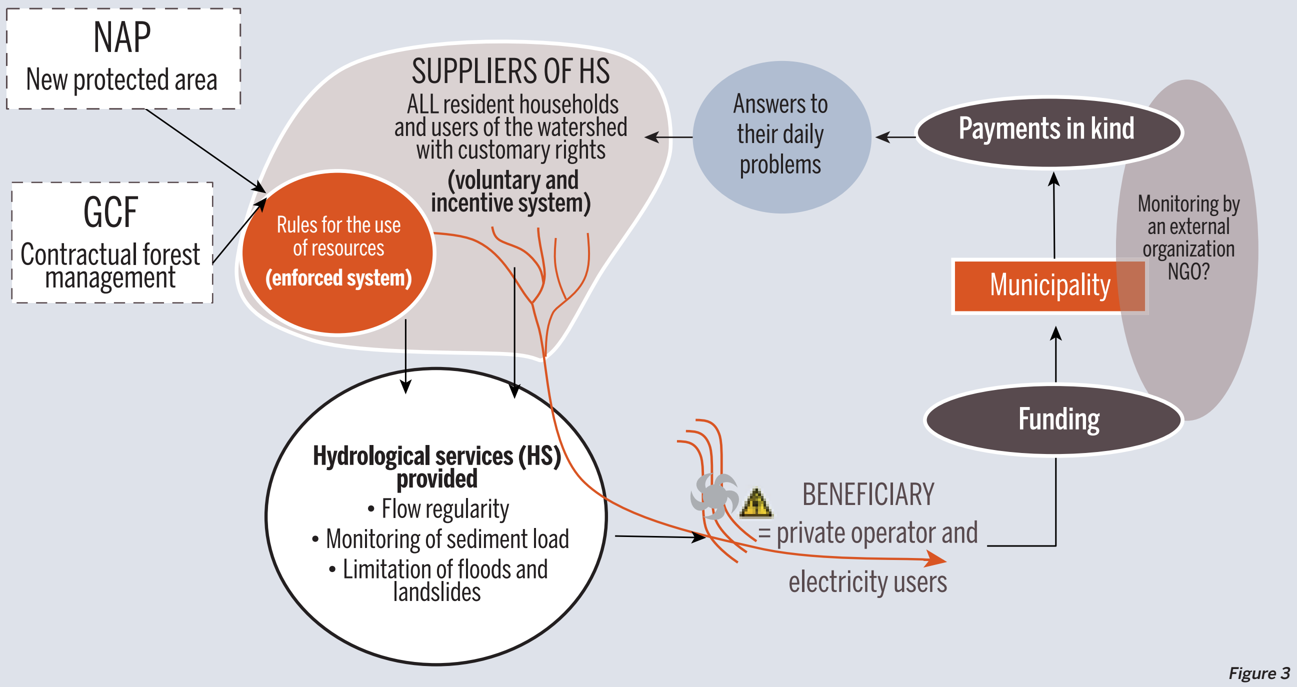

Figure 3

The PES contract, which sets forth the organization of compensation between suppliers and recipients of the Environmental Service (ES), was signed in September 2013. This agreement formalizes the creation of the Andasy watershed management committee (KOMSAHA), whose board brings together representatives of the parties to the agreement, and organizes the payment of the contributions of each ES beneficiary: a 2.5% tax on the monthly electrical consumption of subscribers; flat rates of MGA 100,000 per month (EUR 29) for the delegatee and MGA 90,000 per month (EUR 26) for the municipality. The annual amount is expected to be MGA 3.4M (EUR 971), which should serve to support the implementation of the conservation agricultural activities and the conservation of the forest in the basin.

3. RESULTS AND LESSONS LEARNT FROM THE RHYVIERE PROJECT

Table 1. Main features of the three grids set up by the Rhyviere project

Site	Tolongoina	Sahasinaka	Ampasimbe*
Region	Vatovavy Fitovinany	Vatovavy Fitovinany	Atsinanana
Nbr of municipalities	1	3	1
Target population	355 households	900 households	700 households (1,500 households)
Installed power capacity	2 x 60 kW	3 x 80 kW	3 x 80 kW (2 x 330 kW)
Investment budget % financed by the delegatee	€ 192,000 15.7%**	€ 408,000 31.5 %	€ 409,000 (€ 1.025M) 33.5% (73.5%)
Tariff • Subscription • Lightbulb flat rate	€ 1.3/month + € 0.10/kWh € 0.50/lightbulb/month	€ 1.3/month + € 0.15/kWh € 0.80/lightbulb/month	€ 1.3/month + € 0.11/kWh € 0.33/lightbulb/month

* During the detailed design study, the delegatee of the Ampasimbe site decided to increase site capacity by eventually installing two 330 kW turbines in order to sell the surplus power to the Jirama electrical grid of the seaside town of Foulepointe some 20 km away. The figures in brackets concern this new sizing.

** The financial sustainability outlook for the Tolongoina site being fairly weak, it was decided with Ader and ORE to increase the subsidy amount relative to the 70% ceiling usually allowed. The delegate's investment is therefore less than that for other sites.

Tolongoina grid electricity consumption (June 2014 - May 2015)

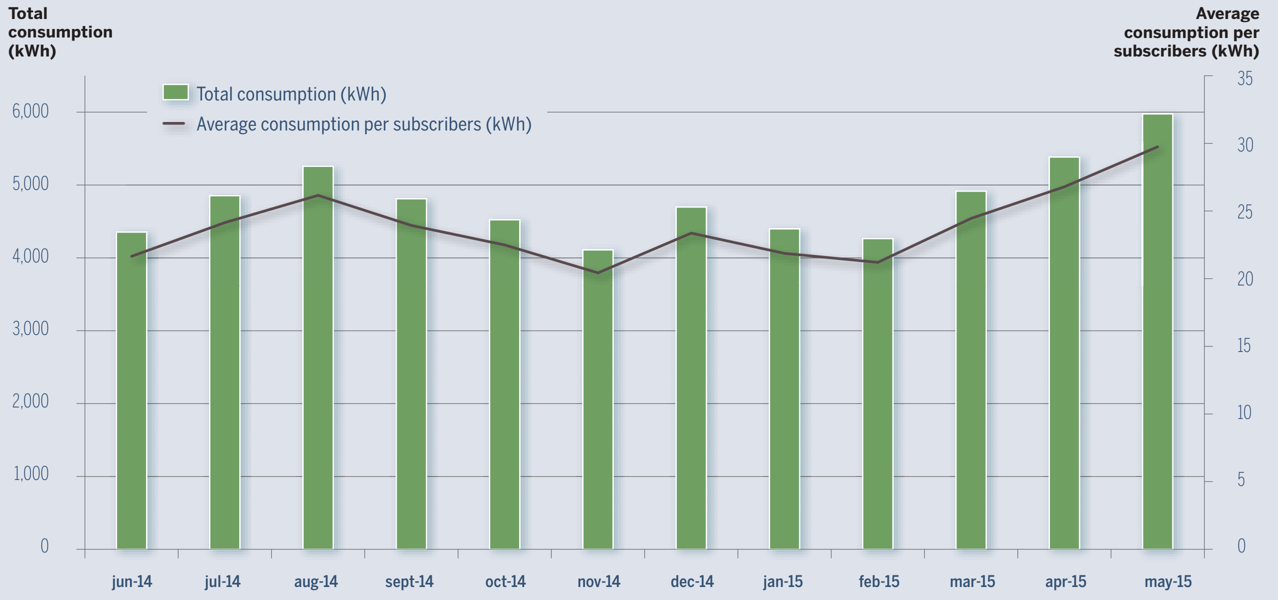

Figure 4

3.1. A QUALITY OF SERVICE DESPITE PERSISTENT INEQUALITY OF ACCESS

Many constraints, in particular concerning the political situation in Madagascar, have caused the Rhyviere project to experience a significant delay which has shifted the start of service of the hydroelectric networks. An analysis of the operating data of the Tolongoina site, operational since June 2013, nevertheless shows that the proposed electrification solutions are suitable to the rural context. The data from the first two years of operation, as well as the satisfaction survey carried out by the project, confirm the good results:

- The number of subscribers has achieved after two years of service the planned forecast for the sixth year of operation, while new connection applications are pending because of meter stockouts;
- The average consumption per subscriber is consistent with forecasts. It shows a non-linear but constant rise since the start of service;
- Over one-third of households have acquired electrical equipment (radio, television, DVD player);
- 87% of the local firms were connected to the network in the first six months of operation, and seven new companies were created during this period as a direct result of the arrival of electricity (grocery store, bar, electronic repair workshop, multimedia store). In addition, 29% of businesses said they had acquired new equipment after the electrical grid started operating (refrigerators and freezers, soldering iron, mixer robot, multimedia equipment, etc.). However, no specific study has been carried out to quantify specifically the impact of electricity on these companies' turnover;
- Peak consumption rose from 49 kW in 2013 to 55 kW in 2014. The installed power of 60 kW has now been reached, which makes the purchase of a second turbine a priority;

Table 2. Key figures of the Tolongoina hydro power network (June 2013 - May 2015)

Number of subscribing households	200
Average consumption per subscriber	24 kWh/month
Peak consumption	55 kW
Connection rate	56% of households
Connection subsidy	MGA 50,000 (€ 14)

"THE LACK OF CONTROL AND REGULATION OF THE DELEGATEES AND THEIR LOW FINANCIAL INVESTMENT IN THE INFRASTRUCTURE CONSTRUCTION SEEM TO BE THE MAIN REASONS FOR THE CONTINUAL WEAKENING OF CONCESSION CONTRACTS SANCTIONED IN THE PAST."

- Subscribers are mostly satisfied with the quality of service and the electricity tariff. The collection rate exceeds 95%;
- The delegatee controls his grid and performs his duties. He carries out improvements on the infrastructure to limit the risk of outages and of service interruption. Service availability is greater than 95%, in accordance with the requirements of the public service concession contract.

However, a closer analysis of consumption data shows that it is the more affluent households (and thus those having a higher individual consumption) that are connected. Thus, according to the satisfaction survey GRET carried out after 6 months of service, 98% of affluent households and 52% of medium income households were connected to the network, but only 3% of poor households[8]. Although a connection plan had been specially designed for poor households, the "lightbulb flat rate", allowing connection without a meter to operate only one or two lightbulbs[9]. Despite very attractive pricing, and even though connection was subsidized, only 6% of households are connected to this „lightbulb flat rate". Therefore the good results of the Tolongoina grid probably mask a strong inequality in access to the service.

This phenomenon can be explained by (i) the nature of the subsidy mechanism, of the type *Output Based Aid*, which encourages the delegatee to make network connections quickly. Poor households, waiting for the service to be tried and tested before connecting to the grid so as not to "lose" their investment, benefit less from subsidies; and (ii) a higher connection cost for poor households due to the grid configuration, which covers the main roads when such households tend to be on secondary roads; (iii) a policy of the delegatee to willingly promote full connection at the expense of the "lightbulb flat rate", less attractive financially.

Although it is complex to target the poorest so that they can benefit most from connection subsidies or to encourage them to connect to the grid from the first months of service, new strategies can be set up to reduce inequality of access to electricity. This can go be done by (i) better sizing of the electrical grid during the design phase to setup low-voltage lines passing through the heart of low income neighborhoods, thus reducing the cost of connection, (ii) mobilizing municipalities to allocate connection subsidies, (iii) raising awareness among the poorest households at the start of service, or (iv) dividing the subsidies between the meter subscription and the flat rate subscription, to ensure all subsidies do not solely go to more affluent households.

8 Household categorization is based on a combination of criteria: main activity of the head of the household, education level, occupancy status, dwelling type (general condition, walls and roof).

9 This package allows poor households to benefit from lighting at a very reduced price, less than the average expenditure for lighting with an oil lamp.

Tolongoina grid - Source: GRET

Sahasinaka hydroelectric dam - Source: GRET

3.2. THE PERFECT DELEGATEE: AN INVESTOR WITH FUNDING AND TECHNICAL SKILLS

The delegatee is the cornerstone of the service. The relative weakness of national institutions, combined with their limited means of control and regulation, puts sole responsibility for service quality squarely on the delegatee's shoulders; it is therefore important to select a competent delegatee. The delegatees selected for the Rhyviere project sites had very varied profiles:

- Tolongoina site: small electricity business made up by several shareholders including university professors specialized in energy. The delegatee had good technical skills but little experience in construction projects.
- Sahasinaka site: a small construction company. The delegatee turned to outside service providers for the electrical skills and construction of the dam.
- Ampasimbe site: civil engineering and drilling company, whose CEO comes from the project area. His profile is more like that of an investor who expects a return on investment in the long term. He has acquired in his company the required technical skills in electricity and demonstrated a true capability to carry out the infrastructure works.

For each site, the tenders were assessed on the basis of precise criteria. The technical proposal was analyzed first, and only tenders attaining a minimum of 60 points were shortlisted. Next the financial evaluation graded proposals on the basis of the amount of the subsidy requested to carry out the work and the proposed electricity rates.

Table 3. Technical criteria for analysis of tenders

Analyzed criterion	Number of points
Activities and experiences in construction and management of an electrical network	20
Proposed solutions for the construction of infrastructure	30
Proposed solutions for management and provision of the service	30
Understanding of public service concession	10
Motivation for the project	10

The lessons learned during the project serve to emphasize the key aspects of the delegatee profile:

- Broader skills: the delegatee's function is multifarious, calling on a variety of skills, both technical and in administration, logistics, supervision, management and negotiation. Delegatees with good technical skills in the field of electricity can be very quickly overwhelmed by the constraints of building hydroelectric infrastructure and managing the service. Technical skills, while necessary, are insufficient on their own;
- Suitable financial capabilities: the delegatee, who must cover at least 30% of the investment, must be able to obtain this funding. The project has experienced several delays because it did not check the financial standing of the delegatees, on the one hand

because it is difficult to assess the financial standing of a business when the data supplied by the bidders is not standard and hard to check, and on the other hand, because a bidder may indicate he will use of a line of credit but subsequently not be granted credit once the concession contract has been signed;

- Investor more than entrepreneur: the delegatee must develop, as soon as he is selected, a medium- or even long-term vision of his activity[10]. This implies in the first place understanding that a utility concession contract is not a works contract: since the return on investment is only possible if service continuity is maintained, the delegatee must promote equipment quality rather than cost reductions that could subsequently lower the profitability of its investment.

The ideal profile to become a delegatee is that of an investor with a service vision and sufficient financial resources, or the ability to mobilize such resources, supported by a team with quality technical expertise.

3.3. A MECHANISM FOR PAYMENT OF ENVIRONMENTAL SERVICES WITH MODEST BUT PROMISING IMPACT

After almost two years of operation, the PES contract has shown that though limited, its effects are real. The money collected has been used to roll out several activities planned in the watershed management scheme, such as monitoring trips to check the state of preservation of the forest or the development of food crops compatible with the protection of the catchment area (beans, peanuts, demonstration plot on good practices for growing ginger, etc.). Even if the impact of these activities on the quality of the environmental service is as yet limited, they serve to improve farmers' living conditions. The farmers regularly submit projects to the committee, which approves funding and supports implementation of the projects.

In the end, it appears that the biggest success of the PES mechanism is to have encouraged a dialog between the inhabitants of the watershed and populations living downstream, on the subject of water resource preservation. While the service providers do not benefit from the effects of electrification, they have agreed "as a service" because their problems are being considered by the beneficiaries (Toillier, 2011). The watershed management committee becomes a sustainable structure rewarding agricultural practices compatible with proper operation of the hydro power station, while at the same time the farmers acquire these good practices. The method based on co-constructing a shared vision around hazards and good practices seems to have created favorable conditions for acceptance of the PES mechanism.

The main weakness of the mechanism, in addition to the fact that the money collected is insufficient to cover all activities identified as necessary to preserve the water resource, lies in the difficulty of monitoring this mechanism, which is not part of an independent project management. The Tolongoina municipality cannot perform this function as it is itself the beneficiary of the ES and stakeholder of the PES contract. The system is missing a third stakeholder who would guarantee the preservation of the water service. GRET will continue to perform this function as long as it is present in the area, but its role is not to continue supporting the local operators in implementing this contract. The PES contract renewal in 2016 should provide the opportunity to fill this gap.

4. THE REASON FOR THE SUCCESS OF THE RHYVIERE PROJECT: THE CREATION OF A STAKEHOLDER COALITION BETWEEN PUBLIC AUTHORITIES, BUSINESSES AND CIVIL SOCIETY

4.1. THE NEED FOR A STRONG PUBLIC AUTHORITY TO SUPPORT PUBLIC-PRIVATE PARTNERSHIP

The analysis of concession practices and relations between the State, the construction owner through Ader and the delegatee, shows that public authorities do not really carry out their duties under the law, which undermines the public-private partnership. Whereas the legal framework in Madagascar is fairly well designed and the institutional framework has been stable for nearly 15 years, delegatees are barely controlled and poorly regulated, which seems to be the main source for the continual weakening of sanctioned concession contracts. Experience acquired on the Rhyviere project shows, on the contrary, all the importance of having a strong public authority to encourage the sustainability of public-private partnerships.

This is illustrated on the question of control of the investment made by the delegatees. Since it is mainly the delegatees who carry out the service sizing preliminary studies (PD and DD), they themselves define the total amount of the investment on which their subsidy will be indexed. However, Ader does not have the means to analyze these technical files in depth, which leaves the

"EXPERIENCE ACQUIRED ON THE RHYVIERE PROJECT SHOWS, ON THE CONTRARY, ALL THE IMPORTANCE OF HAVING A STRONG PUBLIC AUTHORITY TO ENCOURAGE THE SUSTAINABILITY OF PUBLIC-PRIVATE PARTNERSHIPS."

10 In Madagascar, rural electrification concession contracts are usually granted for a period of 20 to 30 years. ORE defines the duration of the concession contract as a function of the forecast business plan of the service, in order to guarantee a sufficient return on investment to the delegatee.

door open for the delegatee to overestimate the investment, therefore raising the amount of the subsidy it receives. This is even more plausible since Ader does not check the investment made by the delegatee during the works, since it has no permanent presence on the worksites and does not mandate an independent works controller. Delegatees may can therefore play with the specifications of materials and declare costs of works exceeding actual costs.

The assumption that we make as a result of these observations is that several delegatees have invested nothing or very little in building their infrastructure. By overestimating the investment budget in the preliminary studies and by reducing the quality of the work, it would be possible for a delegatee to carry out the work without investing its own contribution, and even make a profit. If he does not invest, the delegatee‘s position changes from that of concessionaire to lessor (Levy and Ged, 2007), which changes his assessment of the risk. This may explain the high proportion of grids abandoned by private delegatees: a company not constrained by return on investment can drop the service in the event of difficulties.

The methodology GRET deployed has ensured that delegatees invest. It established three levels of control: (i) the level of subsidy to be received by the delegatee is calculated on the basis of the pre-project study, the preliminary design, carried out by the project team; (ii) GRET checked on funds disbursed by the delegatee, through their invoices of equipment and supplies; (iii) the works carried out are inspected by the project team, as well as by an engineering firm mandated by the municipality. GRET has helped Ader gain awareness of its responsibilities and has demonstrated the need to structure a strong public authority to implement a public-private partnership.

4.2. INTEGRATING LOCAL AUTHORITIES, A NECESSARY LINK TO BALANCE THE CONCESSION CONTRACT AND ENSURE LOCAL POPULATIONS RECEIVE BETTER SERVICE

Madagascar’s institutional framework gives local authorities a limited role. Since project ownership for rural electrification is national, local authorities are poorly informed of the issues in this sector and only slightly involved in projects. These municipalities nevertheless have a role to play in the project management of the rural electrification scheme, and can complement the national authorities:

- Local authorities can play a part in identifying projects and prioritizing needs. The approach used for the Rhyviere project thus relied on (i) involving the municipalities to identify potential energy resources in their territory and (ii) testing a municipal electrification planning scheme to determine the need and demand for electricity, propose solutions adapted to each site, and prioritize the most relevant projects. The municipalities can reclaim control over the issues of rural electrification, which are debated as a component of local development;
- The municipalities must be integrated in the monitoring and the local regulation of the service. In a context where Ader and ORE are distant from the electrified sites and do not have sufficient means to monitor the situation properly, turning to local authorities is a good way of balancing the public-private partnership. A contract between the delegatee and the municipality makes it possible to designate the municipality as project owner, acting on behalf of the Ministry for Energy, in order to control the quality of the public service and monitor the delegatee. The municipality thus becomes local regulator guaranteeing compliance with the social purpose of the service.

4.3. ROLE OF NGOS: COMPLIANCE WITH THE RULES, SUPPORT TO STAKEHOLDERS AND SECURING THE CONCESSION CONTRACT

Alongside stakeholders acknowledged by the legal framework and those whose legitimacy lies in their local presence, what is the role of the NGOs who often sponsor rural electrification projects? In the example of the Rhyviere project, GRET facilitated structuring the coalition of stakeholders, which gave it strength and relevance.

Firstly, GRET defended before the other stakeholders the strict observance of the legal framework, so often neglected. Whereas traditional concession practices were completely divorced from the very letter of the law, GRET based its actions on compliance with these rules and pushed for their application. The control mechanisms deployed around the main steps of the project have therefore encouraged, or even forced, the other stakeholders to play their part in the public-private partnership.

Secondly, the presence of GRET contributed to the emergence of a better understanding of the interactions between the stakeholders. Ader, ORE, delegatees, engineering firms, municipalities and users’ associations were strengthened both to ensure they understood their role in the country‘s rural electrification strategy, and to enable them acquiring a better knowledge of the other players in the sector. An effective coalition of stakeholders can only emerge when businesses, local authorities and national administrations perceive themselves as partners committed toward achieving the same goal.

Finally, the work to formalize the standards, procedures and tools carried out by the project team constitutes a basis that makes the public-private partnership safer, for the national authorities and the delegatees as well. The project feedback shows that delegatees are reassured by good quality data and well-established procedures. Far from slowing down electrification project implementation, the steps of diagnosis, sizing, and control ensure a better chance of sustainability of the service, which is encouraging for both the authorities and delegatees.

CONCLUSION

The lessons learned from the Rhyviere project provide options to improve the mechanism for concessions in Madagascar. Whereas the legal framework is stable and the competency of both public and private stakeholders is rising, improvements are needed to enhance the impact of rural electrification projects:

- *Public authorities must impose their definition of the infrastructure, particularly so when they subsidize a part of the works. Using independent engineering firms to carry out the preliminary design studies and to control the delegatees will ensure the delegatee's level of financial investment is adequate;*
- *The delegatee's financial commitment must be real and relatively high: it is a pledge of motivation and moral commitment to the service. As a corollary, it is necessary to develop financing solutions allowing private companies to engage in rural electrification projects;*
- *The local authorities must take part in the project ownership to complement the national authorities. They can act as local regulators, capable of balancing the concession contract to guarantee the social goal of the service.*

Finally, the project has highlighted the fact that coalitions of stakeholders comprising the State, local communities, businesses and civil society organizations are capable of providing innovative solutions to meet the challenge of rural electrification. By avoiding the pitfalls of dogmatism and simplification, these open and balanced coalitions can offer appropriate solutions to promote universal access to energy that is affordable, reliable, sustainable and modern.

A question nevertheless remains: the impact of the project on economic development and on the living conditions of households. The analysis of the Tolongoina site, in service for more than two years, suggests a true impact: many households have acquired electrical equipment, craftsmen have adapted their production tools, health centers have electricity 24/7. However, it would be necessary to carry out a more precise analysis of these phenomena to better quantify and understand the project's actual socio-economic impact.

A new phase of the project, started in 2015, covers the electrification of three new sites to serve approximately 50,000 beneficiaries in the regions of Sofia, Haute Matsiatra and Amoron'I Mania. It incorporates a specific component to encourage economic development by supporting the small and medium enterprises of the towns concerned. This specific work should strengthen the effects of electrification on the populations and improve living conditions in the target areas.

"COALITIONS OF STAKEHOLDERS COMPRISING THE STATE, LOCAL COMMUNITIES, BUSINESSES AND CIVIL SOCIETY ORGANIZATIONS ARE CAPABLE OF PROVIDING INNOVATIVE SOLUTIONS TO MEET THE CHALLENGE OF RURAL ELECTRIFICATION."

ACKNOWLEDGMENTS

François Enten (GRET),
Albert Rakotonirina (GRET),
Rija Randrianarivony (GRET),
Georges Serpantié (IRD),
Aurélie Vogel (GRET).

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SOLAR POWER INTEGRATION ON THE SEYCHELLES ISLANDS

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Energynautics is a power system analysis, engineering and consulting firm based in Darmstadt, Germany. The main focus of company activities is the integration of renewable energies into electrical power systems, especially wind power and solar photovoltaics. Since 2000, the team has been providing world-wide services considering power systems of all sizes, ranging from small islands to large interconnected systems.

KEYWORDS

- ELECTRICITY SUPPLY
- ISLAND SYSTEMS
- SOLAR POWER
- INTEGRATION LIMITS

The Seychelles aim to cover 5% of electricity with renewables by 2020 and 15% by 2030. The local power system operator commissioned a Grid Absorption Study to determine the technical limits for reaching these targets. The study focussed on how much photovoltaic (PV) generation the grid can absorb. As result, the primary bottleneck was found to be the maintenance of backup generation reserves to compensate for fast down-ramping of PV generation.

INTRODUCTION

The Republic of Seychelles, an island state in the Indian Ocean, has targets to reach 5% coverage of its electrical demand with renewable energy (RE) sources by 2020 and 15% coverage by 2030. In 2014, Energynautics GmbH was commissioned by the Public Utilities Corporation (PUC) of Seychelles, financed by the World Bank, to examine whether the Seychelles grid could absorb so much renewable generation and to develop a Grid Code for the connection of distributed generation units to the power system. In addition our project partners Meister Consultants Group, Inc., prepared draft Feed-In Tariffs and Power Purchase Agreements for the Seychelles. In this paper we present the results of the Grid Absorption Study (Ackermann et al., 2014).

The Seychelles consists of over 115 islands in the Indian Ocean off the east coast of Africa. The main island of Mahé, on which the capital Victoria is also located, has a population of around 80,000, a peak load of 50 MW and an area of 155 km^2. The next-most-populated islands Praslin and La Digue are only 44 km away from Mahé and connected to each other by undersea cables. The combined Praslin and La Digue system has a peak load of just over 7 MW and a population of 8,500. The remaining islands are only sparsely-populated. The interplay between size, weather and the characteristics of the power system makes each island system unique when considering the integration of renewables. In this paper we mostly focus on the main island of Mahé.

In 2013, eight wind turbines were installed in the harbour of the capital Victoria with a combined nominal power of 6 MW, which is enough to cover 2% of Mahé's annual load. Apart from a few dozen photovoltaic (PV) installations, the rest of Seychelles' generation is provided by diesel generators running predominantly on heavy fuel oil (HFO).

1. STUDY INPUT CONSIDERATIONS

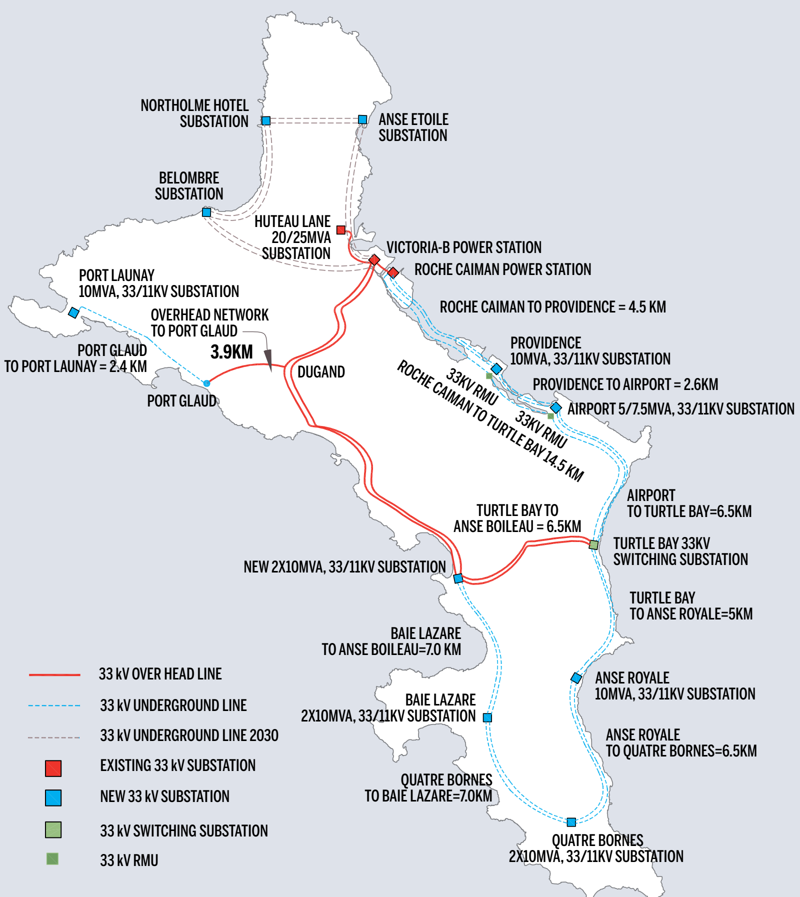
The Grid Absorption Study focussed on two years: 2020 and 2030. Capacities for wind, biomass, hydroelectricity and waste-to-energy were agreed in advance with PUC and the Seychelles Energy Commission (SEC), based on potentials limited by, for example, existing land use. Therefore the chief objective of the study was to determine how much solar power can be installed on the islands, since the potential PV capacity is in theory very high.

Simulations were performed with a network model of the three main islands of Seychelles in DIgSILENT's PowerFactory software tool to investigate voltage problems, overloading of network assets, frequency stability and the maintenance of sufficient reserves with varying amounts of PV.

1.1. SEYCHELLES TRANSMISSION NETWORK

The backbone of the Seychelles power system is an 11 kV and 33 kV network on Mahé and an 11 kV network on Praslin and La Digue. Praslin and La Digue are connected via undersea cables. A complete computer simulation model of these networks (with low voltage feeders aggregated at their transformers) was made available by the network operator PUC, including dynamic models of the diesel generators on Mahé (it was not within the scope of the project to validate these models). In 2014 there were only a few 33 kV lines on Mahé, but because of undervoltage and overloading problems due to growing demand, the 33 kV network will be extended to the South of the island by 2020 (Al-Habshi Consultants Office in association with ECOM, 2013) (see Figure 1). These extensions were built into the network model as well as extensions to North Mahé, which were found during the study to be necessary by 2030 due to the rising load.

Mahé's 33 kV transmission network, in the state foreseen for 2020 (red and blue) Extensions to the North, needed by 2030, are marked in brown



Source: PUC, Energynautics

Figure 1

"THE SEYCHELLES AIM TO COVER 5% OF ELECTRICITY WITH RENEWABLES BY 2020 AND 15% BY 2030."

1.2. LOAD DEVELOPMENT UP TO 2030

The load in Seychelles has two peaks: one at around midday on workdays and another in the early evening (see Figure 2). The peak demand

UNDERSTANDING UNDER/OVERVOLTAGE AND OVERLOADING

Typical cause for *undervoltage* in an electrical power system is the interplay of several factors – too little capacity reserves of lines, cables, and transformers; too high consumer load; insufficient or inappropriate reactive power provision. The consequence is a reduced quality of supply, where electrical consumer appliances do not work as expected. It also creates issues with proper detection of faults like short circuits, which cause physical danger when not cleared quickly. *Overvoltage* signifies too high generation infeed instead of high consumer load, together with the other factors mentioned above, and has similar kinds of consequences. While short circuits may still be properly detected, overvoltage can lead to damage to consumer equipment, and additional faults when electrical insulation is unable to withstand the higher voltage.

Similarly, the interplay of several factors is responsible for *overloading* issues: too little capacity reserves of lines, cables, and transformers; too high consumer load or too high generation infeed. While the voltages may still be acceptable, overloading leads to inappropriate heating of the equipment. The consequences are reduced lifetime of the network equipment, leading either to increased costs for maintenance, repair, and replacement, or reduced quality of supply due to outages. In the worst case, physical danger due to overheating and resulting fire ensues.

is expected to rise by 6% a year until 2030, with additional step jumps because of large individual loads that have been waiting for their connection until the new 33 kV network is built (such as new hotel projects in the South of Mahé). The expected load development is shown in Table 1.

Table 1. Load development assumptions

Peak load [MW]	2014	2015	2020	2030
Mahé	50	53	76	141
Praslin & La Digue	7	8	12	22

The yearly demand in 2014 on Mahé was 323 GWh/a and will rise to 875 GWh/a by 2030; the minimum demand is around 52% of the peak.

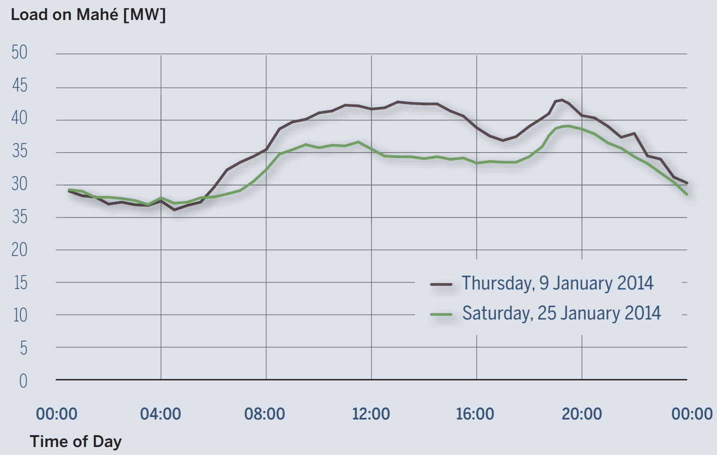
The loads consume not just active power but also reactive power, which is needed in the motors of the large number of air-conditioning units on the islands. Reactive power describes an effect related to alternating voltage and current, where the currents are higher than strictly necessary for the actual (active) power transmission. These higher currents are needed to maintain quality of supply, and must be provided by generators or other dedicated assets. The term “power factor” denotes how much reactive power a generator provides. When comparing generators, a lower power factor means a higher contribution of reactive power. The diesel generators on Seychelles currently provide reactive power with a power factor of 0.86, corresponding to the reactive power needs of the consumer load and the network infrastructure.

1.3. DETAILS OF DIESEL GENERATORS ON SEYCHELLES

On Mahé there was 71 MW of diesel capacity in 2014, with generators ranging in size from 1.2 MW to 8 MW. The newest and largest generator sets were all manufactured by Wärtsilä (Wärtsilä, 2013). The Praslin/La Digue system had a diesel capacity of just under 13 MW in 2014 consisting of units with available power ranging from 0.4 MW to 2.2 MW. To cover the rising load over the next fifteen years, it is expected that new diesel generators of sizes between 8 MW and 15 MW will be installed on Mahé and with sizes around 3 MW in the main power station on Praslin.

The active power output of the generators is usually set between 75% and 80% of the maximum output to leave some backup capacity, which is referred to here as “spinning reserves” because the reserves are provided by generators which are online and therefore spinning. This allows enough spinning reserve to cover the loss of the biggest generator in the system and it is also the operating range in which the engines are

Daily load profiles for a weekday and a Saturday



Source: PUC

Figure 2

at their most efficient. According to the Wärtsilä product guide the engines can be turned down to 50% loading level with only a 6.1% loss of fuel efficiency and can even go down to 30% for short periods, as long as they are run back up to 70% to burn off the products of incomplete combustion. The engines of MAN Diesel & Turbo have similar capabilities (MAN Diesel & Turbo, “32/40 Project Guide”).

Backup generators which are not connected to the grid at a given time are referred to as ‘non-spinning reserves’. The generators which provide non-spinning reserves take 10 minutes to come online if they are already warmed up. This time includes various checks (of lubrication, water temperature, etc.), visual inspection of the generating set, synchronisation to the grid frequency and loading. This means that any fast down-ramping of PV generation that happens in under 10 minutes must be covered by the spinning reserves.

1.4. CAPACITIES AND POTENTIALS FOR RENEWABLE RESOURCES

The installed capacities for wind, biomass, hydroelectricity and waste-to-energy were agreed in advance with the electric utility and regulator on Seychelles based on potentials and can be found for Mahé in Table 2.

Table 2. Renewable capacities on Mahé

RE source on Mahé [MW]	2015	2020	2030	FLHs	Capacity Factor [%]
Wind (Harbour)	6	6	6	1,100	12.6
Wind (South)			10	1,470	16.8
Biomass			5	7,884	90.0
Hydroelectric			2	3,890	44.4
Waste-to-energy		5	7	7,200	82.2
Photovoltaic	depends on scenario			1,400	16.0

The exploitation of wind resources in Seychelles is limited by the mountainous granitic terrain, which makes access for large machinery difficult. The existing wind turbines were placed on artificial islands in the harbour, where access is easier but where the expected energy yield is lower. Sites in the South, better able to exploit the Monsoon winds, could be used by 2030 and reach higher annual energy yield (up to 1470 so-called full-load hours (FLHs)) according to wind speed measurements made in 2011 by Masdar and Lahmeyer (Masdar and Lahmeyer International, 2011).

The biomass potential is based on a feasibility report (Moustache, 2011), which concludes that there is enough biomass from woody invasive species to last 15 years, after which energy crops can be planted (Knopp, 2012). The hydroelectric potential and the factor by which it can substitute conventional generation capacity come from a report on hydro potential for the Seychelles (Lambeau, 2008). The waste-to-energy plant would be located at the refuse site between Victoria and the airport.

In 2014 there were around 400 kW of photovoltaic (PV) panels installed in Seychelles. The capacities in 2015, 2020 and 2030 will be determined in Section 2 and depend on how the power system is operated. The expected annual energy yield figures for PV were provided by PUC based on measurements from existing solar panels.

1.5. ASSESSMENT OF PV SMOOTHING EFFECTS ON SEYCHELLES

In clear sky conditions the electricity production of PV solar panels can be derived from the solar irradiation, which depends on the geometry of the Sun in relation to the Earth. However, in cloudy conditions the production can vary strongly from minute to minute as moving clouds shade the panels (see for example the production curves in Figure 3). This variability in PV production can be mitigated and smoothed by spreading PV panels over a wide area, because it is statistically unlikely that clouds suddenly cover or uncover all panels at once.

Since the diesel generators providing the non-spinning reserves take 10 minutes to come online, any losses of PV power production that happens within 10 minutes must be replaced by the spinning reserves. Therefore it is critical for the determination of required spinning reserve to assess what the maximum down-ramp of PV within 10 minutes might be on each island.

To assess the smoothing effects of spreading PV units across the islands one would ideally use several years worth of insolation measurements from many locations scattered around each island, with synchronised measurements made at least every minute. Unfortunately no such measurements have been made for the Seychelles, but there were power production time series available from 20 PV panels over a period of several months at time resolutions of up to one measurement per minute.

The data from two panels from different parts of Mahé over three days are shown in Figure 3. The measurements do not seem to be synchronous, given the fact that the North Mahé profile leads the Central Mahé by around ten minutes. The profiles shapes differ, which is not surprising given that the PV panels are 10 km apart. There are very sudden drops in the power production due to clouds, with 80% of the nominal power of the unit being lost within 2 minutes.

For a few weeks there were simultaneous measurement data from five panels at different sites, which have been aggregated in Figure 4 to give an impression of the smoothing effects (here we have attempted to correct for the lack of synchronisation of the time measurements). However, there were not enough measurements from sufficiently many sites of sufficient quality to make an accurate assessment of these smoothing effects.

PV production from two sites on Mahé, normalised to their nominal power, for three days

Note that the profiles do not appear to be synchronous (the green profile leads by around ten minutes)

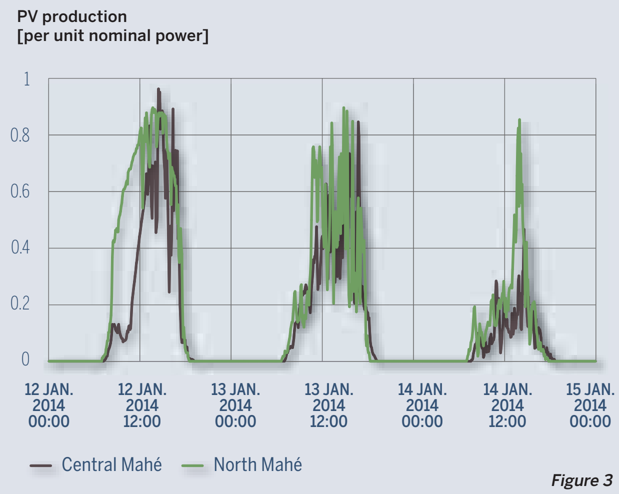


Figure 3

Combined PV production (normalised) aggregated from five geographically separated sites for three days, showing smoothing effects compared to the individual profiles

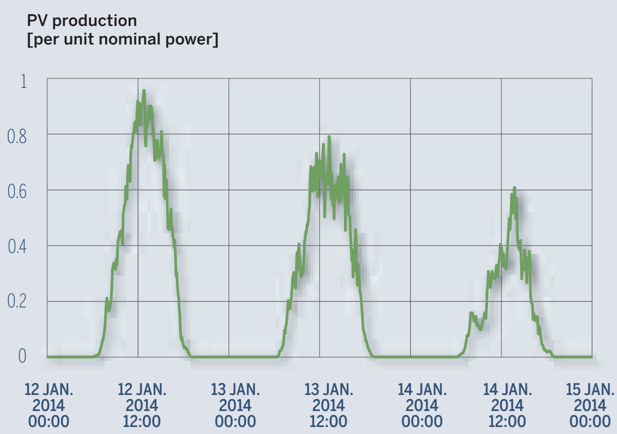


Figure 4

Because of the lack of data, a worst case assumption was made: that 80% of the nominal power of all units on each island could be lost within 10 minutes due to cloud cover. This assumption may seem severe, but it must be remembered that Mahé is small: the island is only 8 km wide, so that a cloud or weather front must only move at 48 km/h in the right direction to cover the whole island within 10 minutes. Based on wind measurements from the La Misere measurement mast, the wind regularly reaches such speeds at 72 m height, so at the height of clouds it is also likely that the wind can blow this fast. In case future measurements find that this worst case assumption is too harsh, we also performed a sensitivity analysis to show the effects of reducing the severity of this worst case to 80% loss at the capital Victoria (where much of the PV will be concentrated) and 50% loss from the rest of Mahé within 10 minutes.

As a point of comparison, the worst PV drop within 10 minutes on the Hawaiian island of Oahu was measured at 21% of the nominal PV power of the island (Piwko et al., 2012). However at 1,545 km^2, Oahu has ten times the area of Mahé and therefore the smoothing effects are much larger.

2. PV INTEGRATION LIMITS

2.1. INTRODUCTION

There are several technical reasons why PV integration in a power system may be limited:

- If PV is predominantly installed in the low voltage network, then high PV feed-in can cause overvoltage and overloading problems on the feeder power lines, which were dimensioned in the past without distributed generation in mind.
- If the PV units do not provide reactive power for the reactive power needs of the load, then the diesel generators may be forced to generate at an even lower power factor than they would otherwise.
- Sudden changes in PV production due to fast-moving clouds can overwhelm the ability of the diesel generator governors to regulate the frequency, which may result in partial or full blackouts.
- If the total drop in PV production exceeds the capacity of available reserves to compensate the lost generation, then load may have to be disconnected to avoid a system blackout.

Each of these issues is now examined for the Seychelles.

"THERE ARE SEVERAL TECHNICAL REASONS WHY PV INTEGRATION IN A POWER SYSTEM MAY BE LIMITED."

2.2. ASSESSMENT OF OVERVOLTAGE AND OVERLOADING IN THE DISTRIBUTION GRID

By statute the voltage in Seychelles must be maintained within 6% of the nominal voltage in all parts of the system. Today there are already undervoltage and overloading problems in the South of Mahé due to the rising load and so the network operator is in the process of extending the 33 kV network to strengthen the grid in this part of the island (see Figure 1). The old 11 kV network in the South will then be reorganised as feeders which will attach to the new 33 kV substations.

It was found during the study that by 2030 there would also be undervoltage and overloading problems in the North of Mahé due to the rising load (as assumed in Table 1), so the 33 kV network was extended here too.

These network extensions are necessary to accommodate the peak load, regardless of the amount of renewables in the system, but also benefit PV integration by strengthening the network.

To investigate PV integration limits, two representative feeders' power lines (one commercial and one residential) were tested using load flow calculations with different distributions of PV units along the feeder (PV clustered at the start of the feeder, at the end and distributed evenly along the feeder), with different limits on PV installation size (big enough to cover 50% or 100% of the consumers' yearly consumption) and with different voltage/feed-in control strategies to reduce overloading and overvoltage problems. The different strategies considered were:

1. Limiting the size of the PV inverter that converts the direct current output of the solar panels to alternating current to feed into the grid, to 80% of the maximum power output of the solar panels. This means that some of the power output of the panels is lost at times of maximum solar irradiation, but because this happens rarely, only 0.6% of the total potential yearly energy production is lost. The advantage is that the rare occasions of overvoltage and overloading are also avoided.

Per unit voltage along the Grand Anse residential feeder with 4.1 MW of PV distributed evenly along the feeder and 1.0 MW of load

The x axis shows metres from the start of the feeder

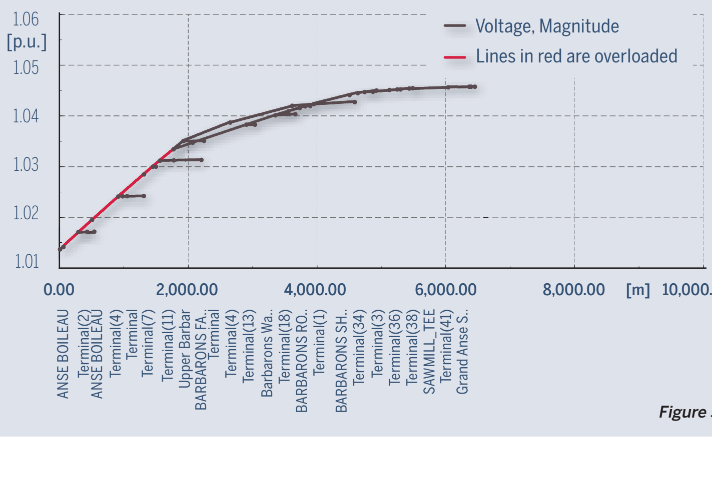


Figure 5

2. Letting the PV units supply reactive power to meet the reactive power demand of the local consumer load, thus reducing overloading (but potentially exacerbating overvoltage problems). The chosen power factor was 0.85 ("over-excited").
3. Dynamically adjusting reactive power provision by PV units to maintain the voltage magnitude within allowed limits.
4. Using measurements of the voltage from all points on the feeder to optimise the PV power output.
5. Reinforcing the grid by installing parallel power lines, to increase grid capacity and reduce the electrical resistance of the grid, which reduces overvoltage issues.

For each situation the worst case of low load and high PV feed-in was tested and the amount of PV was increased until either the thermal limits in some part of the feeder were exceeded or until the voltage limit was violated. An example of a residential feeder voltage profile with high PV levels is shown in Figure 5, for which lines at the start of the feeder are overloaded. It was found that the simplest strategy to increase PV penetration was to limit the inverter size to 80% of the panel size and to force the inverters to supply at power factor 0.85 (which also eases the burden on the diesel generators for reactive power provision).

Using this strategy, the limits for each feeder in the Seychelles system were determined for the worst case that all the PV is installed at the point of the feeders the furthest away from the substation. The sum of all feeder capacities on Mahé was found to be 119 MW in 2020 and 194 MW in 2030 (exceeding the peak demand in both cases). Therefore neither overvoltage nor overloading problems should limit the PV integration, as long as the PV is distributed relatively evenly around the islands and not concentrated on particular feeders.

2.3. REACTIVE POWER IN THE MAHÉ POWER SYSTEM

As explained at the end of Section 1.2, the consumer load in Seychelles requires a power factor at the diesel generators of around 0.86. There are no other assets to provide reactive power (so-called compensation assets), so the diesel generators provide all the reactive power needs of the island.

Frequency behaviour (top graph) after the sudden loss of 4 MW of PV generation on Mahé (the island's residual load is plotted below)

The x axis is the time in seconds

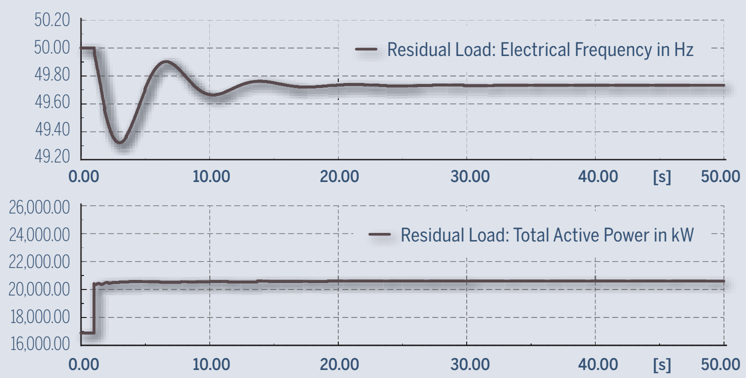


Figure 6

If PV units do not produce reactive power, but only reduce the active power loading of the diesels, then the power factor required at the diesel generators becomes even smaller. This can be seen as putting an unfair burden on the diesel generators to produce reactive power. With 40 MW of PV in 2030, the power factor at the diesels dropped as low as 0.62 in simulations. To bear their share of reactive power demand, it was found necessary for the PV units to feed in with a power factor between 0.85 and 0.9 ("over-excited").

2.4. ASSESSMENT OF FREQUENCY STABILITY

To avoid blackouts, the active power output of the generators must match the electrical demand exactly at all times. This power balancing is performed using the frequency of the alternating current as a signal. If electrical demand and power generation are correctly matched, then the frequency remains constant at its nominal value (50 Hz in the case of Seychelles). If electrical demand is higher than the mechanical energy fed into the generators, then the generators encounter a higher resistance and begin to spin more slowly, resulting in a lower frequency. If electrical demand is lower than the mechanical energy fed into the generators, the generators begin to accelerate, resulting in a higher frequency. The frequency does not change instantaneously because the rotating masses in the generators have inertia. The generator sets contain a control system called a governor, which monitors the grid frequency and regulates the energy fed into the generator (e.g. by changing the diesel fuel input rate) to restore the frequency when it deviates from the nominal value. If the frequency drops and the generators are unable to restore the frequency fast enough, automatic relays start disconnecting consumers to reduce the load in order to avoid a total system collapse. The first feeder is disconnected when the frequency drops below 49 Hz, so it was important in the simulations to keep the frequency above this limit during drops in PV feed-in.

When the wind power plant was installed in Victoria Harbour, a stability study was carried out (Masdar and Lahmeyer International, 2012), for which basic dynamic models of the diesel generators, their automatic voltage regulators and their governors were prepared. These models were then used in the Grid Absorption Study to test the stability of the frequency during sudden changes of PV power production.

In Figure 6 the frequency is plotted for the case in which for 2015, starting from the lowest possible residual load, 4 MW of PV generation is suddenly lost due to a fault (a single PV power plant of up to 5 MW is planned near the existing wind power plant). The frequency stays well above the threshold at which load would be disconnected.

For longer residual load ramps (due to clouds moving over the islands) it was also found that the governors were able to act swiftly enough to keep the frequency stable.

2.5. DETERMINATION OF PV LIMITS BASED ON RESERVES

In providing spinning reserves to cover sudden losses of PV production, there is a tension between the minimum allowed loading level of the diesel generators and the amount of available spinning reserves. On the one hand we want as many diesel generators online as possible to provide spinning reserves; on the other hand the more PV feeds in, the lower the demand for diesel generation is and therefore the fewer generators we can have online (given the minimum loading limits).

Energynautics wrote a computer program to determine the generator fleet configuration that provides the maximum PV integration for a given minimum allowed loading level. It was assumed that the spinning reserve would have to cover the worst case of a loss of 80% of the island's nominal PV power within 10 minutes (the time taken to bring non-spinning reserves online). To test the sensitivity of the results to the severity of the PV loss assumption, one case was tested with 80% loss only at the capital Victoria, where much of the PV would be concentrated, and 50% elsewhere. The resulting PV integration limits are found in Table 3.

Table 3. PV integration limits on Mahé

Max. PV drop [% total capacity]	Minimum generator loading level [%]	Max. PV level [MW]		
		2015	2020	2030
80	75	7.4	12.0	21.5
80	65	10.0	16.0	29.1
80	50	13.9	23.0	40.0
80 at Victoria, 50 at rest	65	11.3	19.3	34.3

As can be seen from Table 3, lowering the allowed minimum loading level has a big effect on the amount of PV that can be integrated, since it both increases the size of the spinning reserve and enables a lower residual load for a given diesel generator configuration. Although the diesel generators are slightly less efficient at lower loading levels (there is a 6.1% loss of fuel efficiency at 50% loading compared to 75%), they would only have to run at 50% for a few critical hours each week, when maximum PV and wind feed-in coincides with the low midday load at the weekend. Thus the increased fuel consumption due to the lower efficiency is dwarfed (by a factor of 10 when 50% is allowed) by the fuel saved due to the displacement of diesel generation by PV. It would also be important to collect data on the wear-and-tear due to more frequent generator cycling.

As an example, here is a short explanation of the 29 MW limit for 65% allowed loading in 2030. The calculation is based on the estimation of minimum demand during the day, which is assumed to be 90 MW (at the weekend) in 2030. The "worst case", meaning the most difficult condition for controlling the system, occurs when as much as possible of the load is covered by wind (16 MW) and PV (amount to be determined). Only the remaining difference (residual load) is covered by the diesel generators.

The spinning reserve available from the diesel generators to cover a PV production drop is proportional to the current diesel capacity and depends on their minimum operating level, 65% in this case, at which we suppose they are operating during the few critical hours. When the reserve requirement is 80% of PV rated capacity, and rated PV capacity is directly anti-proportional to current diesel production (remember the calculation of residual load), we can find at which PV capacity the reserve requirement and the available reserve capacity meet. In this case, it is 29 MW, because the reserve requirement of 0.8*29 MW = 23 MW fits with (90-16-29)*(1/0.65 – 1)=24 MW of available reserve. For a higher PV capacity, the necessary reserve capacity would be too high; for any lower PV capacity, the available reserve capacity would not be fully necessary.

2.6. FLEXIBILITY OPTIONS TO INCREASE EFFECTIVE RESERVES

In addition to varying the minimum allowed loading level, the use of innovative technologies to increase the PV integration was also investigated. The results using a base case of 80% PV loss within 10 minutes and a minimum generator loading of 65% are given in Table 4.

Table 4. PV integration limits [MW] on Mahé in 2030 in scenarios

Scenario	PV [MW]
Base Case (BC) (65% min. generator loading, no extra technology)	29.1
BC + 7 MW of Demand-Side Management (customers can decrease/increase their load within 5 minutes to support PUC's power balancing)	34.3
BC + 7 MW of storage (such as batteries and/or pumped hydro storage)	34.3
BC + Limit PV inverters to 80% of PV panel size (reduces PV peaks with tiny effect on energy production)	36.4
BC + Curtailment of large units during bottlenecks (only when simultaneously feed-in is high and load is low)	38.8
BC + Keep a 15 MW backup generator on standby (so that it can start up in a shorter period, e.g. 5 minutes)	39.5
Conservative scenario (75% min. loading, no changes to existing system)	21.5
Moderate scenario (65% min. loading, DSM, 80% inverter limit, curtailment)	57.2
Advanced scenario (50% min. loading, DSM, 80% inverter limit, curtailment, standby generator)	85.8

Demand-Side Management (DSM) is the time-shifting of flexible consumer loads. It can be used to delay or bring forward electrical demand so that it can better absorb renewable generation peaks and thus reduce the strain on the conventional generators. In Seychelles DSM would be possible at the canning factory of Indian Ocean Tuna in Victoria, where there are big refrigeration units with large thermal inertia, or in the water pumping and/or desalination systems.

Electricity storage can help renewables integration in a similar way to DSM, by absorbing peak renewable generation. Pumped hydroelectricity storage plants may be feasible given the mountainous topology of the island.

Just as for the voltage and network loading investigations, limiting inverter sizes to 80% of panel sizes is very effective, since it reduces the maximum PV drop and has only a very small effect on PV energy production over the year. Similarly restricting PV and wind feed-in to levels below their available power ("curtailment") can be very useful during rare bottlenecks, but practical limitations mean that this would only be possible for PV plants bigger than 500 kW.

These technology options were then combined and grouped into scenarios, based on their cost and complexity. The conservative scenario represents existing practice; in the moderate scenario the most cost-effective and easy-to-implement options are used; the advanced scenario represents the limits of what may be technically possible in Seychelles. The impact on the total renewables coverage of the load for the whole of Seychelles is plotted in Figure 7. Even in the most conservative scenario, Seychelles should have no difficulty in reaching its 15% RE target by 2030.

Coverage of load by all renewables for the whole of Seychelles according to the different scenarios

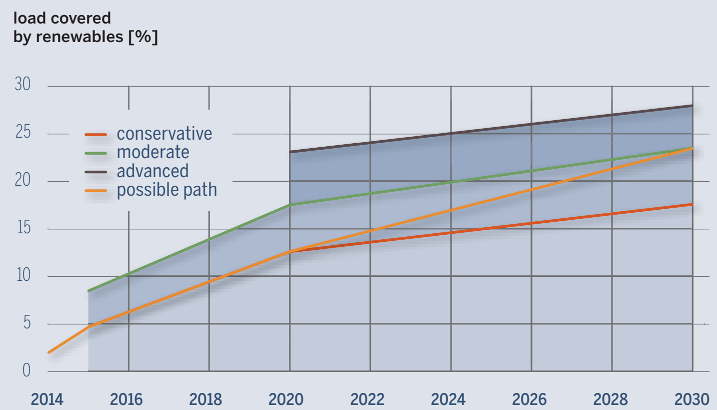


Figure 7

ACKNOWLEDGMENT

We thank the Public Utilities Corporation, the Seychelles Energy Commission, the World Bank and our project partners Meister Consultants Group for their support and collaboration during the study. Responsibility for the contents of this publication lies solely with the authors.

"EVEN IN THE MOST CONSERVATIVE SCENARIO, SEYCHELLES SHOULD HAVE NO DIFFICULTY IN REACHING ITS 15% RE TARGET BY 2030."

CONCLUSION

In 2014 Seychelles covered just 2% of its electrical load with renewables; the rest came from generators running on expensive, imported diesel fuel. According to the Grid Absorption Study (Ackermann et al., 2014) carried out by Energynautics and described in this paper, Seychelles can reach its target of 15% load coverage by renewables by 2030 even with conservative operating practice (see Figure 7). By using innovative technologies such as demand-side management and allowing the diesel generators to operate for short periods of time at lower turn-down rates (to provide additional spinning reserves to compensate sudden losses in PV production), the Seychelles could cover up to 28% of its electrical demand from clean energy sources. As well as contributing to the reduction of CO_2 emissions, the reduced fuel consumption will save money, even taking into account the costs of the renewable energy power plants.

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CULTURAL CHANGE AND FINANCIAL BENEFITS in Rio de Janeiro, Brazil

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KEYWORDS

- SUSTAINABILITY
- ELECTRICITY ACCESS
- INCLUSION
- OLYMPIC GAMES
- LIGHT

Launched in 2011 in Rio de Janeiro, "Light Recicla", an electricity access project, provides a wide range of benefits to low-income communities. It was launched because regularized electrical connections and waste of "free" electricity made bills a financial burden. The project promoted bill payment, recycling, reduced consumption while generating income, encouraging financial education. We describe the project history from its inception to its potential during major events such as the Rio 2016 Olympics.

INTRODUCTION

In Rio de Janeiro, "favelas"[1], with traditionally irregular habitations, are located in different geographies: from hillsides to along riverbanks. They lacked and continue to lack basic public services, including access to electricity, accessed informally and precariously. The number of favela households with electricity access is hard to assess as the 2010 census data was questioned as under-estimated[2] (Paraisópolis.org, 2015; Schmidt and Almeida, 2011). Light is the major electricity distributing company in the Greater Metropolitan Region of Rio de Janeiro and serves the entire State of Rio de Janeiro. Its concession area counts approximately 600,000 low-income household clients in the city of Rio de Janeiro (Light, 2016).

Illegal connections ("gatos") to electricity are made in both favela and non-favela areas. In 2007, Rio de Janeiro had Brazil's largest number of "gatos": 200,000 (Nadaud, 2012). In 2010, irregular electric connections represented a BRL 1 billion/year loss (Prates and Soares, 2010). By 2015, the estimated loss due to "gatos" was BRL 850,000/year (Schmidt, 2015).

Given this context, in 2011, Light launched the Light Recicla project to reduce irregular connections, prevent payment default, electricity theft risks, promote recycling and waste management and ensure that favela households have a sustainable access to electricity.

1 Much debate exists on the use of the word *favela* or *communidade*, the former is defined by public authorities as predominantly housing, characterized by low-income population occupation, precarious urban infrastructure and public services, irregular passageways, lots and unauthorized construction (not compliant with Art. 147 of the 1992 Rio de Janeiro Master Plan). The latter, *"communidade"*, or community, intends to transmit a more positive perception. The Central Única das Favelas (CUFA), Brazil's Union of Favela leaders, specifically chose the term favela to show pride in the roots of this social, cultural and economic area. We use favela as it is used by CUFA and the municipal government (see for more information Luna Freire, 2008).

2 For instance, the Instituto Brasileiro de Geografia e Estatística (IBGE, 2010 and 2014) estimates the Rocinha favela population at only 70,000, whereas community leaders and researchers estimate it at least 125,000.

1. PROJECT PRESENTATION

1.1. ORIGINS

Light is a century-old company based in Rio de Janeiro City serving Rio de Janeiro State. It built the region's power plants. Key to the country's development, it introduced electric lighting, the telephone, and was one of the first to provide service in low-income communities.

Up to the 1950s, informal electricity access was precarious, but tolerated. During the military dictatorship, access was used for clientelistic purposes. In the late 1970s-1980s, Light was nationalized and official electrification of the favelas began as part of opening to democracy. In 1979, electricity began being installed in favelas when local groups demanded basic services (water, electricity, garbage collection). By 1982, 186 communities relied on metered direct electricity consumption.

In the 1990s, the electricity sector was privatized. Light's first regularization program in the city of Rio de Janeiro (1996-2002), Programa de Normalização de Áreas Informais (PRONAI), sought to regularize informal connections (Observatório das Metrópoles, 2015).

Federal Law 9.991/2000 requires that electricity providers invest a minimum of 0.5% of net operating income in Energy Efficiency Programs (EEPs) of the National Agency of Electric Energy (ANEEL) (BRASIL, 2000; Nadaud, 2012)[3]. In 2003, Light began the Efficient Community Project[4]: social inclusion and education for conscious and safe electricity use. It installs electricity in favela homes and provides for the exchange of appliances for National Electrical Energy Conservation Program (PROCEL) labeled lower electricity consumption ones: refrigerators, fluorescent for incandescent bulbs.

In 2008, the State of Rio de Janeiro Security Secretary sought to recover areas under the control of drug traffic, militias and promote the social inclusion of favelas. The Rio de Janeiro State public security program policy was to occupy and "pacify"[5] favelas controlled by a so-called "parallel power" (trafficking or militia). Once occupied, the policy implemented Pacifying Police Units (UPPs)[6]. The state government asked utility service providers to regularize service as part of the pacification process. The process is a two-step partnership: the State rids areas of armed groups, setting up security monitoring, then Light technicians replace old electricity networks, expand the system and electricity is regularized (Nadaud, 2012).

Prior to regularization, in some favelas there were paying clients, but many had to depend on narcotrafficker or militia-controlled service provision. These "providers" were under no obligation to provide services, among other imaginable problems. Upon regularization, the client received a bill that served as a legal document, proof of residency, required for many administrative processes, facilitating access to other citizen rights. Becoming a client also created consumer rights and responsibilities.

As part of the regularization process, in 2008, Light established a "Special Tarif"[7] for low-income clients, gradually increasing bills. This consisted of offering a 50% reduction on the price of electricity consumption the first month and, for each additional month, the 50% was reduced by 2% until there was no more reduction (FGV, 2012).

1.2. THE LIGHT RECICLA CONCEPT

In part, a culture of waste existed pre-regularization because electricity was considered "free", leading to high consumption rates and, after regularization, high bills. One example of high consumption is leaving the refrigerator door open to "cool" the home. Also, access to credit cards with installment payments permitted purchases of high energy consumption products: refrigerators, TVs, irons, water heater, lighting, microwave oven, sewing machine, hair dryer, electric fans, air conditioners (only 1/5 favela households), etc. (Nadaud, 2012; BRASIL, 2012), further contributing to increase electricity consumption and bills.

Three factors, regularization, increased demand and bills, led to high electric bills, which had a major impact on household budgets in the favelas with UPPs units where Light regularized electricity access. This represented a payment default and electricity theft risk.

To respond to this risk, in 2011, Light launched an EEP under the ANEEL, a public-private partnership called "Light Recicla"[8]. It creates electric bill credits for collected recyclable materials. The materials are sold for market value by Light to recover partially the project cost. The goal is to facilitate bill payment, limit defaults and provide long-term access to electricity in favelas while promoting waste management and recycling. From its inception to the present, BRL 6.8M has been invested in Light Recicla. The current cost of running the project is around BRL 1.2M/year (Light, 2015a). As of February 2016, there are 13,900 clients registered in the project.

3 For example, in 2012, Light had to invest BRL 25M.

4 For registered Social Tariff participants, part of the ANEEL's EEP. Since 2003, more than 9,000 electricity installations have been made in favelas. (World Resources Institute, 2016; Diário do Vale, 2014; Light, 2015b).

5 Much polemics exist around the term "pacify", we use it to reflect official use by government bodies as this paper's focus is electricity access (Andrade, 2013; Carneiro, 2011; Catcomm.org, 2015).

6 This program began on December 18, 2008. Currently, there are 50 UPPs in place (UPPRJ, 2015).

7 Light created this tariff policy in 2008. Separately, in 2002, the Federal Government created an Electricity Social Tariff subsidy for low-income families, providing a discount on electricity bills up to 65%, depending on monthly consumption (Law 10.438). The criteria are national and do not consider the residence site.

8 The inspiration was Ceará electric company's (COELCE) initiative Ecoelce, launched in 2007, in which recyclables are exchanged for electric bill credit. Ecoelce is implemented in Fortaleza and other Ceará cities. Light Recicla focuses only on UPPs.

How the project works

The Light Recicla system is shown in Figure 1:

Step 1: Client registers and receives a Light Recicla card.

Step 2: Client separates recyclable waste, brings it to the collection point (ecoponto).

Step 3: Recyclables weighed and valued.

Step 4: Light carries the credit issued onto one of four possibilities that the client selects.

Figure 1. The Light Recicla system
Source: Mayrink et al., 2015

Fixed and mobile ecopontos both exist. Fixed ecopontos are implemented in favelas and are run by two professionals. Mobile ecopontos are used in fairs, exhibitions, etc. to introduce people to the project.

The recyclable waste (paper, metal, glass, plastic and vegetable oil) is weighed and converted into credit amounts reflecting the recycling market value. For example, on March 31, 2015 the credits granted in the city of Rio de Janeiro were BRL 1.55/kg for aluminum cans, BRL 0.75/kg for other aluminum products or BRL 0.80/kg for PET plastic (Light, 2015c).

The four different ways the client can use credit are:

1. Apply it to his personal electricity bill;
2. Donate it to a project-accredited social institution's bill. (Only non-profit institutions are accredited. Currently, there are 51 registered institutions including the Santa Marta Samba School, a Rocinha community center, a children's hospital, etc.);
3. Donate it to another project participant or;
4. For community businesses only: apply 50% of the credit towards bill payment and donate 50% to a participating social institution.

1.3. PILOT PROJECT (JULY 2011 – SEPTEMBER 2013)

At least in the short term, the regularization implied by the UPP policy was very efficient with regard to the percentage of bills paid and the amounts collected by Light. For instance, in Santa Marta, before the regularization (pre-2009), only 15% of bills were paid, for a total amount collected of BRL 242.17. After the regularization (prior to Light Recicla implementation in 2011), 93% of bills were paid, with a total amount collected of BRL 87,729.95 (Light, 2015a). Hence, an increase of 36,126.6%, representing a huge financial burden shock, and a very important long or medium term risk of payment default. This large amount also shows the massive electricity consumption that had become the habit (regularized consumption was metered, so counted; irregular consumption was unmetered).

In July 2011, the pilot Light Recicla project was implemented in the Santa Marta favela, Humaitá and Botafogo with a holistic methodology. The two first ecopontos opened in Santa Marta during the summer 2011, and three other ecopontos opened between October and November 2011 in Humaitá and Botafogo. Communication and educational activities in synergy with civic and sustainability practices were developed to encourage a change in daily habits and consumption attitudes.

Professionals working at ecopontos were trained in selective collection and environmental issues. An in-situ communication methodology was used at the ecopontos. Each ecoponto had an educational booklet available for use. Banners, posters, etc. informed the public about the price of recyclable materials, accredited social institutions, electricity savings achieved by selective collection, events, campaigns, etc. Wide communication contributed to project transparency and provided information to all passersby.

Machine recording credit amounts, Light Recicla card and transaction receipt, digital weighing of recyclable material - Source: Light

"ONE KEY TOOL WAS HOME VISITS, WHICH WERE CRUCIAL AT THE BEGINNING TO INCREASE BUY-IN AND PARTICIPATION. CULTURALLY, IT ENSURED A CLOSE CONNECTION WITH THE CLIENT BY PROVIDING INDIVIDUALIZED INFORMATION. THIS HELPED REDUCE THE FEAR OF NOVELTY. IN SANTA MARTA, HOME VISITS REACHED ALMOST 100% OF HOUSEHOLDS."

Different media were used. For example, community radio stations[9] disseminated specific events, provided project information and tips to encourage residents to adopt positive attitudes and habits regarding electricity consumption and selective waste. Traveling collapsible booths transformed easily into information booths. These were used at events and fairs. Educational games, talks, campaigns and events increased participation.

One key tool was home visits, which were crucial at the beginning to increase buy-in and participation. Culturally, it ensured a close connection with the client by providing individualized information. This helped reduce the fear of novelty. In Santa Marta, home visits reached almost 100% of households.

Transparency is key to the success of this project. Participants can consult the value tables for each recyclable material paid for by the project. They watch as the deposits are weighed and see the monetary amount given in credit.

Finally, partnership creation encouraged wide reach, especially in the private sector. Private schools donated recyclables' value as credit to accredited social institutions (daycare, community centers, shelters, church groups, etc.). A restaurant's recyclables generated credit that was applied to the electric bills of its employees.

Thanks to the system's flexibility, wide dissemination and partner promotion, it encouraged "hill-asphalt"[10] integration, since credit from waste collected in wealthier neighborhoods can be donated to social institutions or other participating accounts.

Since its inception, the project has had the City's support, cooperating with different departments (Depts. of Environment, Social action and Public Space Conservation, Companhia Municipal de Limpeza Urbana the Instituto Pereira Passos and Southern Zone (Zona Sul) Subprefecture[11]). It also counts on the partnership of companies and cooperatives. 3E Engineering Company operates the computer system responsible for billing data transmission and oversees report control and production. A cooperative, COOPAMA - Cooperativa Popular Amigos do Meio Ambiente Ltda., is responsible for collecting vegetable oil. The NGO Doe Seu Lixo is responsible for other logistics, ecoponto operation, collection and transport of recyclable materials.

The project pilot helped generate visibility so that the project could be scaled up, create new partnerships and replicate in other UPPs.

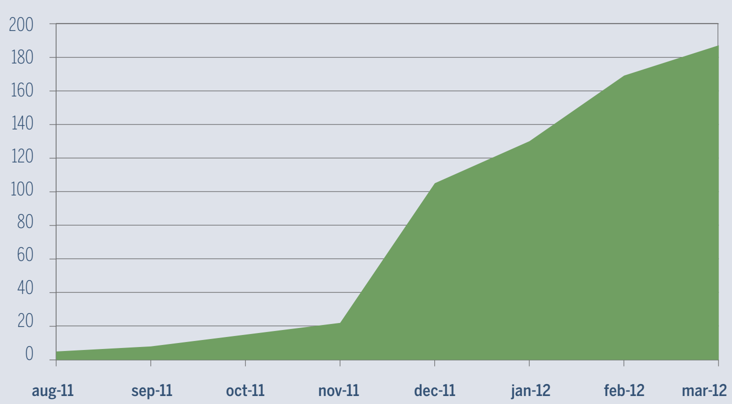
One of the best means of increasing participation was "word of mouth". Figure 2 shows the sharp increase in recyclable waste amounts collected with the opening of the three new ecopontos in Humaitá and Botafogo. By March 31, 2012, 187 tons of recyclable materials were collected at the 5 initial ecopontos, generating BRL 29,920 in credit on electricity bills.

9 Some favelas have speakers installed on top of poles connected to a central radio station, usually the neighborhood association.

10 "Asphalt" refers to the planned city and "Hill" to the hillsides where favelas arose.

11 Rio is somewhat separated into the Northern Zone, traditionally more disadvantaged and the Southern Zone, traditionally more wealthy.

Recyclable waste collected in tons from August 2011 to March 2012



Source: Mayrink et al., 2015, modified by Mitch in 2016

Figure 2

1.4. PROJECT DEVELOPMENT

After the successful pilot phase, the project was expanded to other areas. The evolution of the number of fixed ecopontos created per year is shown in Table 1. We note that after 2011, ecopontos were created sparingly as Light sought to provide the necessary resources to running each ecoponto correctly: quality, not quantity was the main objective of expansion. The first city outside of Rio de Janeiro to receive the project was Mesquita[12] (one ecoponto in Chatuba and one in Banco Nacional de Habitação neighborhoods) in 2014. In 2015, Japeri and Paraíba do Sul welcomed their first ecopontos.

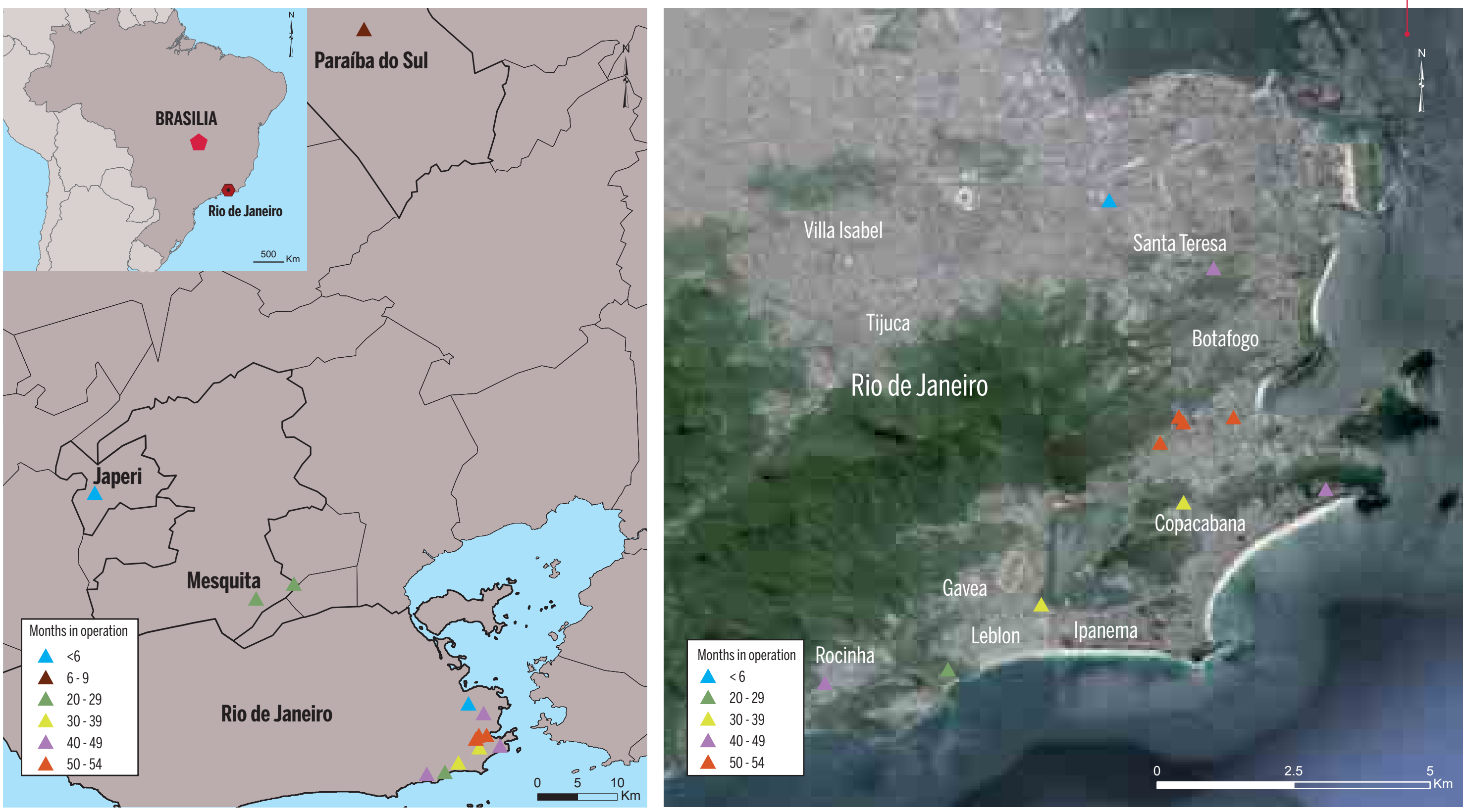
12 The result of the partnership between Light, Mesquita City Hall, the Renascer Association of Waste Collectors of Mesquita and the Hope Association of Workers Collectors of Recyclable Materials of Mesquita.

Table 1. Evolution of ecopontos in the city and in the Greater Metropolitan Region of Rio de Janeiro

	2011	2012	2013	2014	2015	Total	Projected for 2016
City of Rio de Janeiro	5	3	2	0	1	11	1
Outside the city	0	0	0	2	2	4	2
Total	**5**	**3**	**2**	**2**	**3**	**15**	**3**

Source: Light modified by Mitch in 2016.

Figure 3. Location of ecopontos and length of operations (in months) at December 31, 2015 - Source: FERDI



This expansion policy can be seen in Figure 3, representing the distribution of the ecopontos in the State of Rio de Janeiro and in a zoom on the city of Rio de Janeiro and their length of operation. We note that the main cluster of longest-operating ecopontos is in the Botafogo neighborhood. This can be explained by the fact that Santa Marta became the first UPP in 2008. We note that other neighborhoods do not count as many ecopontos. While the ecoponto in Rocinha, Latin America's former largest favela, has been operating for over 48 months, it is the sole one for 143.72ha (Rocinha received its UPP in September 2012).

2. RESULTS AND IMPACTS OF LIGHT RECICLA

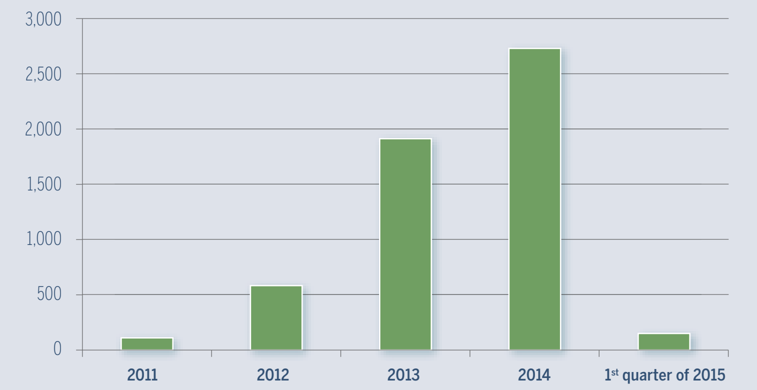
2.1. DISSEMINATION, PARTICIPATION AND POPULARITY

By December 31, 2015, there were 13,752 clients registered in Light Recicla. Among them, 6,143 actually benefited (44,7%) from the project. 4,893 clients were considered as regular participants (35.6%).

It is interesting to note the evolution of Light Recicla participants over time. The pilot phase (July 2011 – September 2013) succeeded in involving more participants than the following phase of the project. Thus, 61,7% of the Light Recicla card were distributed during the first 27 months of the project.

This can be explained in part by the difficulty in maintaining community motivation and program loyalty, even with the greater variations in the buyback price table used in Light Recicla. Moreover, there were operational difficulties that arose due to closing of ecopontos due to public works on the steep slopes of the favelas and internal conflicts in the community also contributed to the participation reduction. Participation fluctuated also due to the

Collected waste in tons from July 2011 to March 2015



Source: Mayrink et al., 2015, modified by Mitch in 2016 *Figure 4*

relative distance between ecopontos. A higher density in an area provides more deposit opportunities for the population, not to mention greater dissemination to increase participation.

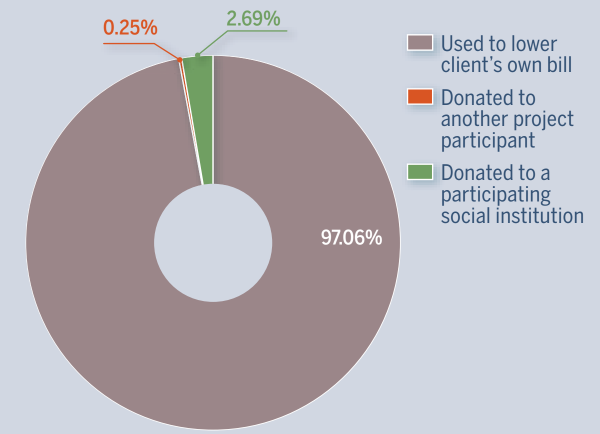
Nevertheless, the number of deposits made at the ecopontos increased by 33.8% between the pilot project and the following of the project. By December 31, 2015, 169,193 deposits have been made at the 15 ecopontos. And, as shown by Figure 4, the collection of recyclable wastes kept on increasing.

By December 31, 2015, more than 6,132 tons of recyclable wastes have been collected by the project Light Recicla. The main products collected are paper, plastic and glass, representing respectively 43.3%, 33.1% and 18.2% of the weight of the total amount collected.

By December 31, 2015 the recyclables collected at the 15 ecopontos had generated BRL 649,129.70 in credit. From July 2011 to December 2015, the average credit per month per Light Recicla participant was BRL 1.96 (approx. EUR 0.5), and on average deposits at ecopontos were made every two months. These averages mask the fact that some people participated a lot while others did so only occasionally, which explains the low average. Indeed, as the project depended on self-discipline and organization, some residents participated more and saved more than others. Some made enough credit to use towards electric bill payment for several years. For three years, Severino, a resident of Santa Marta, paid his electric bills by exchanging recyclables for credit. Vera Lucia da Costa, a resident of Cruzada São Sebastião, did so for two years.

In Figure 5, we can see the distribution of credit granted from July 2011 to January 2016 (no available data for the 50/50 option only used by participating businesses). The large majority of the individual clients (97.06%) opt to apply the credit to their own bills.

Allocation of credit uses



Source: Mayrink et al., 2015, modified by Mitch in 2016 *Figure 5*

In May 2012, a satisfaction survey was conducted among 119 Light Recicla participants. The results showed that 23 % of the participants rated the project "excellent" and 57% "good", showing the project's popularity.

2.2. IMPACTS OF THE PROJECT

As explained earlier, at least in the short term the regularization was very efficient with regard to the percentage of bills paid and the amounts collected by Light. The main objectives of Light Recicla were to relieve Light customers from the huge financial burden shock implied by regularization and to prevent a risk of payment default.

Table 2 presents the situations in Santa Marta before regularization (pre-2009), after regularization before Light Recicla implementation (2011) and in December 2015, allowing a before/after comparison.

Table 2. Impacts of Light Recicla in Santa Marta

	Pre-regularization (pre-2009)	Post-regularization (2011 before Light Recicla)	December 2015
Number of clients	73	1593	1664
Amount billed	BRL 1,585.64	BRL 93,914.21	BRL 170,225.32
Amount collected	BRL 242.17	BRL 87,729.95	BRL 163,410.71
% bills paid	15.3%	93.4%	96%
% illegal connections	93%*	~ 7%**	~ 0%
% commercial loss for Light***	-93%	-10.9%	-5%

* Based on 1991 Census data (Zaluar and Alvito, 1998).
** Based on 2010 Census data (RIO, 2016).
*** Light method of calculations based on % of unpaid bills and % of illegal connections
Source: Light modified by Mitch in 2016.

In December 2015, Santa Marta was 100% regularized. Illegal connections almost disappeared among the community. While, the amount billed increased by 81.3% between 2011 (before Light Recicla) and 2015, the amount collected rose by 86.3%. 96% of bills were paid against 93.4% in 2011 before Light Recicla.

The credits allowed by Ligth Recicla eased the cost burden for the project participants, improved bill payment and reduced disconnections and electricity theft risk.

In addition to facilitating electricity access post-regularization through the credit scheme, the recycling encouraged by the project also promoted electricity savings (Table 3).

Table 3. Energy calculation from July 2011 to December 2015

Recyclable	Total collected (Kg)	kWh saved*	Household consumption/ month equivalent**
Paper	2,654,837.41	12,106,058.59	60,530
Plastic	2,029,424.94	10,755,952.18	53,780
Glass	1,116,669.01	714,668.17	3,573
Metal	253,846.79	1,345,398.59	6,727
Tetrapak	46,155.60	235,393.56	1,177
Oil	31,535.31	118,257.41	591
Total	**6,132,471.06**	**2,5275,728.5**	**126,379**

* EPA, 2000
** Calculation = kWh saved/Average household consumption. Method based on Calderoni, 2003
Source: Mayrink et al., 2015, modified by Mitch in 2016.

From July 2011 to December 2015, 25,275,728.5 kWh were saved thanks to Light Recicla. This total energy saved is equivalent to the consumption of 126,379 households/month (Mayrink et al., 2015). This represents a population size equivalent to about 49% of Dharavi in India, the world's largest slum (Rai, 2015).

"TRANSPARENCY IS ONE OF THE KEYS TO THE SUCCESS OF THIS PROJECT. PARTICIPANTS CAN CONSULT THE VALUE TABLES FOR EACH RECYCLABLE MATERIAL PAID FOR BY THE PROJECT. THEY WATCH AS THE DEPOSITS ARE WEIGHED AND SEE THE MONETARY AMOUNT GIVEN IN CREDIT."

3. LESSONS LEARNED AND SCALABILITY OF THE PROJECT

3.1. KEY DIFFICULTIES FROM 2011-2014

One major difficulty was the time and effort required to align government needs with those of the private companies operating as Light's project partners. Constant negotiation was required, upsetting project timelines. This impacted the expansion of the project in a more clustered fashion.

Another difficulty arose in process logistics as recyclable materials required removal from ecopontos on a constant basis. In Rio de Janeiro, laws restrict the circulation of loaded trucks to specific times, which resulted in a logistically difficult and costly transportation process.

Limited space for ecopontos in the communities made operations difficult. Mobile ones required more maintenance and transportation logistics to set up, remove and store.

Recycling market price volatility, which depends on the amount of recyclable waste circulating, was a major difficulty because it resulted in fluctuating credit values. This impacted the credit granted.

Finally, Rio de Janeiro lacks recycling companies able to work at the project scope.

3.2. SCALABILITY

Replicable in other favelas, this project generated income to pay household electric bills, helping facilitate access to regularized electricity.

Currently, there are ecopontos in 15 locations. All favelas in Light's concession area do not have ecopontos. In many, electricity access has not yet been regularized, so there are areas in which the population has irregular, unstable access and in which Light has great commercial losses.

Light has received more than 40 applications for expansion to other areas, the municipalities of Nova Iguaçu and Barra Mansa, Public Defender's Office and the Federal Accelerated Growth Program (PAC).

Since 2012, many private sector companies are interested in the project. Some became ecoponto sponsors. These are: Supergasbrás, Coca-Cola, Hortifruti and Leblon Shopping Centre.

This project can be scaled for different situations – for small permanent ecopontos to temporary ecopontos for major events. Like the sister project in Ceará, it can expand state-wide.

Major events, like the World Cup and the Olympic Games are great opportunities. In 2014, the Organising Committee of the Olympic and Paralympic Games Rio 2016 (Rio 2016) and Light tried to establish a partnership to benefit the Host City's most vulnerable populations and provide the tangible and intangible benefits of realizing the Games (Rio 2016, 2009; Minnaert, 2011).

The initial plan was to promote and establish recycling ecopontos, especially to benefit the City Center's Complexo São Carlos Community, located right across from the Rio 2016 headquarters. The plan was to encourage engagement, promote civics and sustainable daily practices as part of the Olympic and Paralympic Movement. Rio 2016 in-house recycling could be donated in part to low-income community participant organizations. During Games-time, Rio 2016 would donate part of the credit resulting from recyclables to project-accredited social institutions.

Problems arose given the commercial monopoly of the Games sponsors (Louw, 2012). Although Light is the only electricity distributor in the Games concession area and Rio 2016 pays an electric bill, concern arose about sponsors who had paid for branding privileges. For example, when the Central Única das Favelas (CUFA), Brazil's main organization centralizing favela leaders and communities, tried to organize the "Favela Olympics" so that community residents might benefit from the Games dynamic, they were contacted by International Olympic Committee (IOC) lawyers who threatened legal action for any use whatsoever of the word "Olympic", as it is considered the intellectual property of the IOC[13].

Also, there was a relative lack of interest in the proposal. Light inaugurated the Complexo São Carlos ecoponto without Rio 2016.

Since electricity access for low-income populations is a key to development, allocation of subsidies is a telling factor. Federal subsidies allocated for low-income consumers, promoting electricity development, universalizing electric power and expanding natural gas networks from the Energy Development Fund (CDE) (Eletrobras, 2015) are to be used for electrical Games works, causing polemics (Larkins, 2015; Konchinski, 2014). Some alleged that this reduced the amounts for fund-dependent actions. It was alleged that energy subsidies paid by the CDE and determined by the government would be greater if the fund was not being used to pay for Rio 2016 works. Indeed, supposedly, the Ministry of Sports will pay for the electric works with its own funds; however, only a small portion, BRL 42M has been allocated. For the Olympic Park alone an estimated BRL 152M is needed for these works (Konchinski, 2014).

While some argue the legality of this use, the Olympic Act (BRASIL, 2009) establishes that the federal government must provide the services needed for the realization of the Games.

3.3. PROJECT FUTURE

While the Light Recicla project provided great benefits by offsetting bills, improving community cleanliness, encouraging wiser electricity consumption and recycling, not everyone was able to pay their electric bills. A 2012 World Bank study indicates that some people surveyed in UPP focus groups had monthly electricity bills of more than BRL 50, in comparison to BRL 35 to BRL 41 in 2011 (World Bank, 2012). This is quite high given the Rio State monthly minimum wage average of BRL 929.90, 5.35% of monthly income[14]. Data from a FIRJAN (Federation of Industries of Rio de Janeiro) report on UPPs indicates average household

13 Conversations with CUFA in 2014.

14 It has not been possible to get a viable estimate for average income in favelas (FGV, 2012; ADVFN, 2015).

income as BRL 644 in the Southern Zone (BRL 422 for the Northern Zone) and unemployment levels are 7.3% to 11.3% (FIRJAN, 2012).

While some participants of World Bank focus groups criticized the quality of the electricity infrastructure renovation, they recognized that the main benefit is that people began to believe again in public institutions and insurance of utility provision (World Bank, 2012). Furthermore, people saw regularized Light service as a positive measure because they could count on service repairs and restoration when problems arose. Becoming a client came with rights and duties that included service fulfillment. Previously, if the irregular electricity connection was lost, people had no recourse to re-establishing electricity connections unless there was a generalized problem.

People also noted habit changes, from appliance and electronics accumulation and use to selling them and reducing electricity consumption (Ibid.).

Nonetheless, fear of not being able to pay electricity bills continues. This factor is aggravated by the upswing in electricity bills due to new government rates due in part to low hydro power water levels and lack of water to generate electricity. From March 2014 to March 2015, the electricity rate rose by 50%, leading to a 42% rise in payment default disconnections among Light clients (Barros, 2015).

According to the ANEEL, the increased electric bill cost led to a 113% increase in payment defaults among the lower-income consumers (Barros, 2015). Light Recicla helped ease the burden of electric bills for participants by helping them to reduce bills in exchange for recyclables. In addition, the project raised awareness of the importance of lower consumption, so participants purchased lower energy consumption appliances, like light bulbs, refrigerators, etc. An added benefit was the improvement in waste disposal in favelas thanks to participants' recyclable collection.

CONCLUSION

Exclusion is due to lack of basic infrastructure and the inability to pay the costs associated with its consumption (Dieese, 2015). Light Recicla increases electricity access in low-income peri-urban communities, promotes conscious consumption and sustainability by promoting a behavioral change. It supports social, environmental, economic and cultural transformation. This permits the return on public and private actions and investments made by reducing illegal connections and facilitating bill payment.

While the new (2016) electricity rate scheme is indexed on hydro power production, reducing rates when it rains a lot and much electricity is distributable, bill payment is still a challenge for low-income populations given the lack of access to better employment opportunities and pay. Moreover, recent droughts in Brazil have made hydro power a not so sustainable option and, if rates are indexed on rainfall and if there is little rain, rates remain high.

Given this scenario, electricity providers can play a role extending beyond traditional Corporate Social Responsibility missions, building partnerships in areas falling under government competence. It is important to focus on conscious consumption, as Light Recicla does, so that electricity access for low-income populations could be made long-term, rather than just on income transfer. Noteworthy in this project is the change in consumer behavior towards electricity efficiency. This behavioral change promoted access for low-income clients because it educated consumers on ways to save electricity, reducing bills and disconnections due to payment default. Furthermore, as the consumer became a regularized client, electricity service became reliable, and the client learned that he/she should enjoy full benefits. By limiting illegal connections to electricity provided dangerously and unreliably, Light Recicla helps promote dependable electricity access to low-income clients.

The project´s methodology and results can be used to work in synergy with public authorities, civil society and private initiative to promote a real transformation for sustainable development. The key tenets are civics, income generation, education, social inclusion, transparency, cultural change and environmental preservation. These depend on ethics and transparency as guidelines for material and electricity use decisions made in companies. They are key to changing peoples' daily behavior.

Despite varying electricity rates, we believe that this project has great merit and can be expanded to other regions and other projects like the Rio 2016 Olympic and Paralympic Games. Major events like the Olympics are key opportunities to scale up and acquaint people with the project so that they will have already participated once, making reiteration easier. In other regions or areas of the world, this project can be scaled up to include an entire state, as the inspiration for this project, Ecoelce, demonstrates.

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"THE KEY TENETS ARE CIVICS, INCOME GENERATION, EDUCATION, SOCIAL INCLUSION, TRANSPARENCY, CULTURAL CHANGE AND ENVIRONMENTAL PRESERVATION. THESE DEPEND ON ETHICS AND TRANSPARENCY AS GUIDELINES FOR MATERIAL AND ELECTRICITY USE DECISIONS MADE IN COMPANIES. THEY ARE KEY TO CHANGING PEOPLES' DAILY BEHAVIOR."

Source: Louis Tavernier

2. ENERGY KIOSKS: OFFERING ELECTRICAL SERVICES AS AN ALTERNATIVE TO ELECTRIFICATION

Review of energy kiosk development projects

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The data analysis presented here is based on a study carried out in 2014 by Claudia Knobloch and Judith Hartl, from the research organization Endeva, titled "The energy kiosk model, Current challenges and future challenges"[1], which collected data from 23 actors involved in developing the energy kiosk model.

1. THE ENERGY KIOSK MODEL

Energy kiosks are centres for electricity production and supply of energy services, generally located in rural or peri-urban zones. It is a "pre-electrification" model, offering centralized energy production at the level of an energy kiosk/point/station/hub[2], in proximity to local communities. Indeed, the model doesn't allow direct domestic connection by means of a cable and installation of a meter; it is generally a requirement that consumers travel to the kiosk to access the services provided. Thus, the concept is innovative not for its technological aspects (although these may be notable), but rather for its model of distributing electricity and electrical services, with the goal of reaching the majority of the local population, particularly the most vulnerable.

Although the kiosks could be powered by a variety of energy sources, priority is given to electricity production from renewable energy sources. In most cases, for practical reasons, and in view of the generally limited amount of energy produced (less than 5 kW), solar energy is favored. Hybrid models, which combine renewable (usually micro-hydroelectric or solar) and thermal (usually diesel) energy production, have also been developed, with a view to guaranteeing supply in bad weather, or when climatic conditions do not allow for continuous supply throughout the year.

The electricity generated is used principally for recharging electrical products (lamps, radios, portable telephones, car batteries, and other types of battery designed specifically to work with a solar system). On average, for each kiosk, these recharge services are accessed by fewer than 100 households in the village. A common approach for all the actors is to offer complementary services alongside the recharge service. Printing services, screening of TV programs, internet connection, refrigeration, and direct sale of small solar systems or basic necessities are common (see Figure 1).

1 Knobloch and Hardl (2014), "The energy kiosk model, Current challenges and future challenges", Endeva Business Model Library | Issue 01 | October 2014, p. 8

2 The name varies from one project or business to another

2. OVERVIEW OF THE ACTORS[3] INVOLVED IN DEVELOPING THE ENERGY KIOSK CONCEPT

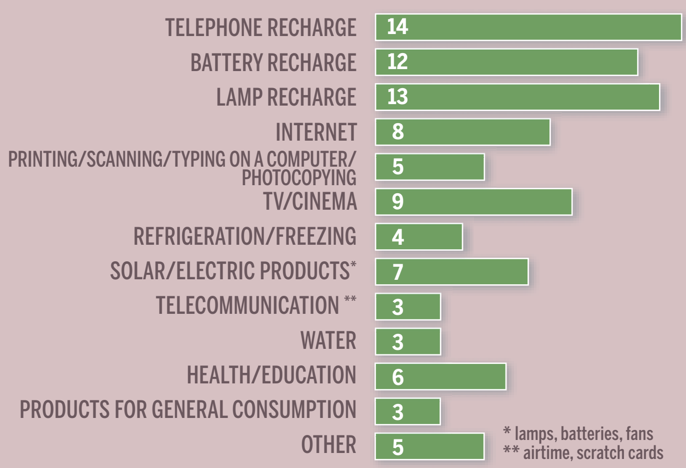
Currently, energy kiosks are installed all around the world, primarily in India and on the African continent, but also in south-east Asia, Latin America and the Caribbean. Most have appeared within the past 10 years, between 2005 and 2013. As of September 2015, five actors are responsible for more than 25 operational kiosks each (Endev, HERi Madagascar, Solarkiosk, Teri and Schneider). Taking an average across all surveyed projects, however, the number of operational kiosks is still quite small, since more than half of the actors surveyed manage fewer than ten kiosks each (see Figure 2).

The different projects are at different stages of development. Seven of 23 actors are currently in the initial phase of validating the technology, designing business plans, and preparing to implement the first pilot kiosks. Two actors have confirmed the efficiency of a prototype and are working on a controlled upscaling. They have tested their models several times but will only extend their network of kiosks when a third party submits a request and guarantees the financing. They are thus operational, but are not systematically pursuing growth. Five actors are currently running their existing kiosks but do not wish to expand their network. Of these, some are dependent on financing (either public or private) to expand, while others are facing difficulties in achieving a sustainable economic model. Finally, nine actors have demonstrated the viability of their model in the business setting, thanks to appropriate technology and a suitable business model, and are currently working towards widespread upscaling.

The principal challenge to the kiosk concept is how to set up the financial model. Establishing energy kiosks generally requires a substantial initial investment, of around EUR 40,000, to cover building expenses, the cost of the electrical system and of the cost of the electrical products proposed. Such charges are rarely offset in the medium term, forcing the actors to be constantly innovative, creating new opportunities and maximising the impact of the services provided. The low purchasing power of the populations who benefit from the scheme also limits the potential financial viability of each kiosk. Thus, the correlation between the investment and the return on the investment is crucial. However, on this point, there has been a lack of communication and exchange of experiences and best practices between the actors, resulting in a lack of research and optimisation of financial models for energy kiosks.

3 Actors can be categorized according to two principal characteristics: i) their structure (business, government or non-governmental organisation, agency, association, individual, etc.), and ii) the scale of their intervention (local, regional, national).

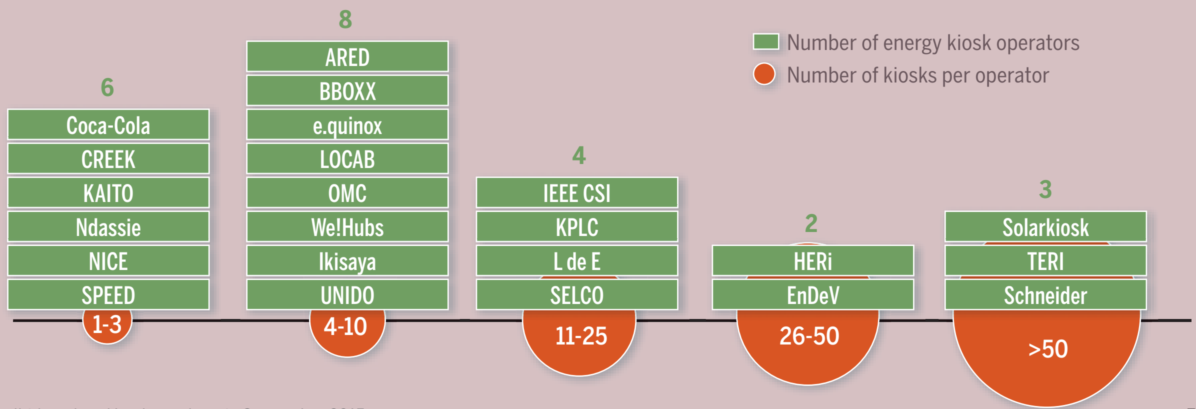
Range of services and products offered by the 23 surveyed actors involved in developing energy kiosks in 2014



Source: Knobloch and Hardl, 2014

Figure 1

Number of operational energy kiosks per actor



Source: Ibid. updated by the authors in September 2015

Figure 2

HERi MADAGASCAR: UPSCALING THE ENERGY KIOSK CONCEPT

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Miantso kiosk (Analamanga region)
Source: HERi Madagascar

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KEYWORDS

- SOLAR ENERGY KIOSK
- RURAL PRE-ELECTRIFICATION
- FRANCHISE
- FEMALE ENTREPRENEURSHIP
- RURAL MARKETING

This article focuses on the experience of HERi Madagascar, a social enterprise that develops energy access solutions for the most vulnerable rural populations, through the implementation of a network of solar energy kiosks throughout the country. The article discusses the lessons learned in the development of the business model in order to understand the challenges in upscaling the system.

INTRODUCTION

In Madagascar, rural populations have very limited incomes (mainly based on agriculture) and are on the lowest level of the power consumption pyramid. The communities must cope with seasonal revenues and also lack awareness on modern, affordable energy solutions. Hence, they always turn to traditional energy solutions for basic services (such as lighting). In these circumstances, how can we reach the most vulnerable rural populations with modern, reliable and affordable energy services, while prioritizing socio-economic development and minimizing impacts on health and the environment?

This is the challenge that HERi Madagascar, a social enterprise created in 2011, is addressing through the development of a "pre-electrification"[1] model based on the implementation of solar energy kiosks (SEKs). These SEKs offer energy solutions with an emphasis on social considerations in the heart of off-grid rural villages in Madagascar. The kiosks are franchised, managed by local businesswomen, and offer sustainable solutions and modern energy services, based on the sale/rental of solar equipment for individuals (rechargeable lamps, telephone charging) or the community (refrigeration, printing). The combined actions of sale/rental, rural marketing and local services have allowed the company to expand its network, in January 2016, to 44 SEKs across the country and to strengthen the technology and impacts model prior to a commercial upscaling phase. While the financial profitability of the business model has not yet been achieved, each kiosk is financially autonomous within a period of two years. Based on this initial success, the company plans to extend its network to 150 SEKs by 2018 and use economies of scale to move toward a financially sustainable model, while maintaining wider socio-economic benefits.

1 Understand as a prior step to electrification. Unlike electrification, end users are not connected to a grid or are not energy self-producer.

1. PORTRAIT OF HERi MADAGASCAR, AN ENERGIZING SOCIAL ENTERPRISE

1.1. GENERAL PRESENTATION OF THE ENTERPRISE

HERi Madagascar is a social enterprise that builds and manages a network of SEKs installed in the heart of remote and non-electrified villages, through a franchise model. Its main goal is to make products and services with a high social value available to as many people as possible, through an appropriate sale or renting system[6]. Thus, HERi seeks to provide sustainable solutions to improve the quality of life in rural areas.

The HERi energy kiosks are franchised and managed by local businesswomen (female entrepreneurs). Currently, HERi Madagascar has 44 kiosks located in seven regions - Analamanga, Itasy, Vakinankaratra, Bongolava, Alaotra Mangoro, Vatovavy Fitovinany, Haute Matsiatra. In 2016, HERi will also extend to the Atsimo Antsinanana region.

Its inclusive business model has been recognized by the German government and by the ACP-EU facility, which has given its support to the PowerKiosk project (HERi Madagascar, ICCO, Solar Kiosk), which benefits from being able to compare lessons learned from the implementation of the kiosk model in three different countries - Ethiopia, Kenya and Madagascar. In particular, this feedback from the commercial exercises will allow HERi to extend its network to 150 kiosks in Madagascar by the end of 2018.

MADAGASCAR FACES "ENERGY STARVATION" (MAGRIN, 2008)

Madagascar, with an estimated population of 23.5 million in 2014[2], is experiencing what could be described as an "energy starvation", characterized by a very low energy consumption due to a very limited access to energy, and in particular to electricity. In 2014, the national electricity coverage was only 15%. Over 78% of the Malagasy population lives in rural areas where the rate of electrification is barely 4.8% (WWF, 2012). By the end of 2014, subscribers to the national grid of JIRAMA (Jiro sy RAno MAlagasy, the national water and electricity utility) numbered fewer than 475,000, i.e. one subscriber for every 49 people across the country (Groupe de Réflexion Energie, 2014)[3].

The average **power consumption** per individual per year is 48.53 kWh[4] – for comparison, average consumption in sub-Saharan African countries (excluding South Africa) is 150 kWh. In addition, average per capita energy consumption is stagnating at around 0.2 toe/year (compared to 1.6 toe/year/inhabitant in the World in the same period). This energy consumption is dominated by wood energy and its derivatives for cooking needs (83%) and by oil products for the operation of diesel generators and lighting (14%), by the still widespread use of kerosene. Electricity accounts for less than 2% (Fondation Energies pour le Monde, 2012). In 2015, the "Doing Business"[5] indicator ranked Madagascar 188th of 188 countries with respect to connection to electricity. The principal reason was the waiting time for a new connection to the grid, estimated at 450 days.

Energy production is also very low. In order to meet a growing energy demand, a total power of 350 MW was installed in the country in 2014, of which thermal production has the lion's share, despite renewable energy resources. Although only intended to be a short-term solution, this makes the country dependent on fluctuations in the price of oil. 75.2% of electricity production in rural areas is supplied by thermal power plants (ORE, 2015).

2 http://data.worldbank.org/country/madagascar

3 The Groupe de Réflexion Energie is a platform bringing together several actors of the energy sector (private companies, technical and financial partners, civil society, members of the government, etc.) which meet approximately once a month and make recommendations for improvement to the Ministry of Energy and Hydrocarbons.

4 http://www.indexmundi.com/g/r.aspx?v=81000

5 The "*Doing Business*" indicator analyses small- and medium-sized enterprises nation-wide and measures the regulations applying to them throughout their life cycle. The purpose of this indicator is to provide an objective basis for understanding and improving the regulatory environment for business around the world. Structured around 10 themes, the indicator aggregates the average per country for each theme. One of these themes focuses exclusively on access to energy. Overall, the Indicator ranks Madagascar 163rd of 189 for 2015. Source: http://www.doingbusiness.org/madagascar/

6 This idea follows the precept raised by Bellanca and Garside, 2013

Figure 1. Network of HERi Madagascar kiosks in January 2016 - Source: FERDI

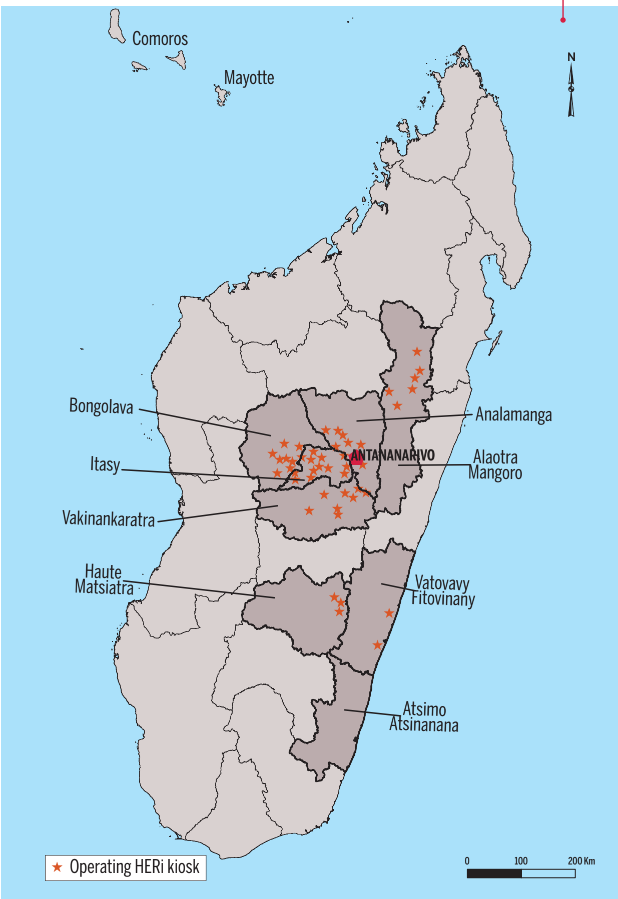

Table 1. Expansion of the HERi SEK network by region and by year

Regions	2012	2013	2014	2015	Total	2016 forecasts
Analamanga	2	5			7	4
Itasy			6	6	12	3
Vakinankaratra			2	6	8	
Bongolava				7	7	4
Alaotra Mangoro				5	5	10
Vatovavy Fitovinany				2	2	12
Haute Matsiatra				3	3	12
Atsimo Antsinanana						11
TOTAL	**2**	**5**	**8**	**29**	**44**	**100**

1.2. SELECTION OF VILLAGES

Although there is no "typical village", the enterprise identifies a number of selection criteria, taking into account the limited financial capacity of rural households. For instance, the villages must, comply with criteria such as non-connection to the national grid, accessibility by motorcycle even during the rainy season, a minimum average demography of 250 households or coverage by a GSM telephone network. A field team of six people is dedicated to the selection of villages.

Shortlisting (5 days): Villages are shortlisted at the headquarters in Antananarivo, on the basis of the socio-economic data available from the National Institute of Statistics (INSTAT). The search focuses mainly in and around those regions where HERi is already present. The experience of the field team is combined with recommendations from the local authorities, the Agency for the Development of Rural Electrification (Ader), and non-governmental organizations (NGOs). This process creates multiple sources of information used to identify and rank the villages. Finally, it is increasingly common for local authorities or villagers to contact the enterprise head office directly to request the installation of a SEK in their village. All requests are considered if they are located in the regions where the enterprise operates. For logistic and budgetary reasons, at least six villages in the same region must be shortlisted before proceeding to the next step, namely the "preliminary field trips".

Preliminary field trips (10 days): The field team undertakes trips to the sites in order to meet with the local authorities and populations of the shortlisted villages. Surveys are conducted with a few households (approximately 30 per village), and with local socio-economic centers (NGOs, health centers, schools, grocery stores, cooperatives, etc.). Next, focus groups are organized by the team to help finalize the energy profile and economic development of the villages by canvassing all participants. The visit concludes with the search for a potential female entrepreneur, as well as the identification of an available plot of land (usually in the heart of the village or close to the marketplace) before undertaking negotiations with the authorities. The field team spends one and a half days in each village on average.

Final decision: The final decision to set up a kiosk in the village is taken by the management team at the headquarters, after the field team's presentation, negotiation with local authorities and selection of a female entrepreneur. On average, the time spent between the shortlisting phase and the opening of the kiosk is approximately two months.

1.3. SELECTION OF THE FEMALE ENTREPRENEUR

The selection of kiosk managers is a crucial step because they are the direct interface between the social enterprise and customers. They are responsible for increasing the commercial activities and they strengthen the impacts of the services offered. This step starts with consultation with local authorities once they have confirmed their interest in having a kiosk in the village. They generally recommend women involved in the social life of the community who have business experience. HERi also invites applications from women by putting up posters in the village (during the shortlisting phase). The goal is to encourage interested candidates to demonstrate their interest by directly contacting the team and arranging their own travel to the head office for the first interviews. After confirmation following a written and oral evaluation, the selected female entrepreneurs immediately start preparing the construction of the kiosk and officially changing their status. They then receive on-the-job training for three weeks (one week prior to the opening of the kiosk and two weeks after the official opening). These courses focus on commercial management of the kiosk, customer relations, communication, cash management, ITs, and basic maintenance of the solar electrical system.

The decision to choose female entrepreneurs followed naturally from the initial selection of pilot villages carried out by HERi Madagascar in 2012. It became clear that women are generally more available by daytime than men, who are responsible for farming activities. Their sales experience in the markets also gives them useful interpersonal and business skills. Moreover, assigning this professional role to women emphasizes their important contribution within the community and their independence, consistent with the social values embraced by HERi Madagascar. The reaction of men to the fact that the kiosk is managed by a woman varies between villages and between regions. Sometimes it disrupts the social norms of the

Figure 2. Services offered by HERi SEKs
Source: HERi Madagascar

village during negotiations with the local authorities, but never to the point where HERi has had to reconsider this criteria since all villages have accepted it. In addition, men often help their women to apply for the position, and also to invest because they are reassured by the support provided by HERi in terms of training and investment.

1.4. THE TECHNOLOGY USED

The solar photovoltaic (PV) technology perfectly fits with the SEKs' needs: it allows the system to become quickly operational, allows for modular production, requires little maintenance and is easy to use. Each SEK has six PV solar panels installed on the roof for a total capacity of approximately 1 kW[7] (870 Wp[8]). The installed power is modular and can be increased or reduced according to changing demand. The electrical system is intuitive and based on "plug-and-play" models. It allows the system to adapt to rural needs, facilitates its use by the manager, and can power a wide range of electrical devices. The system includes two 180 Ah GEL batteries[9] to store the energy, a load regulator (to ensure safety and optimize battery life by regulating charging and discharging) and a 450 W converter (which converts direct current into alternating current and limits the appliance use to a 450 W threshold). Exceptionally, 1,000 W converters were installed in two kiosks in order to increase the entrepreneurs' ability to use multiple devices simultaneously. The available connections are direct current/DC[10] (mainly used to charge lamps, mobile phones and radios) and alternating current/AC (to power other electrical devices). Both solar and electrical equipment are imported from Germany. Since the launch of the first kiosk in December 2012, HERi has experienced no technical problems. The only incidents usually occur a few days after the opening of each kiosk, when the entrepreneurs (despite the operating recommendations and warning) overload the system by plugging in too many appliances, thus exceeding converter capacity.

7 From a study of energy needs during the initial surveys, a one kilowatt capacity was identified as suitable for initiating several activities and supplying a broad enough selection of electrical appliances.

8 Wp = Watt peak. Unit representing the maximum power of electrical production of a solar system, when of solar radiation conditions are optimal.

9 GEL batteries were preferred because they have a relatively long useful life: 8 years.

10 DC (Direct Current): 12 volts; AC (Alternating Current): 220-230 volts

This is not an alarming issue, since the system shuts down for safety reasons and automatically restarts within a few minutes.

1.5. PRODUCTS AND SERVICES OFFERED BY HERI KIOSKS

HERi Madagascar offers three types of services, the details of which are available on the website www.beheri.com.

There are three categories of services offered by each SEK. **Charging** includes recharging lamps (only rechargeable at the kiosk), built-in battery radios (commonly referred to as "card radio") and mobile phones. The rechargeable lamps are supplied to the SEK female entrepreneurs by HERi Madagascar. Unlike other enterprises, HERi does not rent or recharge car batteries or solar batteries due to the fragility of the equipment, the investment cost and the logistical constraints it would cause. However, a supplier study is currently being conducted to identify lighter, more robust battery models to facilitate transportation and reduce the risk of damage.

Sales cover a range of devices such as autonomous solar lamps (often with a built-in panel), mobile phones, FM radios, Solar Home Systems (SHS), and energy-saving stoves.

Service provision involves provision of products and services selected by the female entrepreneurs themselves to develop commercial activities useful to the community: printing and copying services, refrigeration of fresh products (yoghurt, fruit juice, etc.) for community use or commercial use, video projection for entertainment or dissemination of news programs, etc. The female entrepreneurs invest personally in the services and products according to local demand, potential socio-economic impacts and profit opportunities that their activities could generate. This "tailored" portfolio of services and products allows the enterprise to maximize its social impact through the SEK and give the female entrepreneurs an additional source of income. Each SEK is unique, and so are its services. Table 2 presents the number of kiosks offering given services proposed in HERi's portfolio[11].

11 This data must be considered with caution given that the most recent kiosks have not yet, or only barely, expanded their portfolio to productive/commercial services.

"HERI MADAGASCAR'S EXPERIENCE SHOWS THAT LOW INCOME HOUSEHOLDS ARE WILLING TO PAY MORE FOR A MEDIUM OR HIGHER QUALITY PRODUCT."

Table 2. Productive and commercial services installed in 2015

Product/Service	Number of kiosks offering the service
Camera	10
Refrigerator	24
Printer	19
Blender	18
Laminating machine	4
Game console	3
HiFi speaker	4
DVD player	2
Electric hair clipper	2
Television	25

RECHARGEABLE LAMPS AND RENTAL SERVICE

The rental and home delivery of rechargeable lamps are the common services available in every kiosk and are the priority services, since the prime objective of HERi is to increase access to clean, quality lighting for the isolated rural populations. They benefit all consumers, including those who generally cannot afford modern solar products.

Quality and low power consumption are the main criterion of the product portfolio. In addition, the choice of including lamps with strong and diffuse light is preferred in order to illuminate a room and avoid the harmful effects of weak and concentrated[12] lighting on the eyes. HERi Madagascar's experience shows that low income households are willing to pay more for a medium or higher quality product. The price indicator does not always prevail[13].

Two types of lamp are currently available for rent in the kiosk network, and home delivery is free for customers registered on a monthly subscription.

The rental of rechargeable lamps is HERi Madagascar's main activity and the main source of income for the female entrepreneurs (approximately 75% of SEK revenue).

12 The Scientific Committee on Emerging and Newly Identified Health Risks (SCENIHR) of the European Commission highlights the adverse effects on health of too low artificial light, in particular for reading (SCENIHR, 2012). Madagascar does not yet have standards on brightness, so HERi Madagascar has promoted brightness standards similar to those defined by the European Union. Hence, entry range lamp brightness is at least 50 lumens.

13 This confirms the lesson learned highlighted by Graf et al., 2013.

Table 3. Characteristics of the two rechargeable lamps rented at the HERi kiosks

Brand / Model	Lumens	Autonomy	Daily rental price*	Monthly subscription	Aims to replace
FOSERA Scandle	160	8 hours	MGA 300 (€ 0.10)	MGA 7,500 (€ 2.30)	Candle
SUNKING Solo	50	12 hours	MGA 200 (€ 0.06)	MGA 4,500 (€ 1.40)	Kerosene

* 2015 average exchange rate: EUR 1 = MGA 3,254.75 (http://www.banque-centrale.mg/index.php)

2. OVERVIEW OF THE IMPACT OF HERi KIOSKS ON COMMUNITIES

HERi SEKs and the tailored portfolio of products have been developed with the aim of optimizing the socio-economic impacts of the activities. As the main service developed by the enterprise, the rechargeable lamp rental service is the offer for which an impact analysis is currently most relevant. The bulk of collected data derive from the study conducted by ENDEVA[14] in February 2015, focusing on the impacts observed in the first seven pilot SEKs. 292 people were interviewed (contractors, assistants, mayors, community chiefs, teachers, traders, lamp users, lamp non-users, kiosk customers) through individual interviews and focus groups. The FOSERA Scandle lamp clients observed many positive benefits, in particular for health, education, safety, expenditures and even income. 80% of respondents would recommend the use of this innovative lighting solution. Today HERi is trying to consolidate this impact study by extending the scope of the analysis to all products/services offered, and by developing new projects, internally or in partnership, on related issues (management of drinking water, agriculture, etc.). Therefore, the enterprise aims to have a positive impact on the daily life of rural communities, beyond improving access to a source of clean and bright light.

2.1. IMPACT ON EDUCATION

Most rural households use kerosene lamps or candles to light their homes at night. Children are forced to study with poor lighting, which is a source of discouragement and frustration. Thanks to the use of rechargeable lamps, children report greater enthusiasm for their studies and state they study on average 25 minutes longer per day.

The village of Avaratsena (Analamanga region) is a good illustration of the impact of SEK activities on education: the success rate for official examinations in primary and secondary school has risen from 65% in 2013 (the year the kiosk opened) to 100% in 2014. To be fair, this increase is not solely due to the use of rechargeable lamps, nevertheless, the Director of that primary school stated that the "availability of the lamp has played a major role in the improvement of school results, especially during study periods. Not all students are regular users throughout the year, but nearly 90% of students rented a lamp a few weeks before examinations[15]". The students' fulfillment and their desire to learn and to succeed would also seem to have grown in villages where HERi Madagascar is established today.

14 http://www.endeva.org/

15 Ms. Hantsa Rakotomalala, Director of the Primary School of Avaratsena village

Students of Miantso village working using a FOSERA solar lamp - Source: HERi Madagascar

2.2. IMPACT ON HEALTH

The harmful effects of kerosene lamps on children's health, particularly on their eyesight and respiratory system, are well documented (Bruce et al., 2000). Pneumonia is the primary cause of infant mortality in Madagascar[16]. Two thirds of customers who replaced their kerosene lamps by the rechargeable lamps available for rent in the SEK claim to have observed a clear improvement in their health. These statements are supported by the representatives of the Basic Health Centers (CSB), who have observed a decline in cases of respiratory infection, particularly among newborns, in all the villages where HERi Madagascar is present. The impact on health is even greater thanks to HERi's promotion of ADES stoves[17], which is a state-of-the-art cookstove that drastically reduce the emission of smokes and harmful gases during cooking, while cutting in half the coal and wood consumption.

Moreover, most kiosks offer refrigeration services whose high profitability and important commercial nature are complemented by a huge impact on nutrition and access to varied food (refrigeration of fresh natural juices and multivitamin yoghurts). Mothers actively encourage their children to consume these fresh products.

2.3. IMPACT ON THE ECONOMY

Monthly expenditure for lighting (kerosene, candles and batteries) represents approximately 5% of the average monthly income[18] of rural households, i.e. approximately MGA 6,500 (EUR 2). The villagers welcome the quality to price ratio and reliability of the lighting solutions HERi Madagascar offers, expressing satisfaction with the quality and cleanliness of the light source and above all the sale price. Set at MGA 4,500 per month (EUR 1.40), the rental fee makes rechargeable lamps an economic alternative to traditional light sources.

Some villages are particularly isolated and the installation of a SEK allows populations to significantly decrease travel time to purchase fuel and candles, recharge telephones, print documents or photos, etc. This saved time has a value and therefore represents a high opportunity cost[19].

The SEK activities and their economic impacts are appreciated by consumers, who highlight the increased opportunities for job creation: each HERi entrepreneur employs between 1 to 5 part-time assistants. Overall, the enterprise has created more than 158 direct jobs (at head office and SEKs level), 110 of them in the villages. Grocers, tailors and other local entrepreneurs can work later in the evening, and have observed a significant increase in their income. Local retailers of traditional fuels (kerosene and diesel) are likely to be impacted negatively by the introduction of SEKs. However, the behavioral changes are not immediate, and rural populations in Madagascar are generally attached to their habits. In consequence, the penetration rate (in the communities) of the energy services HERi Madagascar offers does not significantly affect the commercial activities of retailers. These shop owners are also gradually integrated into "sub-entrepreneurship" networks (as distribution points) in order to make the most of their experience and their wide consumer networks to disseminate renewable energy technologies.

16 http://www.unicef.org/madagascar/fr/health.html

17 "Agence de Développement de l'Énergie Solaire" a Swiss NGO promoting the production, marketing and distribution of improved stoves in Madagascar and partners HERi Madagascar.

18 Over 80% of rural households work in the informal agricultural sector, with an average monthly income estimated at MGA 131,200 (approx. EUR 40) according to the report of the Groupe Réflexion Energie published in 2014. The HERi experience shows us that a large number of rural households live on only MGA 80,000 per month (approx. EUR 24.50).

19 The concept of opportunity cost is based on the idea of a ranking of tasks or occupations. A rational man is one who, after studying the various ways of spending his time at any given moment, chooses the one with the least opportunity cost, i.e. the one that least sacrifices what he considers important.

Sewing with a FOSERA lamp
Source: HERi Madagascar

2.4. IMPACT ON SAFETY

Some regions and villages in Madagascar are regular victims of vandalism and crime, or located in "red zone"[20]. However, in these locations, people truly appreciate HERi Madagascar's impact in improving safety conditions. Darkness eases theft of livestock and crops which remains the main assets of the villagers. They report that the bright light and self-sufficiency provided by the rechargeable lamps allow them to patrol or maintain a human presence throughout the night. Above all, the users are satisfied to be able to keep a light on all night without spending more money.

The numbers presented in Figure 3 are to be considered with caution because the surveys undertaken by Endeva were focused on parents that use the rechargeable lamps. Figure 3 summarizes the answers of 262 people to the following question: *"To your opinion, what is the main advantage of the Fosera Scandle lamp?"*.

Key interest of the use of the "Fosera Scandle" rechargeable lamp

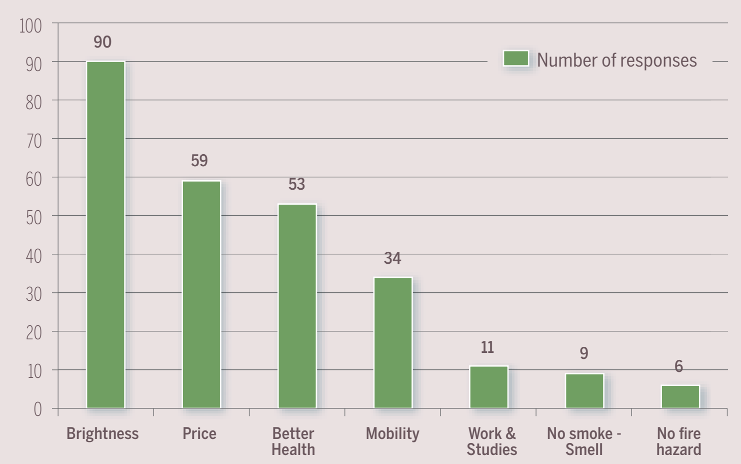

Figure 3

3. LESSONS LEARNED FROM HERI'S SOCIAL BUSINESS

3.1. WOMEN ENTREPRENEURSHIP AND THE FRANCHISE MODEL

Simply introducing innovative and affordable technology cannot be enough to create lasting change in the consumption habits of rural communities, especially when they have very little awareness of solar technologies and the opportunities for productive use of renewable energies. HERi Madagascar's activities have revealed that the quality of the local SEK management is a key success factor for the development of activities and for the strategic visibility of the company.

The women entrepreneurs, who are residents of the village where the kiosk is located, analyze the market, select products with high added value for the communities, and determine the marketing strategy to be implemented at the village level. Their initiative allows the SEKs to become local life hubs, and structures for lasting socio-economic development. They employ one or more assistants as required, working mostly on part-time, for the lamp delivery and recovery service. The entrepreneurs can also create product distribution points in grocery stores for villages that are not covered by the kiosk's activities, in order to increase the penetration of the offers. Ultimately, the franchise model is based on a bottom-up strategy, built on the needs expressed by the users and the sales and services provided by the entrepreneurs.

In order to further support their efforts, HERi gives them training in financial management, rural marketing, customer service and technical use of the electrical equipment. The enterprise also organizes activities to raise awareness among consumers, local authorities and public service centers (schools, health centers, etc.). To this end, HERi invites all entrepreneurs twice a year to the head office in Antananarivo, to take part in additional training courses as well as to share the good practices, challenges and lessons learned from their activities.

The female entrepreneurs pay HERi Madagascar a fixed monthly fee of MGA 40,000 (EUR 12) for the rental of the kiosk (including the electrical system), and an additional variable fee for the electricity costs and the number of rechargeable lamps in stock[21]. The wages of the entrepreneurs and their assistants are covered by the profits generated by the commercial activities of each SEK. However, the viability of the model is largely based on the entrepreneurial skills of these women and their ability to increase the SEK's sales. With monthly income that is often 80% higher than the average wage in rural areas, the female entrepreneurs have a comfortable situation that, paradoxically, does not encourage them to progress further and therefore increase their activities. HERi Madagascar has to make additional efforts to raise the awareness of female entrepreneurs on the financial opportunities of diversifying their offers. The entrepreneur selection method is also constantly being improved in order to identify active and committed women.

"THE ENTERPRISE HAS CREATED MORE THAN 158 DIRECT JOBS (AT HEAD OFFICE AND SOLAR ENERGY KIOSKS LEVEL), 110 OF THEM IN THE VILLAGES."

20 The "red zone" is a local expression designating nearly 200,000 square kilometers spread over the entire island where the government has little or no control and banditry prospers.

21 The female entrepreneurs lease the rechargeable lamps from HERi, and then rent them to individuals.

Table 4. Example of the average monthly income of a HERi entrepreneur

	Price	Unit	Total
Average monthly costs for a female entrepreneur			
Fixed fee/kiosk rent	MGA 40,000 (€ 12)	1	MGA 40,000 (€ 12)
Fee for rechargeable lamps	MGA 4,500 (€ 1.40)	100	MGA 450,000 (€ 140)
Average of the other variable fees	MGA 40,000 (€ 12)	1	MGA 40,000 (€ 12)
Salary of two assistants	MGA 80,000 (€ 24.50)	2	MGA 160,000 (€ 49)
Total average monthly costs			**MGA 690,000 (€ 212)**
Average monthly income for a female entrepreneur			
Income from lamp rental	MGA 7,500 (€ 2.30)	100	MGA 750,000 (€ 230)
Income from other products/ services	MGA 190,000 (€ 58)	1	MGA 190,000 (€ 58)
Average monthly income of kiosk activities			**MGA 940,000 (€ 290)**
AVERAGE NET MONTHLY INCOME / ENTREPRENEUR			**MGA 250,000 (€ 77)**

3.2. THE IMPORTANCE OF AWARENESS-RAISING AND MARKETING CAMPAIGNS

HERi Madagascar develops awareness and marketing support tools for all beneficiaries and local stakeholders. The awareness activities are crucial because rural populations have very little awareness of renewable energies and the risks of using traditional options (kerosene, firewood, etc.). In addition, some households that have already invested in small low-quality solar systems are disappointed by the performance of these products, and by extension are disappointed in solar technology in general. Therefore explanations about the operation of a solar system and raising awareness about purchasing intermediate or higher quality products are not only valuable for individuals but also prevent solar technology being permanently discredited in rural areas.

Rural consumers tend to use several energy sources. Despite the introduction of a new energy solution, some households keep using fuels (mainly kerosene) in addition to the solar energy services, due to their limited purchasing power. This is not surprising, since full energy transitions are never immediate, but occur gradually over time.

To support the female entrepreneurs and to keep up with the changing consumption patterns of populations, HERi's sales representatives help the entrepreneurs organize campaigns to raise awareness and provide information, as well as events, aimed at households, local authorities, schools and health centers. Targets include people within the villages where the SEK is located and those of the surrounding hamlets. In Ampano village, daily lamp rental increased from 50 to 250 following an awareness campaign conducted in 2013 in partnership with the local farmer association TARATRA[22], which in particular gives Ms. Saholy, the kiosk entrepreneur, an ongoing training on communication and management. The innovative technology of ADES energy-saving stoves sold in the SEKs allows households to reduce their wood/charcoal consumption, while preserving their cooking habits. Thanks to awareness campaigns on stove use and to the dissemination of testimonial videos, the sales number on the stoves during the launch in the village of Avaratsena was 300% higher than the overall sales forecasts. This innovative product, sold on average at around MGA 12,000 (EUR 3.70), is three times more expensive than the regular stove that people generally use. But thanks to a strong rural marketing strategy and the establishment of an installment plan for payment, the sale was a real success.

Once kiosks are up and running in the village, they play an additional role in facilitating message transmission and collection of information. The kiosk is a natural communication hub and a strategic site for bringing innovative products to market, subject to finding suitable payment methods. Twice a year, all kiosk entrepreneurs are invited to take part in supplementary common training and to share their experience and insights regarding good practices with the other female entrepreneurs, in order to ensure continuous improvement of their activities and the sustainability of the model.

Ms. Saholy, SEK entrepreneur in Ampano (Analamanga region) rents over 400 lamps a day
Source: HERi Madagascar

22 The TARATRA peasants association of Ampano offers agricultural training, and is a reliable intermediary between the farmers of Ampano and the surrounding hamlets, and the agricultural collectors eager for quality produce.

EXAMPLE OF RURAL MARKETING

Figure 4. Example of rural marketing by HERi Madagascar
Source: HERi Madagascar

Rural marketing is a tailored communication and marketing strategy based on a thorough analysis of the local market and of the constraints related to rural consumers (levels and seasonality of income, etc.), using the most effective communication channels in rural areas, such as word-of-mouth and user reports. HERi relies its strategy on raising awareness at all levels (local authorities, public administrations, households, etc.), trying to involve as many end-users as possible.

In the poster above, Mr. Henry, inhabitant of Ampano village, shares his experience on the benefits of the telephone recharge service available in the SEK. By disseminating this poster in the targeted villages and the surrounding hamlets, the number of phone charging clients at the kiosk increased to over 310% within a year. Since then, similar tailored marketing campaigns were initiated across the SEK network.

3.3. PAYMENT AND COLLECTION METHODS

Given the important impact that seasonal incomes[23] in rural areas have on the cashflow of SEK customers, the development of tailored, easily comprehensible payment methods is key for the viability of energy service provision at the SEKs. The monthly subscription constrains households to cash out the rental fee at the end of each month, before renting the lamps for the following month. But people do not always have money at that time, which results in recurring collection problems for the entrepreneurs. To address this issue, HERi's sales representatives and the entrepreneurs have set up various payment methods: subscriptions can be weekly, biweekly or monthly; consumers have the possibility of paying during the harvest season; and a prepayment model has been developed (the user pays at the start of the rental period rather than at the end). Prepayment involves a specific cash flow management, limits the risk of outstanding payments and gives the entrepreneur a clearer vision of their monthly income. Thus, flexibility remains the best way to deal with these challenges that are typical of rural areas in Madagascar, and has allowed HERi to report collection rates of approximately 85%[24] (payment of monthly subscriptions by lamp-rental customers).

3.4. DETERMINANTS OF THE MODEL'S FINANCIAL PROFITABILITY

Despite a viable franchise model, the business model is not yet sustainable. HERi Madagascar is not yet able to cover its operating costs and to extend its SEK network without recourse to external funding. Setting up the SEKs requires huge investments (SEK structure, PV solar technology, electrical appliances, etc.) and significant qualified human resources.

Structure of expenditures of HERi Madagascar in 2015

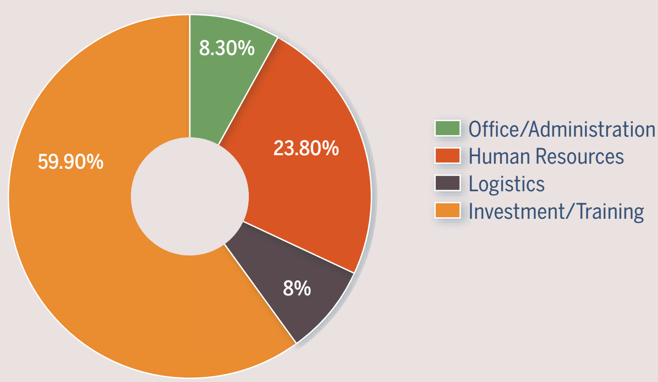

Figure 5

23 Insofar as income depends mainly on agriculture, rural populations go through "hunger gaps" during several months of the year, and have more financial leeway during the harvest.

24 For comparison, the national water and electricity utility, JIRAMA, reports an average collection rate of around 60% in rural areas.

As a guide, setting up an energy kiosk represents an investment of between EUR 25,000 and EUR 50,000 depending on the kiosk's services and products, the size of the building and the solar system, and the particularity of the village or the region. Figure 6 shows the distribution of average costs associated with setting up a kiosk[25].

"GIVEN THE IMPORTANT IMPACT THAT SEASONAL INCOMES IN RURAL AREAS HAVE ON THE CASHFLOW OF SOLAR ENERGY KIOSK CUSTOMERS, THE DEVELOPMENT OF TAILORED, EASILY COMPREHENSIBLE PAYMENT METHODS IS KEY FOR THE VIABILITY OF ENERGY SERVICE PROVISION AT THE SOLAR ENERGY KIOSKS."

Distribution of costs associated with setting up a HERi kiosk

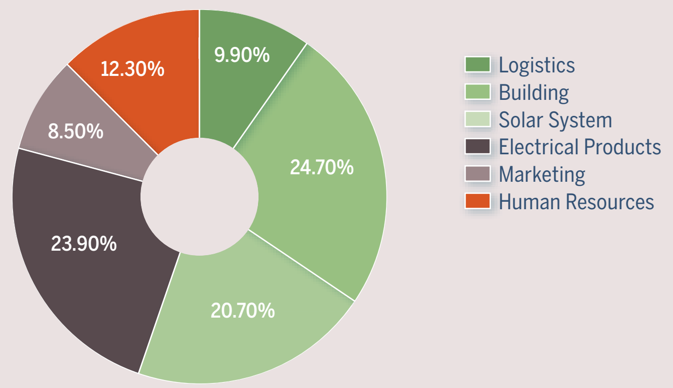

Figure 6

25 The percentages are to be considered with caution since they are averages given here as a guide.

Third and latest version of the HERi SEK building
Source: HERi Madagascar

Since its creation, HERi Madagascar has developed optimization and adaptation strategies in order to increase its revenues and strengthen its operational model, with a view to achieving a sustainable business model in the long-term.

The first strategic axis is based on the optimization of SEK design. The first kiosk model combined a metal structure (imported) and a wooden architecture. The high construction cost[26] led HERi Madagascar to switch to a brick model in 2014, which, moreover, makes use of available local resources (labor, bricks). In early 2015, the kiosk architecture was again redesigned to improve the quality and reproducibility of the kiosk infrastructure, still using durable materials, and with the unchanged aim of reducing costs and promoting the use of local construction materials. The changes to the design between the first and third versions halved construction costs.

The second strategic axis focuses on diversification of the enterprise's activities and the creation of new partnerships. In this context, HERi Madagascar has developed a "turnkey" model, allowing other development actors (private sector, NGOs, etc.) to buy the SEK model in order to increase the impact of the innovative services that they offer in off-grid rural communities. The service allows HERi Madagascar to diversify its areas of operation, and especially to quickly generate a net income, from the sale of the equipment (building and electrical system) and of design, training, marketing monitoring and assessment services[27]. The turnkey kiosk concept also allows the enterprise to increase its impact through the activities of its partners, and to expand the network of energy kiosks throughout the island. The first turnkey kiosk, sold to a Swiss NGO for the village of Antanety (Analamanga region), was built within the grounds of a public school and generates a regular additional income for the parents' association. A contract has also been signed with another international NGO for the construction of four turnkey kiosks, with delivery scheduled for the first quarter of 2016.

The third strategic axis is based on the development of complementary activities, such as the direct sale of solar products in the kiosks and in urban areas, and other internal projects to strengthen the impacts of activities related to energy service provision. In particular, HERi Madagascar is developing a partnership with Bionexx (an agribusiness company specializing in the extraction and purification of aromatic and medicinal plants) under the "HAGRi" program. This project will ignite strong partnerships between the energy sector and the agricultural sector. In other words, it aims to strengthen the local economic dynamics and perpetuate the transfer of energy costs to rural clients, whose income will increase through the agricultural program, thus further improving their access to the energy services offered by the SEKs.

Finally, the fourth strategic axis deals with the up-scaling of the model. The profitability of HERi's business model relies heavily on economies of scale directly related to the expansion of the SEK network across the country. Since supplying an isolated kiosk requires proportionally higher costs than supplying a group of kiosks, pooling the monitoring, support and product delivery actions will reduce logistical costs and lead the company to a lasting and commercially viable model. HERi Madagascar has set itself the goal of establishing a network of at least 150 kiosks in order to benefit from the economies of scale and thus achieve a degree of financial profitability. The European Union's support through the PowerKiosk project, which started in 2015, is intended to help reach this goal by 2018. This project will fund at least 80 kiosks in four regions of south-east Madagascar (Haute Matsiatra, Amoron'i Mania, Ihorombe, Vatovavy Fitovinany). To this end, a second HERi office was opened at the end of 2015 in Fianarantsoa (Haute Matsiatra region) in order to facilitate the implementation of the Powerkiosk project.

"THE PROFITABILITY OF HERi'S BUSINESS MODEL RELIES HEAVILY ON ECONOMIES OF SCALE DIRECTLY RELATED TO THE EXPANSION OF THE SOLAR ENERGY KIOSK NETWORK ACROSS THE COUNTRY."

26 Most materials were imported, which significantly increased the share kiosk construction costs in the investment, compared to other necessary investments.

27 These services include training on the model and the management tools, continuous training and supervision of the kiosk manager, a follow-up/evaluation, marketing campaigns and communication media.

CONCLUSION

Through its rural pre-electrification activities, the social enterprise HERi Madagascar has carved out a position for itself on the Madagascar energy scene. Its inclusive business model and its franchised local management model helped the company reach off-grid rural communities and offer local solutions for energy provision, tailored to the needs of these low-income populations. The design of the HERi SEK and its local management by native women have led to strong integration and acceptance within the communities, which could pave the way for widespread electrification projects in the future.

However, despite the success of the franchise model at the village level, the enterprise has yet to achieve financial profitability. HERi Madagascar has to fine-tune its business model to ensure its sustainability. Profit margins from business activities and redistribution of income must be adjusted in order to allow the business to recover its costs while remaining sustainable. Innovation and growth must be supported by diversification of the offers and the establishment of win-win partnerships with other organizations. Such collaborations, with the agricultural sector for instance, will continuously promote the transfer energy costs to rural consumers. HERi Madagascar has developed various tools for rural marketing, awareness-raising, support and training, which have ensured the success of the model in the pilot phase and secured important funds. Socio-economic considerations are central to the activities of the social enterprise, which must now strive to efficiently balance out upscaling, financial sustainability and broadening the impacts. Commercial objectives should always tie with social goals, and ensuring financial recovery should not affect the quality of HERi's activities.

For the SEK model to grow, collaboration between rural electrification actors and the organizations developing the SEK concept is essential. HERi Madagascar recognizes the importance of sharing experiences and ideas on good practices. In particular, the PowerKiosk project - implemented in Ethiopia, Kenya and Madagascar – helps capitalize on lessons learned from the SEK model and consolidate HERi Madagascar's business model in its commercial upscaling phase.

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ADDRESSING DEVELOPMENTAL NEEDS Through Energy Access in Informal Settlements

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SELCO Foundation is a 5-year-old organization that engages in ecosystem building for deployment of clean energy solutions that alleviate poverty in tribal, rural and urban poor communities. The organization works closely with practitioners in the social sector, energy entrepreneurs and partners from various developmental sectors.

KEYWORDS
- ENERGY ACCESS
- URBAN SLUMS
- SOLAR
- LIVELIHOODS

Integrated Energy Centres, solar power community hubs for need based services, have been operationalised by SELCO Foundation for informal migrant communities in Karnataka, India since 2011. There are 26 IECs till date, offering 22 different services. Through the interventions, 6074 households have been impacted. The paper describes three different models through case studies illustrating their operational and financial aspects.

INTRODUCTION

Migration is one of the main drivers of urbanization, and in Indian cities urbanization has been characterized largely through internal migration (UNESCO, 2011). India's urban population was 79 million in 1961 and rose to 377 million in 2011. Urban migrants predominantly work as unskilled labourers and are associated with the informal sector. Without a steady income or significant assets, they live in highly vulnerable conditions, often squatting on private or public land. This lack of proper housing and therefore proof of identity of residence in the city, serves as a major barrier to their inclusion in the formal sector. Leading to exclusion from basic rights in the city (right to subsidies through the Public Distribution System), right to avail justice (in case of re-settlement and slum demolitions), as well as preventing entry into the formal sector (cannot open a bank account or obtain a driver's license etc). Thus, lack of access to these basic rights denies people of appropriate opportunities, better incomes, education and a decent standard of living. Further, energy poverty keeps the poor locked out of the global economy, not only because they cannot access education, health care or jobs, but because their time, labour and large percentages (30-40%)[1] of their non-expendable income is consumed in foraging for rudimentary sources of power – from wood to dung – that their families require.

According to the International Energy Agency (IEA), globally a total of 208 million people living in urban areas do not have access to electricity (IEA, 2011). Karnataka is home to about 730,000 households[2] that live in informal

1 Based on SELCO Foundation's need assessment survey data

2 This captures households within slums that are notified or legally recognised by the government. The real number of non-notified informal settlements within Bangalore itself is estimated to be more than 1,500 (The Association for Promoting Social Action (APSA) as reported in Daily News and Analysis (DNA), 2015)

settlements, over 55,000 households reported not having access to any electricity (Census 2011).

Keeping the above challenges in mind, this article is an attempt to analyse and study the Integrated Energy Centres (IEC), one of the models used by SELCO Foundation, to use electricity as a catalyst for improving well-being and livelihoods in informal settlements.

1. SOLUTION: INTEGRATED ENERGY CENTRES

1.1. DESCRIPTION OF THE IECS

Integrated Energy Centres (IECs) are solar powered community centres that can host a range of basic services and activities lacking in an underserved community. While electricity is one of the recurring needs of these vulnerable communities, IECs bridge the last mile gap by providing access to other services, education, health etc. The IEC is envisioned to become a community space where the user can charge their mobile phones without walking to the closest source of energy that is sometimes kilometers away; get access to purified drinking water; find batteries and lanterns on rent; as well as gain access to educational aids such as computers, televisions or projectors.

Aerial view of Vasanthnagar: Due to the temporary nature of their tenure, urban poor live in small tarpaulin sheet tent like structures which prevent them from gaining access to important infrastructure and services including electricity, basic health and sanitation - Source: SELCO Foundation

A needs assessment exercise is conducted in the community, capturing basic demographic information, income, spending on energy and the community's most felt needs through a combination of interviews with different stakeholders (which include potential IEC operators/entrepreneurs, land owners, contractors etc) as well as focus group discussions with the community. Each IEC is custom designed to cater to the need in a community such that every aspect of it can be sustainable. Thus, each IEC is unique.

The important features of an IEC, that make it an ideal solution for the context of informal settlements are captured below.

1. Decentralized renewable energy - DRE solutions were deemed appropriate for these communities as existing solutions such as getting connected to the grid is not a viable option due to the lack of identity proof, lack of land ownership documents and high cost of connection. Additionally, individual solar home energy systems might not be the best solution due to their high capital cost, little or no access to financing and the migratory nature of the communities. For basic energy access, solutions such as portable lanterns were not seen as cost effective over a period of time due to a lack of servicing options.
2. Built structure - The IEC could be housed in existing home, shop or community hub, and can be built in a way that it can be moved relatively easily (prefabricated components and the use of dismantlable or re-usable materials) or could be mobile in nature (on a cart, rickshaw etc).
3. Customisable modular design - The services and/or amenities in the IECs are designed in a modular manner (see Table 1). Additional services are added onto systems as modules, i.e. a solar fridge would come in a package that includes a panel, charge regulator, and a battery, all customised to maximise efficiency and minimise costs. This modular design allows for flexibility and the ability to add on services based on entrepreneur and community needs as well as their ability to pay.

"DUE TO THE TEMPORARY NATURE OF THEIR TENURE, URBAN POOR LIVE IN SMALL TARPAULIN SHEET TENT LIKE STRUCTURES, WHICH PREVENT THEM FROM GAINING ACCESS TO IMPORTANT INFRASTRUCTURE AND SERVICES INCLUDING ELECTRICITY, BASIC HEALTH AND SANITATION."

Table 1. Sample technical specifications of the modules for lighting, mobile charging, and digital education services

Equipment	Unit	Wattage	Number of distribution boxes	Battery	Charge Regulator	Panel
LED light system	10 solar LED systems	3 W per lights	1	60 Ah (x 10 lights)	10 A	75 Wp
Mobile charging station	10 mobiles charged at the same time	5 W	1	60 Ah	10 A	50 Wp
Projector/visual aid for education	1 projector	35 W	NA	60 Ah	10 A	75 Wp

Source: SELCO Foundation

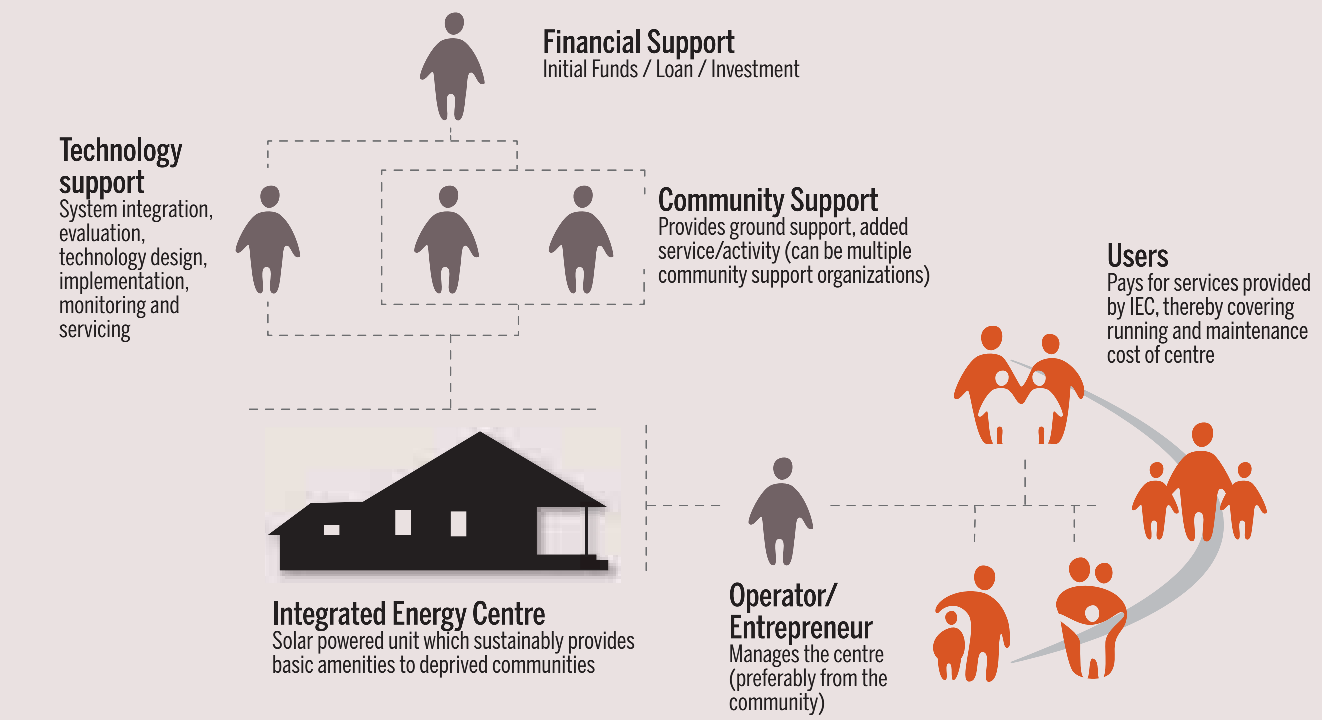
4. Ownership and financial model of the IEC - Entrepreneur, operator, partner and community owned depending on what works best within the settlement (as explained in Table 2). The decentralized concept of an IEC, allows the model to be custom designed according to the community. For example: as mentioned earlier, the urban migrants work as daily wage labourers, forcing them to make economic decisions on a day-to-day basis. Thus, for such communities, a daily rental model of energy services proves to be a more feasible and desirable solution.

The IEC is a dynamic concept, constantly evolving based on community needs. These communities may range from urban migrants to communities impacted by a natural or man-made disaster or a floating population.

1.2. THE DIFFERENT MODELS TO MANAGE AN IEC

In urban informal settlements, access to basic electricity (light and mobile charging) is often identified as the first intervention needed amongst the households, and thus is an easy entry-point intervention. In rural and tribal areas, the interventions might be education, health or livelihood focused. The financial sustainability of models is customized depending on the perceived value, the

IEC Structure and main aspects of its implementation.
Each of the three support roles are key to successful running of an IEC.



Source: SELCO Foundation

Figure 1

willingness and ability of the community to pay, and access to local financing. Examples of designing a financial model could involve a minimal safety deposit, and an affordable fee for services. This allows for not only a financially sustainable project but also a fulfillment of the felt needs of a community.

SELCO Foundation developed four types of models:

1. Partner - the partner organization owns the IEC and regulates or monitors the daily usage. The partner may or may not integrate its own services into the model and hire a local community member as the operator of the IEC.
2. Operator - a model where SELCO Foundation is the key risk taking agency. An operator is hired from the community to maintain records, collect rent and take charge of the equipments. A part of the rent may be used for servicing and maintenance and the operator's fees. The balance amount is taken as a monthly deposit by the operator to buy back the system. The ownership of the IEC lies with SELCO Foundation till the operator has bought back the system through the rent collected. In communities where land rights and number of households are uncertain, this model helps to initiate services, demonstrate the viability of the technology as well as the solution and build the capacity of the operator. After a few months, some operators choose to turn into entrepreneurs.
3. Entrepreneur - entrepreneur directly invests in the IEC and in most cases avails a loan to buy the systems and set up the IEC. Typically, it is the first time these entrepreneurs interact with the formal banking system. Thus, there is a strong financing component required in this type of model.
4. Community - the IEC is collectively owned and managed by the community. There is no single operator to the IEC. It is a preferred solution for communities that are very homogenous in the social and cultural contexts.

During the design of IEC, one of the key criteria is the aspect of risk sharing between different agencies (through entrepreneur debt financing in the case of the entrepreneur model, a supporting and supervisory role of the partner in the partner model, and community cohesion in the community model for instance). While bearing the financial risk initially helps to provide backing to the operator (one who manages and runs the IEC) in the gestation period of the IEC, the sharing of risk and connection with financial institutions encourages the development of local entrepreneurs.

This aspect of risk sharing may also be directly connected to the second criteria of absence of ecosystem factors, such as:

I. Socio-economic factors: insecure land tenure and hence, prone to eviction, lack of documentation, social stigma attached to the household due to their status in the community.

II. Financial factors: no access to formal financial institutions - termed as "risky" due to their socio-economic status and/or insecure land tenure.

III. Technological factors: lack of infrastructure, the need for bringing in aspects of energy efficiency, human-centred design.

IV. Capacity building: the need for building awareness amongst the community members on the technology as well as building the capacity of the operator and entrepreneurs in monitoring, maintenance and bookkeeping etc.

"THE INTEGRATED ENERGY CENTRE CREATES AN ECOSYSTEM THAT CATALYSES OTHER DEVELOPMENT ACTIVITIES, BY BUILDING TRUST IN THE COMMUNITY, CREATING INFRASTRUCTURE AND INCREASING ACCESSIBILITY OF CLEAN SUSTAINABLE RESOURCES IN THE COMMUNITY."

Table 2 highlights the enabling factors that are considered while choosing the IEC's operational model.

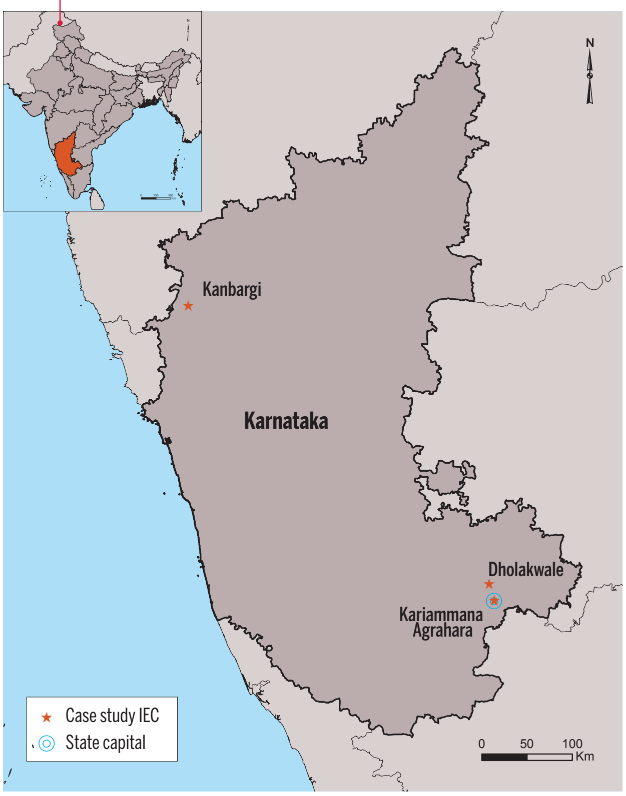
Table 2. Need assessment and model selection

Main factors considered for model selection	Model chosen
• Homogenous Community – no social hierarchy, bound by work & social norms • Live, work, travel together- high social capital • Have a tradition to collectively own things	Community Model
The ownership or operations of the IEC or IEC services are partner driven if the partner: • Has a strong presence in the community • Contributes in terms of technology, monitoring, servicing and or adding services (may or may not have an energy component)	Partner Model
Operator model: The operator is voluntarily nominated by the community or identified as a leader and or someone with entrepreneurial skills. An operator model, if chosen, is done by selecting an individual who has: • A good relationship with the community • Basic bookkeeping skills • Motivation/entrepreneurial spirit	Operator Model
An entrepreneur owned model is chosen if: • IECs potential has been proven & the operator chooses to take on entrepreneurship • The entrepreneur is able to acquire financing (usually facilitated by the Foundation or a partnering entity) • The community is relatively stable	Entrepreneur Model

Since 2011, 26 IECs have been installed offering 22 different services to the communities. These services are as varied as lighting, mobile charging, education, health, entertainment, awareness, photo studio, ticket booking, water purification etc. The IECs can also serve as a centralized charging station for machines such as sewing machines, laptops, projectors, soldering guns, televisions, refrigerators and incense making machines for livelihood based interventions. Additionally, the IECs provide services such as day care services, Alcoholics Anonymous counseling, banking services, market linkages, product diversification support, health care services and printing services.

The different models are distributed as follows: 1 community model, 1 partner model, 22 operator models and 2 entrepreneur models. It is important to note that the 2 entrepreneur model IECs, were previously run through an operator model. Operator driven models are most common due to the vulnerable nature of the communities - lack of financing, insecure land tenure. Entrepreneur models require the identification of a willing entrepreneur, which can sometimes be challenging.

Figure 2. Case study location - Source: FERDI



The development of the IECs is as presented in Table 3.

Table 3. Development of the IECs

	2011	2012	2013	2014	2015	Total
Urban	0	3	6	1	4	14
Rural	1	1	0	0	2	4
Tribal	0	0	0	4	4	8
Total	1	4	6	5	10	26

Source: SELCO Foundation

2. CASE STUDIES

This paper is based on research conducted in Karnataka, India in 2014. It employs a mixed qualitative methodology. Interviews were conducted with 50 community members (including the communities of the 3 cases studies), over a period of two weeks. Three operators or entrepreneurs were also interviewed. In the community, the interviews were conducted with direct beneficiaries of the Integrated Energy Centres, as well as community members who were aware of the intervention but were not using its services. Such social research tools were deemed appropriate for exploring the multifaceted issues relating to energy access in urban slums.

2.1. CASE STUDY 1: PARTNER MODEL: KANBARGI, BELGAUM (2013)

2.1.1. Background

A settlement of about 200 households, this slum rests on land that is under litigation for the past 16 years. Mahesh Foundation, a local NGO working for the welfare of children and youth in underserved populations wanted to actively work on health and education issues in the slum. Through the partner model, an IEC was seen as an effective entry point intervention for the community, serving as a "community hub" for development initiatives.

2.1.2. Implementation

Health: Mahesh Foundation runs a health clinic in the IEC every Tuesday, Thursday and Saturday. The regular consultation visits, helped identify a pattern of diseases that were water-borne, thus, helping identify the next intervention in the community - access to pure drinking water (this is currently being worked on by SELCO Foundation, together with Mahesh Foundation).

Lighting and Mobile Charging: A dark patch in the midst of an urban area, basic lighting was identified as a felt need by the community. The IEC thus, started off by providing lighting systems. Presently, it delivers light to 140 households, directly impacting approximately 840 individuals. The community used to spend around Rs. 50 per month to charge their mobiles in nearby shops. Some of them also reported of thefts from these charging points. They now have access to a mobile charging station at the IEC.

Education: An Anganwadi (government sponsored child and mother care centre) and basic literacy program runs every day at the centre. Mahesh Foundation also uses light as an incentive to promote education i.e the light can be rented by households that send their children to school. In January 2015, a solar-powered projector was installed to encourage educational programmes

Integrated Energy Centre in Kanbargi with Mahesh Foundation serves as a solar powered community centre with education and health facilities, in addition to being a charging station for lights and mobile phones - Source: SELCO Foundation

for the children as well as health awareness programmes for the community. A different social issue is selected every week and a film is shown in the community followed by an open discussion. About 30-40 community members participate every week.

Financial Literacy: With the help of a local financial institution, a bank account opening drive took place at the centre in 2014. This drive leveraged the Pradhan Mantri Jan Dhan Yojana (PMJDY) a scheme to open special zero balance bank accounts for the unbanked population. Approximately 300 new accounts were opened, a significant step towards financial inclusion of the community.

Thus, the IEC creates an ecosystem that catalyses other development activities, by building trust in the community, creating infrastructure and increasing accessibility of clean sustainable resources in the community.

2.1.3. Financial Model

Since this is a partner model the cost of the system and delivery of the services was borne by the partner (Mahesh Foundation). The cost of the structure of the IEC, which was set up more like a community space was seen as a one-time ecosystem building cost by SELCO Foundation. By subsidizing the cost of setting up the structure, the community as well as the NGO is allotted a space that serves as a catalyst for several developmental activities in the community.

While the education and health facilities are free, the financial model for the IEC was designed in a way that the renting of the lights and mobile charging would cover the operations and maintenance of the IEC. As the community is more comfortable with cash flows on a daily basis, the rent charged is Rs.5 per day. On an average, lights are rented out on all days of the month and thus the total revenue is Rs. 150 per month/ light. Through the rent collected, the operator (a community member, identified and employed by the partner organization to run and monitor the day to day activities of the centre) gets a fee of Rs. 2,000 per month.

2.2. CASE STUDY 2: COMMUNITY MODEL: NOMADIC DHOLAKWALE COMMUNITY (2013)

2.2.1. Background:

This settlement is a nomadic north Indian community that is skilled in crafting percussion instruments called *dholaks*. The men in the community craft their *dholaks* and live with their families on encroached public land. Lighting is an important social and economic need as their homes serve as a living and working space. Each drum is priced at Rs. 100. The men roam the streets with *dholaks* on their backs and occupy the main traffic junctions to sell them. Able to carry approximately ten *dholaks* at a time, a physically laborious process, their per day sales were also limited by their carrying capacity. While on better days, they were able to make around Rs. 1,000, most of the days it was hard for them to make any sales above Rs. 100-200. Further, in our need assessments, kerosene was seen as a high expenditure (almost 10-15% of their monthly income). A good quality lighting solution was not only identified by the community as an important aspect to their wellbeing and security, but also directly connected to their livelihood- providing them with longer days, and flexibility of working hours. The artisans also expressed their difficulty in keeping up with the demand during peak seasons, due to the inability to work after sunset.

Being an economically vulnerable community, providing portable and efficient home lighting systems to them was a challenge. When approached with the IEC concept, the families came together and showed a keen interest in the project. They were also willing to put down a deposit for the same. As pointed out by one of the interviewees, Azma, “We all share the responsibility, or in a way we are each responsible for our own batteries. If I want my light to work properly, I will take care of it and put it for charging on time. Similarly, as soon as it’s dark, I will collect it from the charging station

Open Tarpaulin Tents serving as living and work spaces for the Dholakwale nomadic community
Source: SELCO Foundation

Mobile IEC for Dholakwale Community
Source: SELCO Foundation

in the evening. We don't need any one person to do this for us." It is important to point out that, a close knit, socio-economically homogeneous community is a prerequisite for the smooth functioning of the community IEC model.

Following the intervention, while they were able to increase production of the *dholaks* (percussion instruments), they were unable to match it with an increase in sales. Thus, it was realised that the benefit of the technology (in this case, the light) would only be met if it was supplemented by an intervention that helped connect them to a larger market and looked at product diversification to increase their market segment. SELCO Foundation, thus looked at livelihood interventions that helped diversify their product range, connect them to exhibition spaces to cater to the urban market.

Based on the pre-intervention survey, annual income on an average was approximately Rs. 50,000 per household. Post-intervention, the annual income on an average increased by 10-20 percent. The exact amount is difficult to quantify due to the unwillingness of members to divulge specific financial details, and lack of basic bookkeeping. However, from one of the data points we were able to capture, the total profit made by the community from participating in handicraft exhibitions[3] alone (facilitated by SELCO Foundation) was Rs. 30,000.

Designing an IEC for a Nomadic Community: Since the community is nomadic, they move every 6-8 months depending on the proximity to different markets in the city. Additionally, they are highly prone to eviction. This was visible in the way that the households interacted with their physical environment- few or no assets and easy to assemble (and disassemble) tents. Thus, portability of the IEC was crucial. A simple mobile vending cart was modified and used as the housing entity.

3 A market platform showcasing handmade goods

2.2.2. Financial Model

This model includes a 'rent purchase' model. The community pays a monthly instalment to SELCO Foundation, which over a period of time would cover the capital cost of the system. An initial token amount of Rs. 200 was collected from every household before setting up the system and thereafter, every household paid Rs. 100 a month. The total repayment is not yet complete but when enough collections have been made, the community will own the system. The service and maintenance costs is Rs. 1,055 a month (Rs. 35 per household per month), the community will continue to pay the service and maintenance cost after the capital costs are recovered.

2.3. CASE STUDY 3: ENTREPRENEUR MODEL: KARIAMMANA AGRAHARA (2013)

2.3.1. Background

The Kariammana Agrahara slum houses over 500 households from different parts of Karnataka and Tamil Nadu. Migrant labour families have been residing here since 2010, working as contractors, labourers, cleaners, carpenters, gardeners etc.

An existing entrepreneur, Kumar, who runs a petty shop in the slum was chosen as the operator for the IEC. His existing business, relationship with the community, and entrepreneurial skills were beneficial for the centre to run smoothly and expand quickly. Similar to the first case study, the centre was designed to serve as a foundation for other activities in the community. The IEC was thus designed with a community space - allowing provision for activities like awareness campaigns, community TV programs, projector and laptop usage for educational activities.

Initially, 30 households in the community were introduced to solar portable lighting solutions. Several demonstration activities and awareness workshops were conducted in the community to build trust for the technology as well as awareness around the usability. Experiencing the positive benefits from its use, 80 households were renting out lights within 8 months. Seeing a business potential, in November 2014, with the help of the Small Scale Sustainable Infrastructure Fund (S3IDF), Kumar was able to take a loan,

Entrepreneur Kumar at his petty shop in Kariammana Agrahara (Before IEC intervention)
Source: SELCO Foundation

purchase 120 systems (battery and light) and become an IEC entrepreneur. Since then, through the relationship built with Kumar, and the community, the Foundation has been able to explore other services through partner organizations (health camps, literacy groups) and help expand livelihood opportunities.

2.3.2. Financial Model

Currently, after 2 years of initiation of services, Kumar makes a revenue of Rs. 28,000 a month by renting out 140 lights (on an average) at Rs. 200 a month. There was a small grant given initially in order to jump start the business and after that Kumar has taken a loan for a second set of lights and then an expansion loan as well. The total Equated Monthly Installment that has to be paid for these loans is approximately Rs. 9,411 per month. Kumar also spends Rs. 5,050 per month on the service, maintenance and replacement of parts. Thus, he saves approximately Rs. 13,539 per month through the business.

2.4. SUMMARY OF FINANCIAL MODELS

Table 4 describes the key financial data for the IECs including infrastructure costs, revenue generated by renting out services, and the income for the operator/entrepreneur. While some services cannot be monetised, such as those related to dissemination of information, education and health, a financial model is developed around the services that can be monetised. Critical to designing the financial model is achieving a balance between the instalment amount to be paid by the households, and the time required to achieve financial sustainability (break-even period). The quality of services designed for the warranty period, servicing, presence of supply chain and the utility of the end user play a key role in determining the financial sustainability of the project.

Further, while the financial model does keep in mind the sustainability of the project, the social costs and benefits that occur through the interventions are difficult to monetise. As a result the costs which focus on creating a public good in the form of infrastructure (community centre) or knowledge (innovation and capacity building), are seen as ecosystem building costs and may need to be subsidised (the ecosystem factors have been discussed in Section 1).

"THE COSTS WHICH FOCUS ON CREATING A PUBLIC GOOD IN THE FORM OF INFRASTRUCTURE OR KNOWLEDGE, ARE SEEN AS ECOSYSTEM BUILDING COSTS AND MAY NEED TO BE SUBSIDISED."

Table 4. Key Financial Data

PARTICULARS	KANBARGI	DHOLAKWALE	KARIAMMANA AGRAHARA
MODEL	PARTNER	COMMUNITY	ENTREPRENEUR
First Level Interventions			
Cost of IEC Structure	Rs. 180,000	Rs. 18,000	Rs. 200,000
Cost of IEC System	Rs. 250,000	Rs. 120,000	Rs. 555,000
Number of Lights	110 lights Avg. number of lights rented out every month	30 lights Avg. number of lights rented out every day	150 lights Avg. number of lights rented out every day
Income of Entrepreneur	Rs. 2,000/month Salary of operator	Nil	Rs. 13,539/month
Fees Associated with Lights	Rent/day Rs. 5 Monthly rent from lights is Rs. 1,200	Rent/day Rs. 100 Monthly rent from lights is Rs. 2,500	Rent/day Rs. 200 Monthly rent from lights is Rs. 28,000
Second Level Interventions			
Added Services	Health Clinic Schools Water Purification Financial Literacy	Market Linkages Product Diversification	Refrigeration Water Purification

3. RESULTS

While there are a number of benefits from IECs, both tangible and intangible, this paper draws out some of the observed livelihood, health and safety, and economic benefits that were illustrated through the case studies. Some of the more intangible benefits not discussed include an increase in study time for school going children, a sense of safety, flexibility in determining one's schedule, and the simple pleasure of being able to see at night.

3.1. LIVELIHOOD

As illustrated in case studies 2 & 3, the impact on livelihoods is significant for both the energy entrepreneur and the community by reducing the amount that is spent on kerosene for lighting and extending the hours of productivity. However, increase in production as in the case of the Dholakwale community, does not necessarily translate into economic gains. Other factors such as product diversification and market linkages need to be implemented to improve livelihoods. Kumar (Case study 3) said, "My earnings have doubled since I started working as an IEC entrepreneur". While another interviewee reported, "Earlier I had to finish cooking at home by 5:30, so at least the kids can finish eating by 6 while there is still some light outside. Now with access to light I am able to go to one more house for work in the evening" says Shivamma, domestic helper.

3.2. HEALTH AND SAFETY

Since one of the main sources of energy in these informal communities is kerosene, use of solar lighting reduces the dangers to health and safety from the noxious fumes and naked flames, providing much needed relief from smoke throughout the night. Field observations and interviews highlighted a self-perception of improvement in health including reduction in burn injuries from using kerosene or candles for lighting. Additionally, there was a sense of increased safety from harmful animals such as snakes and scorpions as a result of access to improved lighting.

"EARLIER I HAD TO FINISH COOKING AT HOME BY 5:30, SO AT LEAST THE KIDS CAN FINISH EATING BY 6 WHILE THERE IS STILL SOME LIGHT OUTSIDE. NOW WITH ACCESS TO LIGHT I AM ABLE TO GO TO ONE MORE HOUSE FOR WORK IN THE EVENING" SHIVAMMA, DOMESTIC HELPER.

Entrepreneur Kumar's shop in Kariammana Agrahara (Post IEC intervention)
Source: SELCO Foundation

In case study 2, one of the biggest problems that came up in the needs assessment was a threat from snakes, rodents and scorpions - biting young children and infants in the dark. As one of our interviewees stated, "We have snakes and rats here, sometimes even mad dogs enter our community. How do we check if there is a snake in our tent, if we can't even see?"- Radhava.

In case study 1, Mahesh Foundation doctors are positive that with a regular health clinic, the health levels and practices within the community have started transforming. Dr Faraz noted a decrease in children's bronchitis cases since the kerosene lamps in households have been replaced by LED bulbs charged at the IEC. Also, as mentioned earlier, it has resulted in creating evidence as well as identifying some of the preventive health measures, like access to clean drinking water, that can be taken in the community by analysing disease patterns. A solar powered water purification system is scheduled to be installed by end of March 2016.

Further, while there is anecdotal evidence of the benefits of clean lighting solutions on indoor air quality, studies to capture and quantify the effects need to be carried out.

3.3. ECONOMIC BENEFITS AND SAVINGS

As we go down the poverty ladder, the cost of energy goes up. Spending approximately 30-40% of their monthly income on unsustainable and harmful energy fuel, this expenditure is a representation of their citizenship, as discussed in introduction. The high expenditure reflects their limited access to the Public Distribution System (PDS)[4] and high black market prices based on their location.

4 Kerosene is subdised through the Public Distribution System and targeted at households that are below the poverty line (BPL) and have the documentation to prove the same. Through the PDS BPL households can purchase up to 5 litres of kerosene/month at a subsidised cost. However, studies have shown that approximately 50 per cent of poor households do not have a BPL card (Lang and Wooders, 2012).

Some people get the first few litres of kerosene subsidized and then have to buy the rest on the black market. On average, from baseline studies, 1 litre of kerosene through PDS costs Rs. 30 for the first 5 litres. Any additional kerosene needs have to be met through the black market at Rs. 60 per litre. On average, households without access to the PDS system spend Rs. 300 per month on kerosene. By investing approximately Rs. 200 per month on solar lights, the household will get better quality lighting, reduce indoor environmental pollution and also save money as compared to kerosene. In addition, by looking at preventive healthcare measures (less exposure to kerosene fumes, access to clean drinking water), the IEC results in indirect savings by avoiding regular expenditures on private health clinics (public health infrastructure may not be accessible in some case due to legitimacy issues, as explained in introduction).

4. CHALLENGES AND LESSONS LEARNED

4.1. LAND TENURE

The lack of secure land tenure poses a significant challenge when working with these communities. Care needs to be taken to customise solutions such that they do not attract unwanted attention and antagonise the landowner, leading to evictions. In the case of evictions solutions should be easily packed and moved. There have also been instances where political leaders or landlords in these areas have felt threatened by the work of NGOs in the communities. One way of addressing this has been by including, or seeking endorsement from, these parties for the initiative.

4.2. COMMUNITY DYNAMICS

When entering a community the existing dynamics and power structure plays an important role in gaining buy-in for interventions. In one case an IEC entrepreneur, taking advantage of his monopoly of the market and the need for his services, started charging the community Rs. 20-25 for daily rent as opposed to Rs. 5-7. Addressing such issues requires constant conversations with operators or entrepreneurs so that they understand their social responsibility. However, ongoing follow up and engagement can be resource intensive.

4.3. IMPORTANCE OF CUSTOMIZATION

The above case studies highlight the importance of customization of solutions according to the community needs. While on the one hand the technology systems need to be tested to optimise end user experience and efficiency with the aim of making it more affordable. On the other, customization and innovation needs to be made in delivery mechanisms and approached with a holistic perspective that takes into consideration the social, financial and environmental sustainability of the solution.

4.4. COMPETITION FROM SOLAR LANTERNS

With solar lanterns gaining popularity and being perceived as a universal solution to energy access; inexpensive Chinese made solar lanterns and products with shorter life cycles are currently flooding the market. Due to their inferior quality and the lack of servicing options these products significantly drain household incomes. Additionally, these lights are limited in their utility (only providing lighting) and reduce market confidence in solar technology. The IEC model advocates for going beyond merely a one time lighting solution by providing a sustainable model that evolves according to community needs.

4.5. CHALLENGES IN MONITORING AND EVALUATION

A number of the operators and entrepreneurs we work with do not engage in regular bookkeeping practices, which poses a challenge for effective financial monitoring and evaluation. By visiting the community every 2-3 weeks for rental fee collection and technical assistance, the field coordinators are able to help fill in the gaps in monitoring and remedy any issues that may arise on an incremental basis. This helps provide a data set for future replication.

5. DISCUSSION: SUSTAINABILITY, FUTURE WORK AND POLICY IMPLICATIONS

5.1. FUNDING AND SUSTAINABILITY

While most IECs start as an operator model, the focus is to encourage entrepreneurship and make the IEC model sustainable. Since the IEC is a relatively new concept and there is a significant risk associated with these vulnerable communities, the Foundation takes a larger stake in the initiative in terms of the capital cost. While most funders are keen to set up the IEC, they are more reluctant to support any expansions or innovations. Additionally, when an operator is interested in expanding his services and becoming an entrepreneur, refinancing from traditional channels such as banks becomes an issue. Thus, building relationships and establishing strong financial linkages with a range of institutions - banks, donors, micro finance institutions, etc is critical.

5.2. FUTURE WORK

While scaling of solutions is critical, SELCO Foundation does not define scaling as “supersizing” the organization to spread a standardised solution (which is convention in the business world). Diverse terrains, issues, and socio-economic conditions in India push for contextual innovation at different levels. Multiple challenges are overcome by customised technical and financial service solutions.

If we look at the detailed case studies and break them down into processes that were used to analyse the need, address issues of ownership, land tenure, operations and monitoring, they are very different. Thus, to ensure that interventions impact and sustain, it is important to localize the solutions. If we see the concept of IEC as a model that looks at electricity access to off-grid vulnerable communities, or as a concept that encourages shared economy, it can further be replicated to address other issues that come with energy poverty by scaling the processes and concepts as opposed to one specific model.

A model to provide energy to off-grid livelihood activities: The insecurity of tenure and informality of a migrant labour settlement can be compared with the vulnerability of street hawkers or similar communities. Replicating the financial model of an entrepreneur run IEC, a central charging station in one of the hawker[5]'s home, who then delivers the light to the other hawkers operating out of the same market or neighbourhood, can be used to address the electricity issues in such a scenario. Adoption of this model can also be explored to meet the electricity needs for other vulnerable communities such as those displaced by natural disasters, refugees, etc.

5 A person who travels around selling goods

A model that encourages shared rather than individually owned resources: The concept can also be seen as a rental model for technologies that are expensive but don't require constant usage. Shared resources ensure energy efficiency and economic viability. Shared water pumps in rural areas combined with night-time drip irrigation can reduce water usage and increase economic viability of irrigation. IECs have the potential to anchor such capital-intensive resources through shared ownership in rural and informal settlements.

5.3. POLICY IMPLICATIONS

The energy access sector has the potential for a range of business models, across technologies and scales of operation. However, there are certain critical components that have to be in place for the sector to succeed and scale. By enabling these critical components, any delivery model should be able to sustain and flourish. Thus, for more organisations to be successful in providing energy access to the poor, it becomes crucial to shift the focus from technology alone, to considering a holistic approach that looks at other factors in the ecosystem such as combining customized technology with affordable financing; a sustainable dissemination and maintenance mechanism; and a conducive entrepreneurship and policy framework (Figure 3).

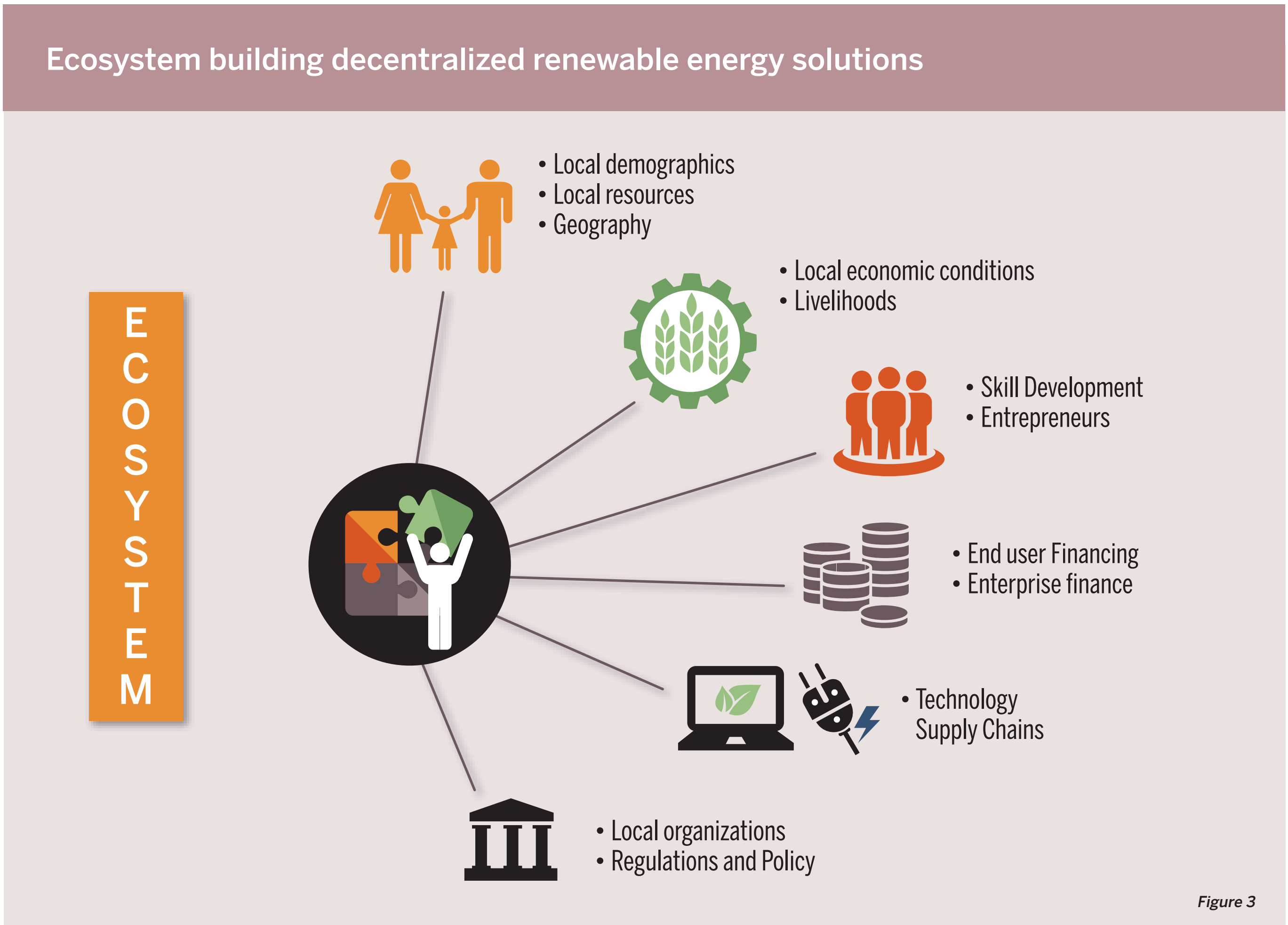


Figure 3

During the course of writing this article there have been a number of evictions in the communities that we work with. Further emphasising the need to address issues related to migrant communities in a more holistic manner such as land rights and the need for the government to intervene on affordable housing. Government can adopt a two pronged approach, one that addresses the issue of distress migration caused due to lack of livelihood opportunities in rural communities. And two, ensure that cities are more inclusive and provide affordable access to basic housing and basic resources and amenities for these migrant communities. Current conversations in India are focused on ambitious and innovative ideas such as Smart Cities and Digital India. Ironically, a large proportion of urban migrants are engaged in building and catering to the needs of these Smart Cities that have no room for them.

While further studies that measure the direct and indirect impact of the IEC over time will be useful in influencing policy change and replication in other contexts, some specific recommendations from a policy perspective are:

- Awareness campaigns about the benefit of clean energy and the health implications of using polluting fuels such as kerosene.
- Rationalising of government subsidies for kerosene that can be re-directed to finance cleaner alternatives.
- Addressing issues of urban migrants and affordable housing.
- Provisions for financing across the supply chain, including for the entrepreneur and the end user.

CONCLUSION

Lack of opportunities, climate change, caste dynamics, dwindling natural resources, local conflicts, war, etc. are some of the reasons for increased vulnerability of underserved populations. To escape from the impending challenges, some migrate and many others try to face it with whatever meager means they have. In many cases the vulnerability has increased, just that the variables have shifted from one part of the eco-system to another.

Integrated Energy Centers (IEC), as a concept, was thought about to mitigate some of the short term challenges of these communities, paving the way for medium and long term solutions to help them get out of the vulnerable situations they find themselves in. As shown by pilots implemented by SELCO Foundation and its partners, the concept of IEC is highly customizable thus providing the flexibility to be replicated across all types of populations – rural, urban, tribal, migratory, disaster affected etc. The initial sets of IECs have also explored a broad range of ownership models from being entrepreneur run to community owned. The IECs can also be an ideal first channel to optimize the connection of energy and essential services like education, health, water and livelihoods: especially to the underserved communities by providing them a way to avail services with minimum infrastructure related resources.

IECs are in no way a long term or permanent solution, but help ensure that vulnerable populations (and more importantly generations) do not lose out on critical parameters of development (like energy access, health, education and livelihood opportunities). In the larger context, IECs can be the very foundation for new types of innovation in technology utilization, business model applications, models for delivery of essential services, new methods of social inclusion etc.: aspects critical to lessen the technology, financial and social divide for the poor.

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3. INDIVIDUAL SOLUTIONS: ORGANIZATIONAL ISSUES AFFECTING UPSCALING

PAY-AS-YOU-GO SOLAR PV IN RWANDA:

evidence of benefits to users and issues of affordability

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Indigo Duo Solar Home System
Source: Azuri Technologies

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KEYWORDS

- OFF-GRID ELECTRIFICATION
- SOLAR HOME SYSTEMS
- PAY-AS-YOU-GO SOLAR PV
- RWANDA
- ENERGY FOR ALL

In 2013 Azuri Technologies, a provider of solar home systems, entered the Rwanda market with USAID support. During project implementation various distribution challenges were encountered and useful lessons learned. Impact studies were conducted which showed households using the Azuri systems benefiting from significantly more hours of light and from the ability to charge phones at home. These households were among the wealthier segments of the rural population indicating affordability challenges for some households.

INTRODUCTION

Azuri Technologies is a company headquartered in the UK which provides pay-as-you-go (PAYG) solar PV home lighting products to customers in off-grid areas of sub-Saharan Africa. In May 2013 the company entered the Rwanda market with financial support from the USAID Development Innovation Ventures programme. According to World Energy Outlook 2014 only 17% of Rwanda's 10 million people have access to grid electricity. In rural areas the electrification rate is 5%, one of the lowest in sub-Saharan Africa. The product provided by Azuri is called Indigo Duo. It consists of a power unit using a lithium iron phosphate battery, a 2.5W solar panel, two light points using LEDs, and adapters to enable the user to charge a phone. Customers pay an installation fee of RWF 6,600 (approx. USD 8.80, though currency degradation was a factor throughout the project) and the rest of the cost in regular 28 day instalments RWF 3,500 (approx. USD 4.70). Each Indigo unit has a key pad which is used to enter a code provided to the customer when they make a payment. If payments are not made the unit switches itself off. After an agreed payment period (21 instalments or 84 weeks) the customer can unlock and own the system by paying a single "unlock fee" of RWF 6,600. Customers "top up" either by purchasing scratch cards which provide a number they can use to obtain a top up code via SMS, or through mobile money payments.

Azuri partnered with GVEP International, an NGO which provides support to SMEs working in the energy access field. GVEP's role was to help identify a local distributor, and provide training, support and advice to the distributor. GVEP also commissioned and supervised a *baseline survey at the start of the project which helped determine the pricing strategy. An impact study was later conducted to assess the benefits experienced by households using the Azuri product. The impact study included a socio-economic profile of Indigo users relative to the general off-grid population.*

LITERATURE REVIEW

Previous studies have been conducted on the impact of solar home systems on households in several countries including Bangladesh (Khan et al., 2014), Indonesia (Djamin et al., 2002), Zambia (Gustavsson and Ellegård, 2004), and Kenya (Jacobson, 2007). Data on the impact of these types of products, particularly in sub-Saharan Africa, are however scarce and most pre-date the arrival of pay-as-you-go products. The studies which do exist generally show improved quality of lighting and economic benefits from reduced expenditure on kerosene and batteries. Evidence of impact on children's education is mixed.

One study, a randomised control test examining the benefits of pico-solar lamps in Rwanda, is of relevance to the present paper (Grimm et al., 2015). This research found that adoption of small solar lanterns significantly reduced household expenditure on dry cell batteries and kerosene, and improved air quality in the home. The researchers found no overall increase in the time children spent in studying each day, though there was a switch of study time from daylight hours to the evening. There was some increase in the time women spent on housework in households using the lamps, and a reduction in leisure time. Also of interest is a study of the impacts of mini-grids in Rwanda conducted as part of the GIZ programme supporting mini-hydro developers which provides some relevant information (Bensch et al., 2010). This study used data from existing mini-grids to predict likely impacts in areas where new sites were to be developed using propensity score matching (PSM) techniques. No study of the impact of solar home systems in Rwanda has been published that we are aware of.

1. THE PROJECT

Azuri Technologies' business model relies on partnerships with in country distributors. In the case of Rwanda a number of potential distribution partners were investigated and negotiations were held with two local companies, both involved in distribution of solar lanterns. The selection criteria was based around their reach into rural communities and access to last mile distribution, experience in solar lighting and interest in developing a service based offering for their business. The business eventually contracted to manage distribution is a Rwandan company based in Kigali and employing around 4 staff. Prior to engaging with Azuri the company had been selling retail solar lanterns, primarily serving the Northern and Eastern provinces. Normally Azuri would require a distribution partner to pay in advance for the supply of goods. In the case of the USAID funded project the grant covered the initial costs of the manufacturing and shipping, so the distributor only paid for product as it was sold. The revenue generated from this activity covered Azuri's costs associated with the implementation of the project. The product is promoted by mobile sales agents who visit the various target communities and acquire customers (typically around 100 customers per agent). The mobile sales agents are in charge of the installation of the system. The solar home systems should not need regular maintenance beyond keeping the solar panels clean (customer instructed how to do this) and replacing the battery after a few years. In case of a technical problem, the customer has a helpline to call to report the fault. The customer service team goes through a series of questions to establish whether there is a fault or whether the problem can be easily fixed (the panel having come unplugged or a LED having failed). If the unit is faulty, it will be replaced. The sales agents in this case would deliver the new unit and collect the faulty one.

The project identified several challenges in the execution model and the technical capabilities of the product. A number of these were addressed within the project. Unlike some other markets in which Azuri operates, a significant number of households in Rwanda have more than 2 rooms, indicating that a larger product with more lighting capacity would likely increase the impact of the solar home systems, and consequently reduce the consumption of alternative lighting sources.

In some areas where systems were installed long periods of overcast conditions reduced the charge generated thereby affecting the available power/run time. Next generation products are now fitted with oversized solar panels to address this issue. The main technical issue experienced by the product was intermittent faulty switches in a proportion of the units. This manifested as a flickering of the lights due to contact resistance developing in the in-line switch. Later units shipped to the project had a higher quality switch as standard and a supply of these new switches has been provided to the distribution partner to address issues in the installed base. In future products, mechanical switching has been eliminated and replaced with digital switching.

One further product improvement has been established – the use of greater levels of "tamper proofing" for the devices, both in the electronics and the packaging to make it considerably more difficult to tamper with the unit.

Because of the limited development of mobile money services in Rwanda, the project initially utilised physical top up cards (scratch cards, available from the distributor's sales agents) as a mechanism for customer payment and validation. The customer purchases a top up card, scratches off the covering to reveal a code that is then sent along with the customer's unit serial number via SMS to an in-country gateway. The gateway then contacts the Azuri server which validates the numbers and generates a top up code which is unique to the customer's system. This is sent back to the customer via SMS. This payment validation method has the advantage that it is broadly similar to airtime purchase, so does not require extensive modification of customer behaviour, can be readily set up and requires limited in-country infrastructure to execute. This allows relatively rapid business development and does not tie the technology to a specific mobile service provider. As the product does not have an integrated mobile phone module the build cost is lower and deployment location is less constrained as the customer does not need to have a mobile signal inside the house at the point where the unit is installed, he or she merely needs to be able to send a text message once a week.

However, there are a number of disadvantages to a physical top up card system that provide some challenges and, in the extreme, limit its effectiveness and long term scalability. The major issue is the in-country logistics to manage and distribute physical cards to the target rural communities, which in the case of reasonably disbursed population in mountainous terrain, can require considerable time and expense. Local agent networks also need to be sufficiently integrated into the distributor's organisation to manage physical cash and flow this back to the distributor (and onwards to Azuri). In the case of the project there were significant challenges in ensuring adequate and timely disbursement of funds from agents back to distributor. Whilst this can be mitigated by a debit-approach (agents must first purchase the cards themselves), this introduces a cash-flow element to another layer in the distribution chain. These issues proved to be problematic for the local distribution partner, despite significant intervention attempts by the project partners, and hence led to intermittent supply of cards to agents and end users in some areas.

During the course of the project steps were taken to trial mobile money solutions. Initially this involved integrating a mobile money system into the Azuri server to provide real-time service to the customer – .e. the customer could initiate a payment from their phone and receive a top up code back in a fully automated manner. This service was due to go live when changes with the mobile money platform led to failure of the integration (from the mobile operator's side). This remains an ongoing issue and illustrates the "single point of failure" that can exist with mobile money platforms, particularly in the situation where a PAYG provider is tied to a single Mobile Operator. Azuri is in the process of broadening the number of mobile money platforms it is integrated into to offer customers maximum choice and reduce dependency on a single provider. Unfortunately, the sophistication of the systems currently available in Rwanda is significantly lower than systems available in Tanzania and Kenya. This is a rapidly evolving area and will be the direction for future deployments, but for the course of the current project a robust integrated mobile money offering was not available.

In the meantime the project developed a more "manual" mobile money system that allows customers to purchase top ups either directly from the distributors office or via their agent, but without the need for physical cards or cash handling. This requires access to a mobile money account (either at customer level or agent level) but not the fully integrated service. This was fully supported by the project partners, with dedicated teams set up and trained to assist the distributor.

One of the most important lessons learnt in the project was around the scalability of smaller distribution partners. The project encountered significant issues when working with the local distribution partner as the project started to scale. This is reflected in the slower than planned ramp of deployment and some of the issues with cash flows in the field. These problems were encountered despite a significant level of in-country support from GVEP, and resource from Azuri (both directly from Azuri employees and from in country support managed by Azuri). The requirement for an active management in country (and at the last mile) of the installed base of customers means a significant "post-sale" commitment is required to ensure reliable customers and reliable cash flows. This is a significant change for most retail based businesses and whilst this is reflected in lifetime revenues achievable, it does require a certain level of structure, organisation and process to be put in place in partner organisations. By their nature, larger organisations or those already providing services tend to have a more process driven business model and so may adapt better than smaller retail-based organisations. In the case that a new organisation is being created to support the deployment of PAYG systems, a common understanding about resource requirements needs to be in place from day one with an adequately resourced growth plan.

During the course of the project, agent training and communication to the customer was highlighted as a key area for improvement. Despite a number of initiatives, a train-the-trainer model was only partially successful, as evidenced by the issues raised by customers around knowledge of the payment scheme and term. In some areas solar panel positioning was sub-optimal, and in some other areas there was a lack of understanding and over expectation on the part of the customer about how the product would perform in certain seasons (due to overcast conditions for extended periods, reducing the charge generated which reduced the available power/run time). A number of the issues highlighted in the end line survey around remaining balance and messaging have been addressed, with improvements in the local language SMS text and a technical change to SMS messaging to ensure every communication around top ups includes a remaining balance to unlock as standard.

Finally, during the course of the project a number of changes were made to import regulations in Rwanda. These had considerable impact as changing requirements were not always communicated or were

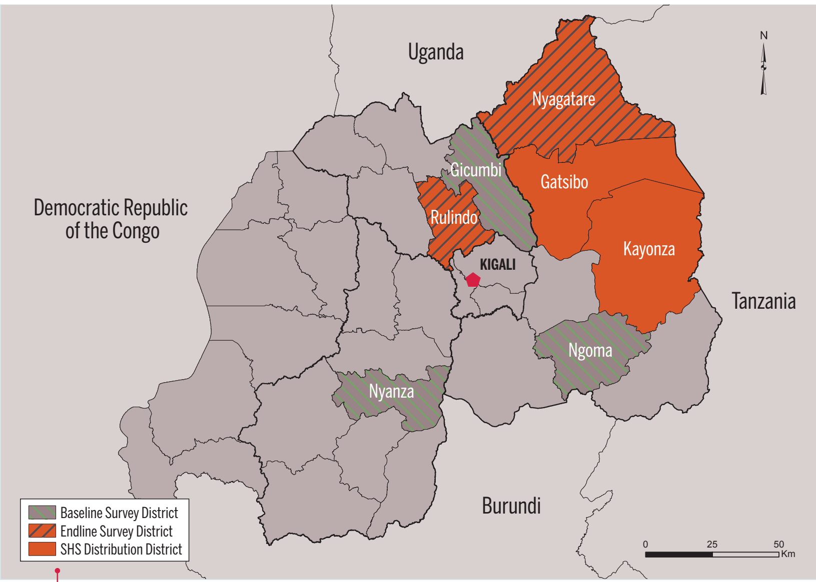

Figure 1. Survey and distribution districts - Source: FERDI

implemented on rapid timelines such that goods in transit fell foul of the newer regulations. Examples include the introduction of pre-shipment inspection and sudden changes in VAT regulations. Given the long shipment times (up to 3-4 months for a shipment to travel from Malaysia to Kigali was not uncommon) the requirement for sensible timescales for changes is key. Ultimately the project partners were able to resolve these changes without significantly changing the underlying economics for the project, but there were considerable delays which had impact on deployment rate and project momentum.

Because of these various factors roll-out of the units proceeded more slowly than originally planned. The project had a headline aim to deploy 10,000 PAYG solar home systems in Rwanda. At the time of project completion in September 2015, ~5,100 units had been deployed (in Nyagatare, Gatsibo, Kayonza and Rulindo districts), 2,800 were in stock awaiting deployment and 2,100 were in transit to Rwanda (stocking levels were managed so as to not overwhelm the local warehousing capability). Azuri expects the remaining units to be deployed over the next 6-9 months. It is worth noting that a period of a year or more to get distribution operating at a significant rate is not uncommon.

Of the units deployed 100 had been unlocked by project end (reached the end of the PAYG period). Given the term of the PAYG period and project timelines, this is higher than expected and reflects that a proportion (70%) of the unlocked units were unlocked early – i.e. the customer accelerated the payment plan to reach the end ahead of PAYG schedule.

2. BASELINE RESEARCH

The Azuri project started in May 2013 and a contract was signed with a local distributor, in late October 2013. The first units were distributed in January 2014. The baseline study was conducted in October 2013 prior to any sales activity, and took place in three districts: Gicumbi, Nyanza and Ngoma districts. These districts were purposively selected as places where sales and marketing activity was likely to occur based on the preliminary discussions with potential distributors. Within these districts the study targeted rural areas with no electricity connection.

The study used a multistage sampling technique to determine households to be interviewed. The sample frame for the survey was the list of households in all the targeted rural areas in the districts of Gicumbi, Nyanza and Ngoma. The primary sampling units in this study were the villages in each district as they are the smallest administrative entities in Rwanda. The sample size was 480 giving a confidence level of 95% for a margin of error of +/- 5%.

- A list of all villages in the three chosen districts was obtained from the National Institute of Statistics in Rwanda;
- Urban and peri-urban areas were excluded from the list;
- From the remaining villages, 5 villages in each of the 3 districts were randomly picked using Excel; that is 15 villages in total for the study;
- Within each village 32 households were selected for interview;
- Based on the total number of the households within each village provided by local authorities, a sampling interval was established for each village giving the number of households that each enumerator should jump. For example, for a village of 200 households a sampling interval was estimated to 6 given by 200/32.

Table 1 provides the list of the villages randomly picked and the number of interviewed households.

Table 1. Sample distribution of the baseline survey

DISTRICTS	GICUMBI		NYANZA		NGOMA	
Selected villages	Sunzu	32	Buhoro	32	Karenge	32
	Rwinyana	32	Nyagatovu	32	Kavumve	32
	Kabingo	32	Shinga	32	Bukokoza	32
	Matyazo	32	Kamushi	32	Akinteko	32
	Kabeza	32	Nyabinyenga	32	Kibimba	32
Total per district	160 households		160 households		160 households	
TOTAL	480 households					

"ON AVERAGE THE MOBILE OWNERS HAD TO SPEND 3 HOURS AND 22 MINUTES TO GET THEIR MOBILE PHONE CHARGED."

Primary data were collected using a semi-structured pre-tested questionnaire administered by eight trained enumerators using the local language. Household interviews were conducted during the period of 4-12 October 2013. The household questionnaire captured data on households' demographic and socio-economic characteristics as well as data on the use of different sources of energy for lighting and mobile phone charging.

The survey found that the most commonly used lighting devices were home-made LED devices (DIY) powered by batteries (51% of households used these), tin lamps which use kerosene (41%), but also other sources like mobile phones (24%), candles (11%), hurricane lanterns (5%), and firewood (5%). Households generally use multiple devices and the average amount of light daily was assessed as approximately 2 lighting hours.

Rechargeable LED lamps, solar lamps and lamps using biogas were used by only 1-2% of households. Where they are used they appear to provide superior lighting. Solar and rechargeable LED lamps ranked 1st and 2nd regarding longevity of use with 3 and 2.5 hours per day respectively.

Thirty-five percent (35%) of the surveyed households have children who are studying in primary and/or secondary schools. These children mainly do their homework at home, and 54% of households with children in school said their children study at night. Twenty-nine percent (29%) of the respondents said they put on light when their children are studying and doing their homework. The DIY and tin kerosene lamps are the main lighting devices used for children's education and the indicated average time children spent studying was 1 hour and 10 minutes.

Fifty-five percent (55%) of surveyed households own at least one mobile phone and use it for more activities than calling and sending SMS. They are used for lighting for an estimated 50 minutes per day, and for 1 hour per day to listen to the radio. Mobile phones are charged from small shops in the community which supply general products, and from barbershops. Currently car batteries, grid electricity and sometimes solar energy are used for charging mobile phones. On average the mobile owners had to spend 3 hours and 22 minutes to get their mobile phone charged. This included the average walking time of 37 minutes to get to the charging place and 2 hours and 45 minutes needed for charging mobiles. About 20% of phone users reported that their phones ran out of battery twice a week and batteries could be flat for 15 hours. Sixty-four percent (64%) reported that there was a high risk of the mobile phone and/or batteries being stolen when charging mobile phones outside of the house.

The average weekly expenses for lighting for households that did not have mobile phone was RWF 392 (approx. USD 0.60)[1] while the households that own a mobile phone paid an average of RWF 680 (approx. USD 1) per week for both lighting and mobile phone charging. The average amount that each household said they would be willing to pay for a product which combined lighting and phone charging functionalities with weekly payments, such as the Indigo unit, varied depending on whether the household owned a phone, and on the types of lighting devices currently used. Thirty-three percent (33%) of households surveyed said they would pay RWF 1,000 (approx. USD 1.50) per week for such a product. Households with at least one mobile phone were willing to pay RWF 762 (USD 1.10) compared to RWF 505 (USD 0.75) for households without a phone. Forty-two percent (42%) of phone owning households were willing to pay RWF 1,000 (USD 1.50) per week. Households which use phones as a source of lighting also showed a high willingness to pay for Indigo or a product like it. Drawing on the findings of the baseline study the weekly fee for the Rwanda market was set at USD 1.20 with a payment period of 21 months.

3. IMPACT RESEARCH

In the original project design it was envisaged that most of the Indigo units would have been installed by the time the impact study was conducted. The goal was to install 10,000 units to create a viable scale of business for the local distributor. To evaluate the impact of the units the team had planned to randomly select a representative sample of Indigo users, and a control group of non-users with similar socio-demographic characteristics. This sampling was expected to take place in the districts where the baseline research was conducted.

Ultimately, the research plan had to be modified. After completion of the baseline, a distributor was ultimately selected whose footprint and access to last mile sales and marketing networks were chiefly in alternative areas to those indicated at the time of the baseline study. Consequently, the sales and marketing activity took place in different areas from those where the baseline was conducted. This was not a major issue as the baseline was designed to be statistically representative of the off-grid population in general.

More challenging was the slow growth in sales and problems encountered by the local distributor. Because of the low pricing necessary for the product to be affordable to the target customers, the margins on the product were thin and the distributor and agents found it difficult to make money. Customers initially were fairly dispersed and therefore expensive to service as agents would have to navigate rural terrain. Consequently, some customers could not access the scratch cards easily and fell "out of credit". In some locations attempts were made to unlock the units through tampering with the security systems in the units. As the business scaled, the distributor struggled to support customers and basic processes

1 The exchange rate used here is that prevailing at the time of the study (USD 1=RWF 670).

such as new customer registrations, customer follow up, and scratch card management broke down. Additional resources were provided by Azuri, and GVEP staff helped rebuild processes and clean up a backlog of data entry and customer queries with funding from the USAID grant. In light of these challenges USAID agreed to extend the project by six months.

At the time of the impact survey in May and June 2015 only 3,306 units had been deployed and there was still much work to be done to improve the local distributor's execution of customer support. Units were being repossessed from customers who had been out of credit for a long period (customers are considered in default if they are more than 28 days with no credit on the system) or who had tampered with the product. Supply of scratch cards to customers was still patchy and an alternative "top up" method where customers could use mobile money to pay was being implemented.

In the circumstances it was clear that random sampling of Indigo users would include many who had periodically been out of credit or had encountered other issues with the product, thus making it difficult to obtain robust data on the full impact of the product. Focusing purely on those customers who were known to have been always in credit would not have provided a representative sample of all Indigo customers. Securing the cooperation of customers, especially those who had experienced frustration with the product, could not be guaranteed. In consequence, it was decided to conduct a qualitative study, using a smaller sample size than originally planned, to provide a picture of what customers were experiencing and how they were using Indigo.

3.1. METHODOLOGY

The impact survey compared customers and non-customers with similar characteristics in areas where a large number of systems had been sold. Indigo users tend to be wealthier than most of the rural population, thus to understand any potential impact the study needed to draw comparisons with households with the same socio-economic profile. In some areas a comparison of the data from the baseline with those from both Indigo users and the control group were made in order to check consistency across all the data available. By end of April 2015, a total of 3,306 Azuri units were registered as sold in the database from the Azuri server. Of these 1,792 units were distributed in two districts, Rulindo and Nyagatare, which corresponded to 54% of all units installed. These districts were selected for sampling.

A sample of 100 Indigo users was randomly selected from customer records. For this treatment group of Indigo users a similar sized control group of non-users was identified during the field work, with enumerators identifying neighbouring households with similar characteristics. The socio-economic indicators used included types of housing (cement floors, tin roofs), phone ownership, the occupation of the head of household, ownership of house, animals and other assets. Each Indigo user was paired with a corresponding non-user making a total of 100 users and 100 non-users. In order to minimize the risk of having non-users that were not exactly matching with the users, 10 additional control households were added, increasing the targeted number of non-users that were to be interviewed to 110.

As anticipated, securing the cooperation of customers proved to be challenging. From the sample of 100 customers, the evaluation team managed to reach 78 users. Among the 22 Indigo users who were not reached 13 had agreed to be interviewed but subsequently refused to pick up calls, or had their phones switched off, or were not at the locations provided. Despite repeated attempts to contact these individuals no response was obtained. Three did not have any contact phone number and no one in the neighbourhood or among the agents knew the listed individuals, 3 were registered within two targeted districts but in reality they were living in other districts and 2 were duplicated on the interview list. In one case the customer declined to be interviewed. To establish a matching group of non-users, 88 control group interviews were conducted.

The survey was carried out using a questionnaire which was essentially a repeat of the baseline but with additional questions for Indigo customers relating to product performance and the quality of after sales support. The questionnaire was field-tested to ensure its usability and confirm the quality of the data gathered. Interviews took place during May and June 2015. For each household socio-demographic data were captured, such as age, gender, income, location, education level and occupation of head of household, household size, and assets owned. This information was useful to create a profile of Indigo customers relative to the rural population at large.

3.2. RESULTS

The impact survey findings reflected shortcomings in the distributor's sales and customer support operations. Fifty-two percent (52%) of the Indigo customers reported that they had been out of credit at least once since acquiring the unit. The main reasons were the unavailability of scratch cards, lack of money, and misunderstandings about the date of credit expiry. Forty-four percent (44%) of Indigo users reported experiencing a "technical" problem while using Indigo. Among those customers that encountered technical problems, 43% said that the light was "not bright enough" while 32% complained about lamps that "cut out". Problems with the battery and the switch were reported by 6 and 4 % respectively.

Further investigation following completion of the survey showed that, in many of the cases, "technical faults" were related to a lack of sufficient charging in cloudy conditions and the associated reduced run-times, which are not actual faults in the equipment, but rather stem from either installation challenges in finding an optimal placement for the solar panel, or due to local microclimates leading to insufficient insolation and thus reduced charging of the battery. This indicated a lack of customer education about the capabilities of the product (such as performance differences in the rainy season) rather than actual technical faults and pointed to a requirement for improving agent training. For those that reported problems to customer support, only a half had seen these resolved. These and other findings proved useful in helping to improve the overall levels of service delivery.

Six types of lighting devices accounted for most of the lighting in both treatment and control households. These include Indigo (treatment group only), torch lamp, mobile phone, candle, DIY lamp and traditional tin lamp (known as "Agatadowa" and powered by kerosene), see Table 2.

Out of 78 households using Indigo 17 (22%) are using Indigo only while 61 (78%) use other devices alongside Indigo. 34 (44%), 8 (10%) and 19 (24%) are combining Indigo respectively with 1, 2 and 3 other lighting devices. For the control group 36 out of 88 (41%) of the households use a single type of lighting while 7 (8%) and 45 (51%) are using 2 or more lamps. The most commonly used devices apart from Indigo were torches, candles and mobile phones. This finding is to a degree consistent with the baseline study which found that households typically owned from 1-4 lighting devices, though DIY lights, tin lamps, and mobile phones were the most commonly used. The widespread use of torches in the control and treatment groups may reflect the relative affluence of these households.

Table 2. Primary sources of lighting for Indigo users and the control group

	USERS OF INDIGO				NON-USERS			
Types of lamp	On its own	With other devices	Total	% of the hhs using each device	On its own	With other devices	Total	% of the hhs using each device
1. Indigo	17	61	78	100				
2. Lamp torch		30	30	38	14	24	38	43
3. Candle		22	22	28	6	16	22	25
4. Mobile		25	25	32	4	24	28	32
5. DIY lamp		3	3	4	5	12	17	19
6.Traditional lamp (kerosene)		**9**	**9**	**12**	**4**	**8**	**12**	**14**
7.Hurricane lamp (kerosene)		**1**	**1**	**1**	**1**	**4**	**5**	**6**
8. Nuru lamp		3	3	4	1	4	5	6
9. Solar lamp		5	5	6	1	1	2	2
10. Rechargeable lamp		3	3	4	5	5	10	11
11. Firewood		1	1	1		1	1	1

The treatment and control groups were asked about purchases of energy sources during the week before the interview. For both treatment and control groups, dry cell batteries, candles and kerosene for lighting were the most frequently purchased items. The percentage of households that did not buy lighting fuel during the week prior to interview was bigger for Indigo - 40% against 28% for the control. This reflects the fact that Indigo is typically topped up monthly (28 day top up precisely), but also suggests that households with Indigo use secondary devices less than the control group. In the Indigo users group, the most bought source of energy was Indigo by topping up, 23 of 78 of respondents (29%) reported that they topped up the system in the week before the interview. Apart from Indigo, dry cell batteries were the most bought source of energy for lighting both for Indigo users and non-users - 27% and 43% of Indigo users and non-users respectively. While Indigo reduces reliance on some sources of lighting previously used, the indications are that these other devices are not fully eliminated. The majority of households using Indigo appear to be spending more on lighting than they did before acquiring the units. The enumerators attempted to collect information on amounts spent per household on lighting but this data proved difficult to obtain and levels of expenditure could not be reliably determined.

"OUT OF 78 HOUSEHOLDS USING INDIGO, 17 (22%) ARE USING INDIGO ONLY, WHILE 61 (78%) USE OTHER DEVICES ALONGSIDE INDIGO."

Those that combine Indigo with other devices had light for 263 minutes per day (181 minutes for Indigo plus 85 minutes for the other lighting devices) on the day prior to interview, that is 4 hours and 23 minutes of lighting, see Table 3. Households which only used Indigo and had no other source of light reported having 182 minutes of lighting (approx. 3 hours) on the day prior to interview. Results for both groups compare favourably with the control group which reported an average of 104 minutes (1 hour 44 minutes) of lighting, and with the baseline study which reported an average of 2 hours of lighting per day for all households.

Table 3. Mean minutes of lighting on the day prior to interview for Indigo users compared to the control group

CATEGORIES OF RESPONDENTS	N	MEAN TIME PER DAY OF INDIGO	MEAN TIME LIGHTING PER DAY OF OTHER DEVICES	THE TOTAL TIME FOR LIGHTING
1. TREATMENT GROUP				
Customers using Indigo only	17	182	0	182
Customers using Indigo as well as other devices	53	181	82	263
Customers who are not using the Indigo lantern but other devices only	8*	0	108	108
2. CONTROL GROUP	88	0	104	104

*The reason Indigo was not used on the day prior to interview is not known for certain but the most likely reason is that they were out of credit.

Survey respondents were asked about different uses of lighting in the household and the amount of time spent on each. "Family gathering" was the activity most commonly mentioned by both users and non-users of Indigo. This was followed by "reading for adults" and "studying for children". Table 4 shows the average time that households use light for these three activities. It also shows the share of Indigo in the lighting time for each activity. These different activities may take place simultaneously, making use of a shared lighting source. The results suggest that in households with Indigo which also use other devices there is significantly more time spent on all three activities, with the largest differences being on adults reading and children studying. The time for education/doing homework for children has almost doubled in the households that are combining Indigo with other lamps (128 minutes) compared with households just using Indigo (69 minutes), and is almost three times the study minutes for households not using Indigo (48 minutes). In the baseline study the average time children spent studying at home was reported to be 71 minutes. The survey asked about the overall amount of time children spent studying. The results suggest that there was an increase in total study time per day. This contradicts the findings of Grimm et al. (2015) mentioned earlier.

Table 4. Lighting time per day used by household for different activities (in minutes)

	TREATMENT GROUP				
ACTIVITIES	Type of lighting device	Customers using Indigo only	Customers using Indigo as well as other devices	Customers who are not using the Indigo lantern but other devices only	CONTROL GROUP
Time for Family gathering per day (lighting minutes)	N	11	53	8	61
	Indigo	93	99		
	Other devices		56	106	
	Total time	93	155	106	90
Time for Reading adult per day (minutes)	N	10	31	6	42
	Indigo	74	85		
	Other devices		80	28	
	Total time	74	165	28	66
Time for Study of children per day (minutes)	N	17	30	5	37
	Indigo	69	67		
	Other devices		61	47	
	Total time		128	47	48

As well as benefitting from more hours of light Indigo users also benefit from being able to charge phones at home, saving money and time, with less worry about phones being damaged or stolen. All households in the Indigo users group had at least one mobile phone while in the control group only 4% did not have one. The number of phones varies from one to four in the treatment group and from one to three in the control group. The study showed that 60% of Indigo users charged their mobile phones at home using Indigo, while 40% combined Indigo

"AS WELL AS BENEFITTING FROM MORE HOURS OF LIGHT, INDIGO USERS ALSO BENEFIT FROM BEING ABLE TO CHARGE PHONES AT HOME, SAVING MONEY AND TIME."

with external phone charging services. Indigo users and non-users that charge phones outside the home spent about the same amount of time, approximately 3 hours, to get their phone charged. This includes the charging time and travel. Both groups also reported paying a similar amount for charging a phone RWF 200 (approx. USD 0.26) a week. So a household with two phones and Indigo which charges those phones at home saves around RWF 400 (USD 0.52) a week on charging fees.

Households with Indigo use their phone as a lighting device more often than the control group, presumably because charging is easy and free. However, being able to charge phones at home seemed to make no significant difference to the amount of use made of the phone, except for their use as torches. Time spent calling, sending SMS, using mobile money and listening to the radio on the phone were similar for Indigo users and the control group.

Both Indigo users and non-users reported that they have experienced cases of headaches, respiratory problems, ocular problems and/or burns by kerosene in the 6 months before the interview. The number of households that reported that they suffered from these different sicknesses is higher in the group of non-users (66%) than in the users group (42%). Sixty-three percent (63%) of Indigo users against 32% of non-users reported that the quality of air is very good without specifying the reasons. The data suggests that Indigo users experience some health benefits as use of kerosene and candles is reduced.

3.3. SOCIO-ECONOMIC PROFILE OF INDIGO USERS

Based on the socio-economic data collected from the survey, which included age, education, occupation of head of the households, land size, house and other assets ownership, and monetary income of the households, a profile of the households owning Indigo products was created and compared to the national socio-economic classification of the population known as *Ubudehe* categorisation[2]. Households are placed in one of four categories based on their socio-economic status, and their property – in terms of land and other assets – and the occupation of the households' members. The categories and characteristics of Ubudehe have changed over time. The former classification consisted of 6 categories plus one for very rich people. In this classification categories 1 to 4 were considered as poor (extreme poverty, very poor, poor, resourceful poor) while 5 to 6 were considered as food and money rich. The current classification is made of 4 categories as follows:

- **Category 1:** Families who do not own a house and can hardly afford basic needs.
- **Category 2:** Those who have a dwelling of their own or are able to rent one but rarely get full time jobs.
- **Category 3:** Those who have a job and farmers who go beyond subsistence farming to produce a surplus which can be sold. The latter also includes those with small and medium enterprises who can provide employment to dozens of people.
- **Category 4:** Those who own large-scale business, individuals working with international organizations and industries, as well as public servants.

Updated figures for these new categories of *Ubudehe* classification are not yet available: the related national data collection is currently going on countrywide. However, based on the characteristics of new and old categories, the two first categories of the current classification seem to cover the old categories 1-4, while categories 5 and 6 correspond to the new 3rd and 4th categories. The Integrated Household Living Conditions Survey known as EICV4 shows that people considered as poor in 2013/14 were 39.1% and this could be considered as the equivalent of the current categories 1 and 2 of *Ubudehe.*

The households that acquired Indigo have an average size of 6 permanent members which is larger than the national average of household size which is 4.3[3]. Households using Indigo are mainly headed by men (76%) and the average age of the head of households is 47 years. Indigo customers are living on agriculture and earn an estimated monthly monetary income of RWF 36,000 (approx. USD 50). A large part of their income comes from selling plant products (56% of cases) and animal products (53%). Among Indigo customers, 67 households (86%) have some type of animal/livestock while 14% do not. This is much higher than the national situation where households with any type of livestock are estimated to be 32%[4] of the total. This means that Indigo users that own any type of livestock are more than twice the national average.

Almost all Indigo customers are living in their own house. The data shows that Indigo customers (87.2%) have houses covered by an iron sheet while 11.5% of them have houses with a tile roof. This is well above the standard for the average house based on the information provided by the EICV4. This report says that 61.1% and 0.4% of the local population have houses respectively roofed with iron or clay tile[5]. A big difference between the national situation and the Indigo customers has also been found on the type of floor of the house: 62% of Indigo customers have cemented floor while the national average of households with cemented houses in rural area is 21.1%.

Considering the characteristics of *Ubudehe* categories (2014-2015) and the profile of Indigo customers, most Indigo users could be classified under category 3. This is motivated firstly by the fact that 99% of Indigo customers own a house roofed with iron sheet or

2 http://www.gov.rw/news_detail/?tx_ttnews%5Btt_news%5D=1054&cHash=a315a8b0054e76f9c699f05ce24d3eb8 and/or http://loda.gov.rw/single/article/revised-categories-of-ubudehe-officially-launched/

3 NISR (2012), Rwanda population and housing census (2012)

4 NISR (2012), EICV IV: Enquête Intégrale sur les Conditions de Vie des Ménages (Integrated Households Living Conditions Survey)

5 The roof covered by the iron sheet is considered to be more expensive than the ones of local manufactured tiles

tiles, and with a cemented floor. Secondly, the Indigo users produce agricultural surpluses which they can sell. The survey found that 56% and 53% are selling respectively plant and animal products and have an average monthly income of RWF 36,000 (USD 50).

It is clear that Indigo users are not from the poorest sections of the population. This suggests that at least 39.1%[6] of Rwandan households, which are living under the poverty line, are unlikely to be able to afford Indigo. In addition, 24% of Indigo users said a monthly payment which is above RWF 3,000 is a challenge for them (the current fee is RWF 3,500 per month). There were also 32% that reported that they have been out of credit at least once because they were lacking the money to top-up the system. Even at the current low price a significant number of Indigo customers find it difficult to top-up their system because they don't have enough money. This is consistent with the baseline study finding where only 33% of rural households said they could afford RWF 1,000 a week for a product like Indigo.

6 NISR (2012), EICV IV: Enquête Intégrale sur les Conditions de Vie des Ménages (Integrated Households Living Conditions Survey)

This raises significant issues for policy makers who see solar home systems as a potential means to provide basic electricity for all off-grid households. More households could be reached by reducing the top up fee and extending the repayment period, but this would require businesses distributing systems to have access to additional working capital. Over time as the customer base grows scale efficiencies should also help lower costs, and the cost of components such as solar panels is also expected to fall. Even with reduced fees, however, many households will be unable to afford the product. Targeted subsidies for the poorest households might be considered but could be complex to manage and risk undermining the market. Cheaper, more basic products such as solar lanterns might be promoted as an alternative solution for poorer households, many of which do not own phones.

CONCLUSION

The project faced a number of challenges with the payment methods, with the local distributor's capacity, with changing tax regulations, and to a lesser degree with the technical performance of the product. Some of these issues were overcome during the project, while others remain lessons for future projects. Azuri continues to work with the local distributor and expects to complete deployment of the 10,000 units funded by the project around mid-2016.

Households which acquired Indigo reported clear benefits from using the product, though in the majority of cases it did not fully replace other devices, but rather allowed for additional lighting or phone charging. Households that adopted Indigo as their sole source of lighting or in combination with others had respectively 1.75 and 2.5 times more lighting time per day than the control group. This allowed Indigo users to find extra time for family gathering, education of children and reading for adults.

It proved difficult to establish the real amount spent per week by Indigo users and non-users on lighting, but it seems that the Indigo users pay more than the control group of non-users for lighting purposes. This is explained by the fact that many of the households that are using Indigo continue to use and buy other sources of lighting fuel.

Sixty percent of the households which own Indigo products charge all their phones at home and have seen the amount paid per week for charging disappear. This may offset spending on lighting. This leaves 40% of Indigo users that are charging phones out of the house, and spend money and time for charging. Households with Indigo appear to make much more use of phones as torches, perhaps because of the ease of charging them.

Seventy-six percent of Indigo customers said a monthly payment of RWF 3,000 would be convenient for them (slightly less than the current RWF 3,500 per month). Thirty-two percent of customers had been out of credit at least once because they did not have money to pay for the top up.

The Indigo customers can be mainly classified as category 3 of Ubudehe, i.e. the better off households in rural areas. It appears that the poorer sections of the Rwandan population are likely to find it difficult to pay for Indigo. This raises important issues about affordability and access to electricity in rural areas. Costs are likely to fall over time but other solutions, such as solar lanterns, may be a more appropriate option for the poorest households in the short-term. Issues of affordability can only ultimately be addressed through economic growth and increased household incomes.

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ACKNOWLEDGMENTS

This study was made possible by the generous support of the American people through the United States Agency for International Development (USAID). The contents are the responsibility of the authors and do not necessarily reflect the views of USAID or the United States Government.

VILLAGE POWER SCALING RURAL ELECTRIFICATION IN UGANDA

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KEYWORDS

- SOLAR POWER
- RURAL ELECTRIFICATION
- OFF-GRID

This paper discusses Village Power's role in the "Light Lwengo" project in Uganda's Lwengo District. Key learnings from this project focus on the design and implementation of subsidy schemes and the implications of becoming a Pay-As-You-Go (PAYG) provider to increase roll-out speed.

INTRODUCTION

Swiss based Village Power AG (VP) was launched in January 2014 to deliver reliable, affordable and accessible modern energy solutions to rural sub-Saharan Africans. Energy is a fundamental need, and one cannot benefit from other modern improvements to the standard of living without access to electricity. The purpose of each VP kit is to deliver reliable, safe, and affordable electricity to customers.

VP currently has operations in Uganda, Mozambique and Zambia and offers a range of Solar Home Systems (SHS) between 10W - 1,000W. By the end of 2015, VP had deployed over 4,000 SHS in Uganda. VP's SHSs consist of a polycrystalline solar panel, lead acid battery, and a charge controller with GSM device[1], complimented by connection cables and select efficient accessories such as LED light bulbs and mobile phone charging cables.

At its core, VP believes in founding its business upon partnerships that matter to achieve results that count. VP has therefore pursued an approach of partnering with local government entities and community associations that undertake to support the deployment of solar systems to their constituent bases. In a market tainted by poor quality components and unsupported systems, such partnerships with trusted local organisations offer credibility, foster trust in the brand, and offer access to our partners' constituents. In this paper, the set-up, impact, and learnings from one of VP's first projects, "Light Lwengo", is discussed.

The "Light Lwengo" project was launched in May 2014 by Uganda's President, H. E. Yoweri

1 Only installed in Pay-As-You-Go (PAYG) systems.

Museveni. Locally it is supported by the Lwengo District Local Government Chair Person, George Mutabaazi. The project is part of the "Energy and Infrastructure Development Program" for the Lwengo District in Central Uganda. The program aims to develop Lwengo from "peasant" to "middle-class" status by 2025. "Light Lwengo" expands access to electricity through supporting the deployment of SHSs by VP.

Components of a VP SHS
Source: Village Power

1. CONTEXT AND PRESENTATION OF THE PROJECT

1.1. LWENGO DISTRICT

In 2009 (last census) the total population of Lwengo District was 254,362 living in 59,571 households, 70.6% of the population was under 30 (Uganda Bureau of Statistics, 2012). Agriculture was the main source of household income: ~68% of households cited crop farming as their main source of income; ~65% of households identified as subsistence crop farmers (Ibid.). ~20% of the Lwengo population lives on less than USD 1 per day (Lwengo District Local Government, 2015). 56.5% of the local population lived without access to electricity[2] (Uganda Bureau of Statistics, 2012) versus the Uganda-wide number of 85% (World Bank, WDI, 2010). The main source of energy for lighting was kerosene lamps (~44% of households overall, ranging up to ~83% in some areas), followed by electricity (~43.5%), and paraffin (~10%) (Lwengo District Local Government, 2015). The local government estimates an average spend of ~350,000 UGX per household per year on lighting and power[3].

2 Including batteries, generators, mini-grids etc. Based on field observations, however, in towns and in rural areas, conventional electrification rates in Lwengo would be closer to 10%.

Figure 1. Project location - Source: FERDI

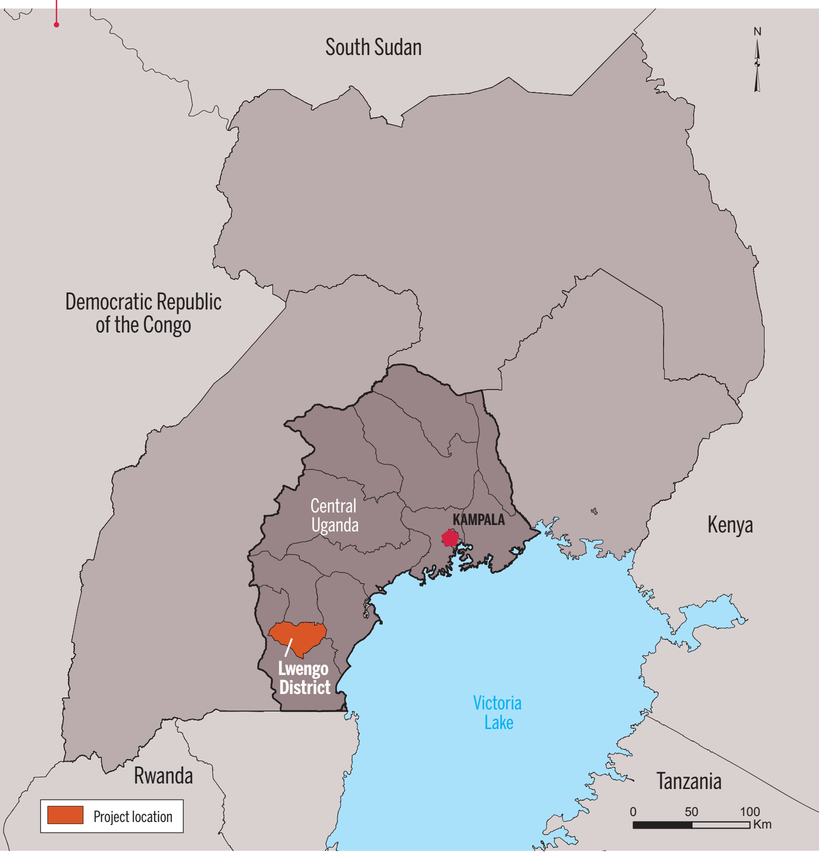


Table 1. Average spending on lighting/power

ITEMS	Monthly Expenditure (UGX)
Fuel for a lamp	20,000
Other	6,000
Transport	3,000
Total	**29,000**

1.2. "LIGHT LWENGO" PROJECT DETAILS

"Light Lwengo" is a project of the Lwengo District Local Government and VP in partnership with Finance Trust Bank (FTB) and the Uganda National Entrepreneurship Development Institute (UNEDI). It was approved by Uganda's Rural Electrification Agency (REA) to qualify for subsidies under the Photovoltaic Target Market Approach (PVTMA), funded by the World Bank Energy for Rural Transformation (ERT II) project[4]. It provides a generous subsidy to pre-qualified companies on the sale of each SHS to qualifying end consumers.

In order to pre-qualify, companies had to offer products meeting the PVTMA guidelines, approved by the Uganda National Bureau of Standards (UNBS), supplied with an instruction manual and backed by a 1-year warranty. Companies also had to show an installation track record.

Subsidy model

The subsidy is based on the size of a system's solar panel : USD 5.50 per Wp for systems with panels up to 50Wp. Only sales to customers who live over 100m from the grid are eligible.

3 Information provided by the Lwengo District Local Government via email on 30/12/15.

4 http://documents.worldbank.org/curated/en/2009/03/10378680/uganda-second-energy-rural-transformation-ert-ii-project.

Under the project, VP sold the K-2 model: 40 Wp solar panel; 20Ah battery; delivered with four 3W LED bulbs and one mobile phone charger. REA undertakes to pay UGX 580,000 of each K-2 system valued at UGX 950,000. The balance of the purchase price to be paid by the customer is UGX 370,000. The project targeted the installation of 3,000 SHSs.

After a company makes a claim for a number of installations, prior to payment of the subsidy, REA undertook to inspect these installations to verify that they were complete and in compliance with the scheme. No timeframe for the completion of such inspections and payment of the subsidy was given.

Customer financing

The provision of financing is crucial to maximising the addressable market for SHSs, even at subsidised prices. Some studies have shown that access to finance can increase the addressable market from ~50% without financing to ~85% (AT Kearney/GOGLA, 2014a). However, since only 25% of the subsidised system sales[5] and 10% of the non-subsidised system sales have been paid upfront, VP believes that the local addressable market without financing is much lower than 50% and the need for financing is high.

The project contract required the establishment of a credit facility for the purchase of SHS through Savings and Credit Cooperatives (SACCOs) or local Financial Institutions (FIs). VP partnered with FTB and established several SACCOs (government regulated[6]) and Village Enterprises (similar to SACCOs in function but unregulated by the government) to provide this financing for customers purchasing systems under the "Light Lwengo" project.

Working through the SACCOs, FTB provides loans with 24.15% interest and requires a down payment of 100,000 UGX. The customer may select a pay-off period of between 3 and 12 months but may pay-off the loan in full in advance if s/he so chooses.

The process to secure a loan at the individual level has multiple steps.

1) Establish a network of borrowing groups

- In the context of customers having very limited to no prior exposure to loans and financial services, a group approach is favourable to introduce an element of social pressure to the service of loans, and to streamline credit approval, administration, and customer contact. Additionally, the borrowing groups effectively serve as guarantors for their members' loans.
- The existing network of "borrowing groups" was tapped into. Existing SACCOs were leveraged. Where local SACCOs did not exist, the establishment of Village Enterprise borrowing groups was encouraged at training sessions.
- Two executives were nominated by each group. Executives were issued a financial card[7] and represent the individuals within the groups and their loans.

2) FTB embarks upon a group approval process

- Information required includes the financial cards of executive members, identification, and fingerprints of members.
- A credit-worthiness assessment of each group based on the residential location, occupations, earnings, etc of their members.

3) If a group is approved, no further assessment at the individual level is required when an individual requests a loan. All group members receive the same loan terms.

Service & logistics

Initially, all logistics (product deliveries, technicians, trainings etc) were coordinated from the head office in Kampala (180 km from Lwengo town) and the closest local VP shop in the neighbouring Sembabule District.

VP coordinates its local sales and services from its Village Power Centres (VPCs). VPCs serve as a place for customers to learn about and purchase VP products, connect with the brand, and access after sales service. There is at least one manager, one dedicated sales person, and one technician based at each VPC. The manager leads the sales efforts and coordinates the installations and maintenance visits to customers' homes in the district. The manager and sales person may travel within the district to do sales events. The technician travels throughout the district doing installations and after sales service. Customers may contact the VPC directly for after sales service but they are also supported by a centralised Village Power helpline. Some stock is held in the VPC.

In June 2015, VP opened the Lwengo VPC in Mbiriizi to coordinate sales and logistics for "Light Lwengo".

Reaching the customers

Many potential customers are not aware of solar and the benefits that a SHS can offer them. They think that solar is unaffordable, or they are wary of solar products. Therefore, a significant effort is required involving several actors to "mobilise" customers towards solar: to inform them about the benefits and quality of SHSs, their functionality, and the financing options available, and to introduce them to the VP brand.

Local authorities and politicians (project partner, the Lwengo District Local Government) provide introductions to village leadership who

"IN A MARKET TAINTED BY POOR QUALITY UNSUPPORTED SYSTEMS, PARTNERSHIPS WITH TRUSTED LOCAL ORGANISATIONS OFFER CREDIBILITY, FOSTER TRUST, AND OFFER ACCESS TO PARTNERS' CONSTITUENTS."

5 Over the period of time where full upfront payment was an option.

6 Uganda Cooperative Savings and Credit Union Ltd (UCSCU) http://www.ucscu.co.ug/data/smenu/36

7 A financial card is required in Uganda in order to apply for loans from a regulated financial institution.

advocate for VP solar, help to coordinate visits to local villages, and drive attendance at "training/ sensitisation" sessions. Where they are engaged, the local political leadership can serve as a face of the project.

SACCOs provide access to members and work with FI partners to get approval for loans. SACCO leadership help encourage and collect regular payments.

VP coordinates sales efforts, delivers "trainings/sensitisations" at a village level to the Lwengo population to educate them about solar products and their accessibility, ensures product delivery, and performs installations. VP also launched an extensive training program with a specialist training organisation. This organisation reported that training sessions were held in 465 villages and 400 borrowing groups were formed.

Financial institution partners provide financing to customers, participate in village "trainings/sensitisations" to explain financing, and manage the collection of loan payments.

2. RESULTS AND IMPACTS

As of December 31st 2015, VP had installed 1,999 SHSs under the "Light Lwengo" project impacting nearly 11,000 people. Out of these 1,999 SHSs, the purchase of 1,241 systems was facilitated by a loan provided by a VP FI partner. VP customers who have secured a SHS through "Light Lwengo" to date are experiencing significant benefits from transitioning from traditional lighting and power sources (e.g., kerosene) to solar.

"CUSTOMERS CAN EXPERIENCE AN INCREASE IN HOUSEHOLD DISPOSABLE INCOME, AS SOON AS THEY PURCHASE A SOLAR HOME SYSTEM, DUE TO DECREASED REGULAR ENERGY COSTS."

INCREASED DISPOSABLE INCOME

Customers can experience an increase in household disposable income as soon as they purchase a SHS due to decreased regular energy costs (and travel costs associated with purchasing fuels). Furthermore, they are insulated from increasing costs of fossil fuels due to currency fluctuations. After the system is paid off, regular

A "LIGHT LWENGO" CUSTOMERS' PATH TO SHS OWNERSHIP

1. A villager in Lwengo hears his local political leader talking about a VP solar training session that will happen in his village next week. He is interested so makes sure that he attends the training session.
2. At the conclusion of the session, he approaches one of the presenters who is the local VP sales manager to ask some questions and say that he wants to buy a system.
3. He is a member of his village SACCO and he starts to save around 8,000 UGX every week to prove his creditworthiness. Every week he gives some money to his SACCO leader and after 12 weeks he saves 100,000 UGX, the full 20% down payment.
4. Once he has saved full down payment, the FI partner informs the villager that he has been approved for a loan for the balance of a solar home system, triggers the disbursal and installation of a SHS.
5. The FI partner invites the villager to a second training which is designed to motivate customers to keep up their regular savings and payments against their loans and to seek feedback on system use and sales process. (The FI considers this an important element of managing customer payments).
6. Every week he pays his instalments to his SACCO leader.
7. After (on average) 9 months he has paid off his system and no longer has any weekly instalments.

"LIGHT LWENGO" VP CUSTOMER SNAPSHOT[8]

- **Approximately 60% of customers are male**
- **The average age is 43** (ranging from 22 to 72)
- **~12% of customers report a monthly income of less than 199,000 UGX (USD 58)[9];** 35% between 200,000 and 499,000 (USD 58.01 and USD 145); 40% between 500,000 and 999,000 (USD 145.01 and USD 290); and 15% between 1,000,000 and 2,000,000 (USD 290.01 and USD 580)
- **70% of VP customers are farmers**
- Prior to switching to solar, VP customers report a median **monthly spend on lighting of UGX 65,000**
- VP customers' **sources of lighting prior to switching to solar include kerosene (~50%),** paraffin (~40%), batteries (~10%), and candles (~10%)

8 "Light Lwengo" customer interviews, December 2014 - January 2015. N=99.

9 Using an exchange rate of USD 0.00029 per UGX

energy costs disappear as customers generate their own energy (energy costs usually constitute between 10% and 25% of the average monthly household income (Lighting Africa, 2010)).

Of course, the choice of what customers do with this extra disposable income is theirs. They may choose to spend more on services such as additional lighting or consumables. However, over time, customers may use this extra disposable income to make significant investments in their family's well being such as sending an additional child to school or making investments in their home or business. In a sample of "Light Lwengo" customers[10], 51% reported saving the savings realised, 27% spent the savings on their childrens' education, 20% reported investing in home improvements, and 1% bought electrical devices. Approximately 30% of this sample group reported that they still used some traditional fuels (kerosene and batteries) after installing solar. In over 80% of these cases, these fuels were used for lighting in latrines.

POTENTIAL TO SUPPLEMENT INCOME FROM NEW REVENUE STREAMS

"Solar became an income, because it reduced the money that was spoilt on buying kerosene... For example we are spending about [UGX] 20,000 per month but now it brings in money, because we can charge phones for our friends who don't have power."

- Village Power customer, Lwengo District

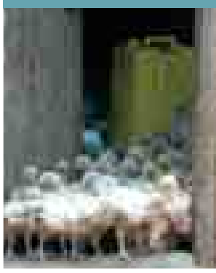
Over 6% of "Light Lwengo" customers either engage in income generating activities opportunistically after purchasing their SHS or factoring such activities into their calculations for paying off a system when deciding to buy a system. However, in other districts up to 20% of VP customers use their SHS to generate some income. With support and encouragement this number could be higher. VP sees the opportunity to provide basic business education and support to customers interested in using their SHS to generate income and therefore to increase the value of the systems to the customers.

10 "Light Lwengo" customer interviews, December 2014 - January 2015. N=99.

"AS COMPANIES WILL DELIVER THE ULTIMATE IMPACT, COMPANIES NEED TO BE INVOLVED IN THE DEVELOPMENT OF SUBSIDY SCHEMES AND IMPLEMENTATION PROCESSES FROM THE START."

Examples of such activities and supplemental income are contained in Table 2.

Table 2. Snapshot of potential revenue generation opportunities[11]

MOBILE PHONE CHARGING	
	**Potential income:** approx. UGX 500 per charge **Investment needed:** None (mobile phone charger suited to many models is included in system's purchase price)
HAIRDRESSING	
	**Potential income:** approx. UGX 1,000 per cut **Investment needed:** DC cutters: approx. UGX 50,000 AC cutters: approx. UGX 100,000 (larger SHS required to support cutters)
CHICKEN RAISING (chicks need light throughout night)	
	**Potential income:** approx. UGX 540,000 per batch (50 chicks)/ 6 weeks (up to UGX 4,500,000 per year) **Investment needed:** UGX 75,000 per batch - chicks & feed (UGX 650,000 per year)

Source: Village Power

ESTABLISHING A CREDIT HISTORY AND BUILDING FINANCIAL LITERACY

For the majority (~65%) of "Light Lwengo" customers, the loan for their SHS is their first foray into the world of commercial borrowing and financial services[12]. Customers have started to build a credit record that they can leverage for further loans.

A number of the borrowing groups established by VP for the "Light Lwengo" project are now being used by other companies such as agricultural providers and construction materials companies to sell seeds, other agricultural goods, water tanks, and corrugated iron roof sheeting.

INCREASED PRODUCTIVE HOURS PER DAY

The children of VP customers can now study in the evenings, without risking their eyesight due to dim, flickering light, and without breathing dangerous fumes. Increased hours available to study is also a selling point for parents as this serves to help level the academic playing field for off-grid children. All Ugandan children sit an exam at the end of primary school that determines their next level of education.

11 Village Power field research and customer interviews.

12 Percent of customers who received a financial card or opened a bank account for the first time.

VP customers can start saving on energy costs in the year they purchase an SHS and benefit from zero regular energy costs after system is paid off

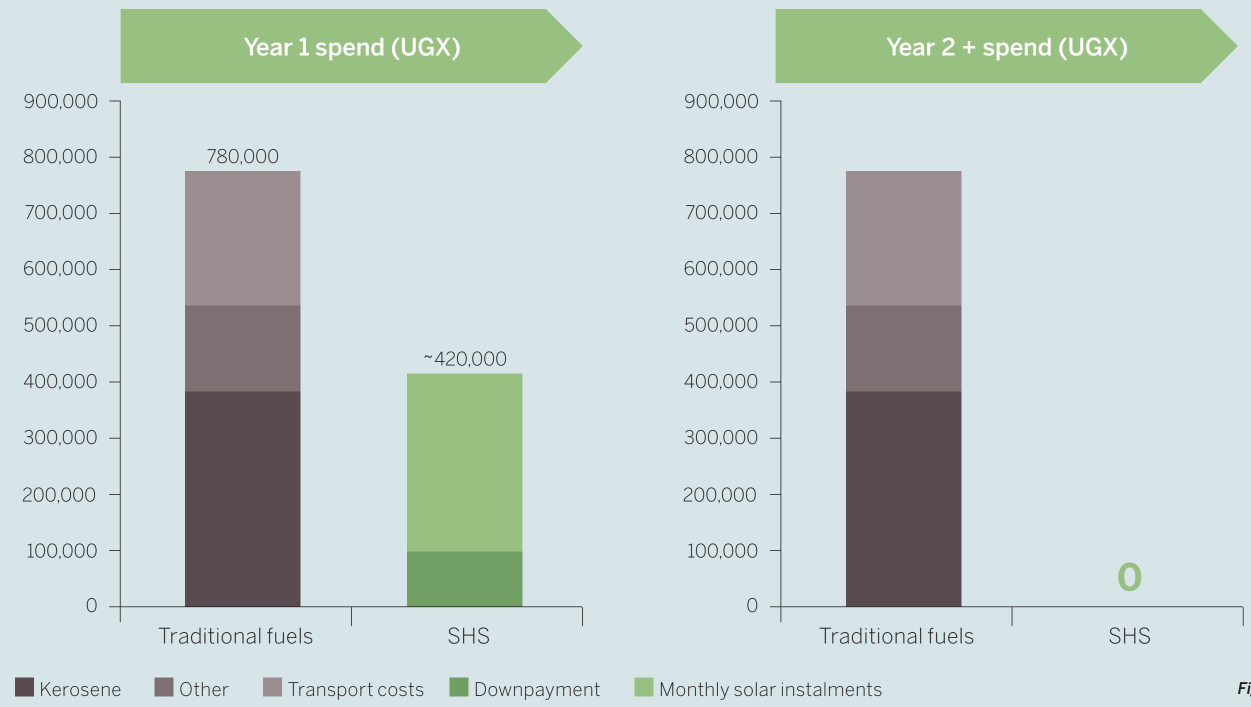


Figure 2

Monthly instalments can be less than average monthly spend on traditional fuels

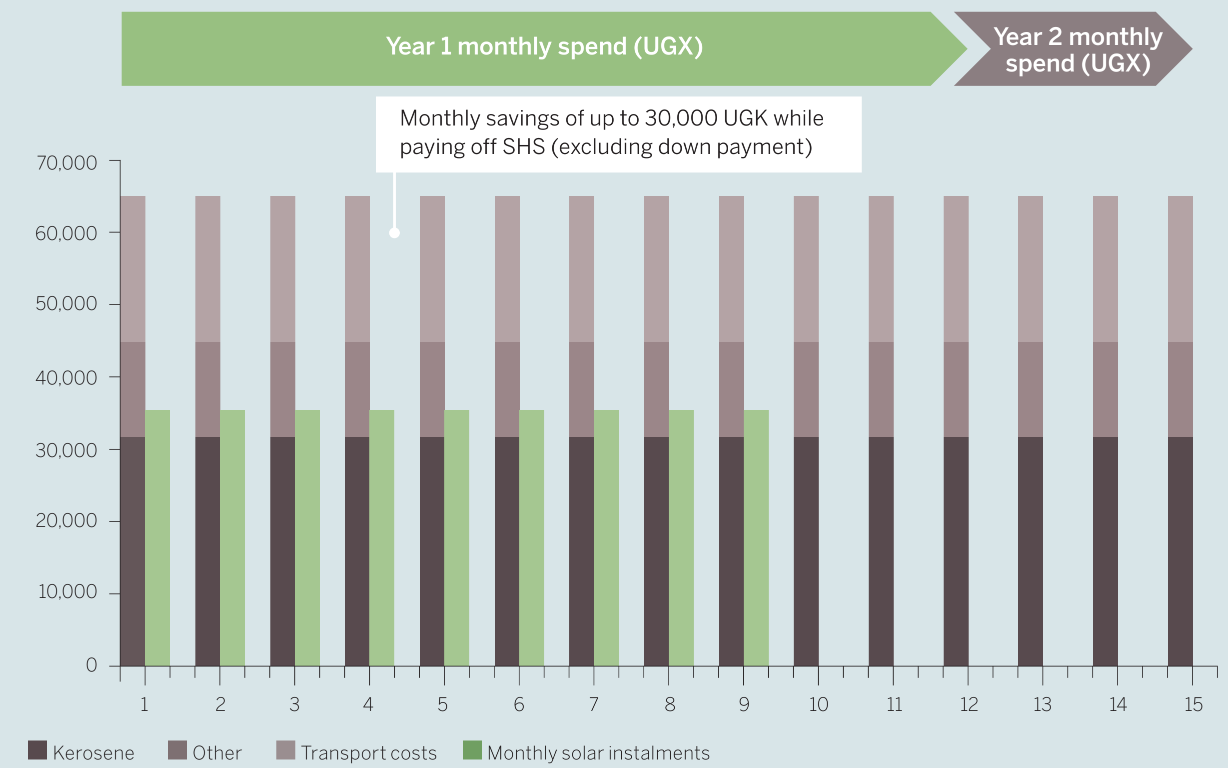


Figure 3

Off-grid children have been competing against on-grid children who have had more hours of light available to them to study on a daily basis[13]. 80% of VP "Light Lwengo" customers report that their children spend more time studying after the installation of their SHS, on average an additional 11 hours per week. Of these, ~80% report "improved grades" as a result of extra study hours[14].

"Students who study under solar lights do the same national exams with those who use candles or those with no access to any lights… and recall their performance is a crucial point towards attaining jobs…"
George Mutabaazi, Lwengo District Governor, as he addressed soccer fans and players at Kajjalubanda play ground (October 21, 2015)

IMPROVED HEALTH

Health impacts of substituting solar for traditional fuels go beyond the avoidance of smoke and toxic fumes. Fearing house fires, customers report not using their mosquito nets near the flames of kerosene lanterns. After switching to solar, customers start using their mosquito nets decreasing the chances of contracting malaria.

"When they gave us mosquito nets we were scared if the small kerosene lamps won't burn our children. So we first kept them. But when we got solar, in all homes, all beds, you find mosquito nets"
Namatovu Gerald Majera, Village Power customer, Lwengo District

3. OBSTACLES

SUBSIDY AS DESIGNED DOES NOT DEVELOP THE MARKET EFFICIENTLY OR ENCOURAGE OPTIMAL PRODUCTS

The subsidy was designed to be a fixed amount over the duration of the project, artificially depressing market prices in the long-term even where the market could bear an increased cost. These depressed prices hurt market development by limiting the attractiveness of the market to companies.

The REA subsidy program was based solely on the size of the panel, not on complete system size or performance. This created an incentive for companies to game the program by focusing on maximizing panel size rather than optimizing total system performance.

THE PROPER FUNCTION OF THE SCHEME RELIES ON THE EFFICACY OF THE ADMINISTRATIVE BODY

Subsidies can foster a liquidity challenge for companies if outstanding subsidies are not paid in a timely and predictable manner. From very early on, the REA program administration has been caught up in internal audits. This has delayed the installation inspection process and therefore subsidy payments to participating companies, ultimately leading to an interruption of project execution.

SPEED OF FINANCING PARTNER DETERMINES ROLLOUT SPEED

Some financial partners are neither focused on nor equipped to deal with base-of-pyramid customers whose applications for a loan for their SHS may be the first interaction they have had with a FI. Loan approval processes are relatively complex and take a long time. For example, the process requires fingerprint scans of customers. The scans may need to be done in a FI branch requiring the customer to travel, potentially long distances, to a branch. The branch finger print scanner was sometimes not available so a long expensive trip to the bank branch might turn out to be fruitless.

Additionally, the use of an external financing partner increases the distance between VP and its customers. It adds to the number of touch points required with the customer (and therefore time) to finalise a sale and requires an efficient interface between the company and the financing partner to share a view on the status of all loan applications and active loans.

LACK OF KNOWLEDGE OF BENEFITS OF SOLAR AND GENERAL MISTRUST OF SOLAR IN MARKET

Whereas there is a general awareness of solar thanks to panels appearing on roofs and an increasing number of stores offering solar components in towns, there is limited knowledge of the benefits and significant long-term cost savings offered by solar. Trainings aimed to directly provide this knowledge.

Additionally, there is a history of poor quality, unsupported product in the market. As a result, some customers mistrust solar, especially considering the size of investment required for a SHS.

CYCLICAL CONFLICT OF INTERESTS WITH POLITICAL LEADERSHIP

A strength of the "Light Lwengo" project was the strong support of the political leadership in the Lwengo District. However, around campaign times some political leaders became distracted by the politics of the elections, and the pressures of re-election resulting in a drop off of support for the project.

Additionaly, such a project may become tied to a political leader associated with the project and hence become politicised. As a result, the opposition may try to undermine the project despite its merits or incite a boycott of the project by supporters. Some customers are hesitant to buy a SHS not wanting to support a project associated with a specific politician that they may oppose.

As a mitigating measure, VP ensures that such contracts are made with local district governments and not with the individuals associated with them. VP also does not make any political endorsements.

4. LESSONS LEARNED

The "Light Lwengo" project has afforded a number of clear learnings both on how to establish such SHS market development initiatives and on refining the VP approach to scaling the business.

13 Village Power Uganda Head of Business Development and Sales.
14 "Light Lwengo" customer interviews, December 2014 - January 2015. N=99.

ESTABLISHMENT AND OPERATION OF SHS MARKET DEVELOPMENT SCHEMES

Government agencies, funders, and the private sector should work together to set up such programs in order to ensure that the perspectives of the businesses are heard and that the processes are pragmatic from a business perspective. This includes input into subsidy design, installation verification process (including information sharing to facilitate the process), and disbursement process.

Furthermore, businesses should have an open communication channel with the ultimate sponsor in order to facilitate feedback on the subsidy program and identify and address any problems early on. Program execution should also be spot checked by the ultimate project sponsor (in this case, the World Bank's ERT II program) in order to ensure effective scaling.

DESIGN OF SUBSIDIES

Subsidies should focus on offsetting costs to scale. To develop a sustainable market, a subsidy should stimulate demand initially by increasing the number of people who can afford to purchase the product and accelerating economies of scale. However, the subsidy should taper over time to the ultimate cost of a product once economies of scale have been achieved so as to not distort the market.

It would be more productive to focus subsidies on overall performance of systems, such as available power output (Watt Hours) and not on one element of the system (e.g., panel sizing). This would not encourage the gaming of subsidies by oversizing panels compared to the overall capacity of the systems.

The subsidy applied to VP in the "Light Lwengo" project was to a single product, the K-2 (see Section 1). Just offering one standard kit does not cater to the full range of customer circumstances and demands (due to varying positions on the energy ladder). VP is now offering its full range on an unsubsidised basis and awaits more insight as to the impact of the subsidy on sales of the broader range.

CONSUMER FINANCING MUST BE READILY AVAILABLE

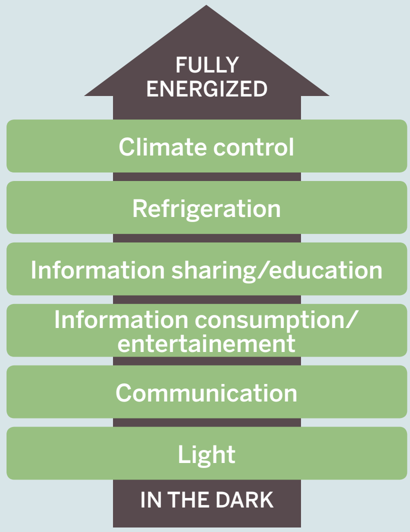
As stated, rollout speed is determined by the speed of the financing partner. In VP's experience, this is not fast enough to facilitate meaningful impact on electrification rates. Therefore, recognising the need to move to directly provide financing to customers, VP has developed its own Pay-As-You-Go (PAYG)/Mobile Money (MM) platform. VP started to offer PAYG on sales of un-subsidised models (outside of the "Light Lwengo" project) to interested customers in Lwengo in August 2015.

In order to qualify as a VP MM customer, a customer must be able to pay a down payment of 20% of the purchase price of their system upfront. Customers have 12 months to pay back the balance of their system cost, with interest, but are encouraged to pay back the loan as soon as they can. If they pay off their system in less than 12 months, they qualify for a discount of the interest saved.

Operating a VP MM platform has the following advantages:

- **Efficient process:** VP already has various contacts with the customer. These encounters can be used to gather all necessary data so no additional visits by or to a FI are necessary.
- **Roll-out speed:** VP does not depend on the account opening and loan approval processes of the FI, which can be quite slow.

The energy ladder and VP offer *



DEVICES USED	VILLAGE POWER SYSTEM
Fan /AC	VP-9+
Fridge	VP-7+
Computer/printer	VP-5+
Television/set-top box	VP-4+
Radio/stereo	VP-2+
Mobile phone charging	VP-1+
Lights	VP-1+

* For more detail on the Village Power product range, please visit the VP website (http://village-power.ch/solar-home-systems/). VP-7, VP-8 & VP-9 scheduled for launch in 2016.

Figure 4

- **The SHSs serve as collateral for the outstanding payment amounts:** VP has a branch and technicians close to customers and can much more easily retrieve a SHS associated with a defaulted loan than can a FI. Additionally, since VP has the ability to refurbish and resell the retrieved systems, the collateral has a much higher value to VP than to a potential financing partner.
- **Transparency:** Since the collection of the outstanding payments is conducted through MM, this process can be highly automated and made very transparent both to VP and to potential re-financers of the outstanding payment portfolio.
- **The ability to switch off the SHS remotely** in case of overdue payments from the client increases the incentive for the client to resume payments and to not fall behind the payment schedule, further reducing default rates.

VP was already dealing with the majority of its customers individually during the sales process through representatives at training and sales events and at the VPC. The immediate impact on District organizational structure is limited as the sales, installation, and after sales service processes remain largely unchanged. Centrally, VP has developed and is growing a dedicated customer service team in order to manage and follow up on customer payments. VP is also tackling the challenge of re-financing growing receivables.

Customers have expressed that they prefer dealing directly with VP. They feel that VP understands their needs better and does not apply punitive penalties for short periods of late payments as they believe banks, via SACCOs, will do.

To the end of December 2015, there were 51 customers on PAYG plans in Lwengo District.

COMPANY FINANCING DEMANDS ARE COMPLEX AND EXPAND BASED ON THE NEED TO OFFER CONSUMER FINANCING

The expansion of a PAYG offer leads to significant re-financing requirements to cover the outstanding loan portfolio. Ideally, this re-financing should be in local currency in order to remove the currency risk. VP is therefore now seeking the development of an appropriate refinancing facility.

The outstanding instalments of the PAYG clients have to be pre-financed (a portfolio of many micro-loans of around 100-1,000 USD). There is potential for debt investors or a working capital facility.

There are a number of attractive features of the VP MM loan portfolio for investors that are interested in new types of opportunities:

- Outstanding instalments are managed through the VP MM dashboard that provides full access to and transparency of the loan portfolio to the financing provider.
- The loan portfolio does not contain clustered risks.
- The SHSs serve as collateral and VP can offer a buy-back guarantee at pre-defined prices.

However, local FIs are often not willing to lend to solar companies. Even if funding is available, the interest rates are far too high and the credit assessment process is long and inflexible. Additionally, if loans are not in local currency, the solar companies need to absorb the currency risk.

There is an opportunity for governments and development institutions to create significant impact in increasing solar company access to financing, critically in local currency, and further develop the local "solar ecosystem" through two options:

1. **Lend directly to approved solar companies** by pre-approving select solar companies operating in a market, issuing repayable loans to approved solar companies, assessing performance against agreed targets, and then extending or terminating the credit facility based on progress to targets.
2. **Providing first loss guarantees** (in USD or UGX) to local Ugandan FIs combined with guidelines on how, and to whom, FIs can lend under the first loss scheme. This would be done by pre-approving select local FIs and defining the rules of the game, selecting local FIs lending to solar companies, assessing performance against agreed targets, and then extending or terminating the credit facility based on progress to targets. Various financers and FIs have expressed interest in such first loss guarantees. Solar PAYG default rates are not rigorously quantified: anecdotally they range from 2-4%. A 10% first loss guarantee would address the uncertainty surrounding default rates until sufficient data is available to accurately quantify the industry default rate.
   A first loss guarantee also offsets the risk associated with a FI needing to call in, and liquidate, systems as collateral on a failed solar company. Indeed AT Kearney and GOGLA also support the innovation of a revolving working capital fund with a first-loss tranche to encourage debt investment in the sector (AT Kearney/GOGLA, 2014b).

BUILD CONFIDENCE IN SOLAR PRODUCTS AND COMPANIES

To boost consumers' confidence in solar, and address the poor perception of solar due to early experience with poor quality unsupported products, there is a need for independent local certification of products by a familiar, trusted entity. This could be a local standards agency, such as the Uganda National Bureau of Standards, supplementing the work of IFC's Lighting Global standards and certification program[15].

Co-branding with a trusted local organisation has had a positive impact on confidence in VP products. VP has another agreement for the deployment of SHS in the Buganda Kingdom (the largest traditional Kingdom in Uganda). There, VP features the seal of the Buganda Kingdom on the products. In localities where this branding is featured on the systems and where the local Buganda Kingdom leadership are engaged with promoting solar, this provides surety to customers on product quality. It facilitates the sales pitches and drives a marked uptick in sales.

As PAYG grows and requires more credit, trust in companies and the market becomes increasingly important. Product quality is a key success factor in the success of a solar PAYG company and indeed the sector. Good product quality ensures minimal post-sales customer service costs and is seen as necessary by financers in order to keep a business as a going concern. It also lays the foundation with customers for a trusted brand in the market. Each stakeholder (from financers through to customers) is not able to independently certify products therefore centralized certification would be useful for the sector.

As such, both the public and private sectors, including potential financers, are interested in ensuring quality through product standards and company certification to foster trust in the sector and therefore growth. The Uganda Energy Credit Capitalisation Company (UECCC) is, at present, looking to certify solar companies so that those companies can benefit from certain solar funds.

15 https://www.lightingglobal.org/products/?view=grid

ESTABLISH A BRAND THROUGH LOCAL PRESENCE

VP has made the decision to control the brand and has therefore invested in developing a direct local sales and service network. Developing and maintaining a local presence is crucial to convince customers of the legitimacy of the solar offer, the company, and access to after-sales service that will ensure that their investment performs as expected. This presence is built upon the VPCs.

STRONG POLITICAL LEADERSHIP AND SUPPORT REQUIRED

People living in rural areas usually do not have access to much information about new products and services on offer. They do not have the opportunity to compare prices, assess the offer, or determine the reliability of the product or service. They are therefore very reliant on word of mouth and that usually starts with local leaders. These are individuals from different sectors that have the respect and trust of the community. If they buy into a product, they lend credibility to the offer and can attest to its benefits.

In the "Light Lwengo" project, these leaders were the political leadership who were bought into the project from the outset. Their advocacy for solar was important to initiate and sustain sales.

CONCLUSION

The "Light Lwengo" project has been a positive experience of working closely with local government to gain access to and develop a local market. It has also been a tremendous learning experience.

Subsidy schemes have the potential to develop sustainable SHS markets. Where there is ability to pay in the market, subsidies should focus on facilitating and accelerating companies' progress to achieving economies of scale and therefore taper off over time. SHS subsidies should also incentivise efficient overall system performance matched to customers' needs. ***Since it is companies that will deliver the ultimate impact, such companies need to be involved in the development of subsidy schemes and the implementation processes from the outset.***

There is an appetite in Lwengo for VP's unsubsidised (larger) models indicating a level of maturity in the market. Since launching the unsubsidised models in Lwengo in August, the monthly sales of unsubsidised models have been growing as a portion of total units sold reaching 56% in December. In 2016, VP is looking to scale Lwengo sales significantly and is targeting the majority of sales to come from unsubsidised models. VP will also focus on making sales via Village Power Mobile Money to expedite the sales process and scale rapidly. Associated with expanding the PAYG business and the closer relationships with customers afforded by this channel, VP will also be refining and expanding its data collection to better understand impact and target business decisions.

As companies such as Village Power move to PAYG in order to grow and better serve their customers, there is an increasing need to help develop financing products tailored to solar companies in local currency to ensure companies' ability to grow and satisfy the increased financing demands.

Other key success factors that VP sees for expansion are as follows:

Build the on-the-ground sales organisation *based in the Lwengo Village Power Centre in order to be close to customers not only in the sales process but also in offering and coordinating after sales service. This proximity and availability is one way in which VP will be building customers' confidence in VP products and the brand. After many customers' initial experience of poor quality unsupported solar goods in the market, significant and ongoing efforts are required to build confidence in solar and in a company and brand in the market.*

Maintain strong but unbiased relationships with the local political leadership. *This will be especially important this year considering the 2016 elections held in February.*

Sales of unsubsidised models as percentage of total units sold

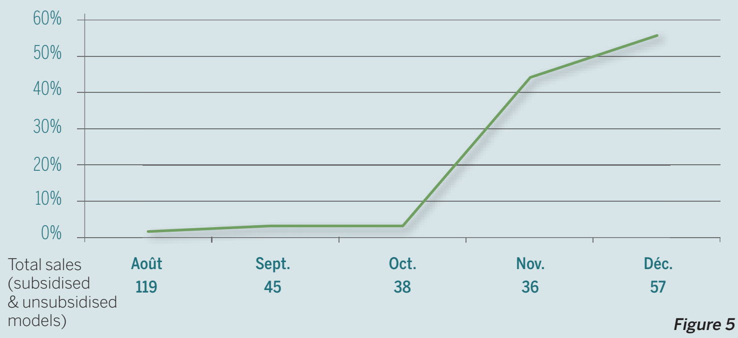


Figure 5

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SOLAR MICROCREDIT,
or how to facilitate access to electricity in rural areas: an example in Burkina Faso

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Example of activity that may be developed: charging of mobile phones
Source: Fondem

With a Master's degree in Economics and Energy Rights, Sarah Holt started her professional career at the ADEME, French environment and energy management agency, and then went on to work in Senegal, particularly with the German technical cooperation, on renewable energies and rural electrification. She is currently Secretary General of the Fondation Energies pour le Monde, a French NGO which has been working since 1990 on projects for access to electricity through renewable energies in several countries of sub-Saharan Africa.

KEYWORDS

- MICROCREDIT
- SOLAR KIT
- ELECTRICITY
- BURKINA FASO
- DEVELOPMENT

This article presents the "Solar Microcredit in Burkina Faso" program of the Fondation Energies pour le Monde (Fondem) which enables electrification by solar kits through microfinance. This innovative program relies on pairing subsidies, covering 40 to 50 % of the investment, and microcredit. It helps satisfy local demand by overcoming the barrier posed by the limited payment capabilities of rural and peri-urban customers.

INTRODUCTION

Burkina Faso is a country whose population is 71% rural (World Development Indicators, 2014). Burkina Faso is strongly dependent on its agriculture. Over 80% of the active population live off farming and cattle raising and contribute 34% to the country's GDP (Ibid.).

Access to basic social services such as health, education, water or energy, is poor. In 2013, with 14 million people without electricity, Burkina Faso posted an electrification rate of 17% (World Energy Outlook, 2015). The situation was even more alarming in rural areas, with a 1% electrification rate (Ibid.).

The Fondation Energies pour le Monde (Fondem) has been working in Burkina Faso since 1995, through:

- *electrification of individual venues (schools, health centers),*
- *electrification of village in pilot projects,*
- *dissemination of solar kits through microcredit.*

In the early 2000s, Fondem was approached by resellers of solar kits, themselves approached by rural populations wishing to access of electrical services via a kit, but lacking the means to pay cash for the equipment.

Fondem then set up an innovative scheme, named "Energy Credit", based on the credit sale of photovoltaic systems with a subsidy covering 40 to 50 % of the investment amount. Involving technical (supplier and local installer) and financial partners (local microfinance institution), this scheme can satisfy local demand by overcoming the barrier of the limited payment possibilities of rural and peri-urban customers. The method helped disseminate a little over 300 complete photovoltaic kits in the 14-65 Wp range between 2003 and 2010, reaching out to *approximately 4,000 beneficiaries. Despite a modest start in terms of quantitative results, this first step served to determine an operating scheme and the associated business model, which needed to be analyzed in depth in order to enable kit distribution on a larger scale.*

1. PRESENTATION OF THE PROGRAM

In the face of this scheme's promising results in Kourittenga province in east Burkina Faso, in mid-2011 Fondem launched a 5-year solar microcredit program (MICRESOL) in Burkina Faso, whose aim is to adapt and extend the "solar microcredit" scheme to the entire Est region of Burkina Faso, in order to:

- distribute up to 1,000 solar kits and reach approximately 15,000 beneficiaries by the end of the program in mid-2016,
- make the business model sustainable and replicable.

The operating partner of the MICRESOL program is the Réseau de Caisses Populaires de Burkina Faso (RCPB), the country's first microfinance institution (MFI).

The financial partners of the program are:

- the European Union, in the framework of the Energy Facility II of the 10th European Development Fund (EDF),
- the French Ministry of Ecology, Sustainable Development and Energy (MEDDE),
- the French Environment and Energy Management Agency (ADEME),
- the Credit Coopératif (cooperative bank), through its partnership with Fondem around Agir products, which serve to receive additional donations intended for field programs,
- the Fondation Énergies pour le Monde (Fondem),
- the Réseau des Caisses Populaires du Burkina (RCPB).

The overall cost of the program is EUR 1.9M over 5 years. The area of operation concerns the east part of Burkina Faso. The program is still ongoing. It will end in mid-2016.

The solar microcredit combines two mechanisms without which the equipment would be outside the financial reach of the targeted clientele (rural and peri-urban):

- a subsidy component used to bear the cost of the equipment. This component concerns the photovoltaic modules, batteries, regulators, inverters and converters. It is covered by Fondem through the program's various co-financing schemes, based on an international call for tender for the provision. The amount of the subsidy has been set following a survey conducted by RCPB revealing the capabilities for payment through microcredit of the targeted rural populations,
- a microcredit component serving to spread the remaining financial effort of the kit buyers. This component relates to the provision of electrical equipment and the installation-maintenance service. It is therefore borne by the final customer through a microcredit granted by the local partner of the RCPB.

1.1. ORGANIZATIONAL DIAGRAM

Fondem is in charge of general program coordination, management of the business model, relations with the main financial backers, and the operation of the subsidy component serving to disseminate quality equipment at locally affordable microcredit conditions.

The RCPB manages the development and implementation of financial terms favorable to proper product dissemination, the implementation of a training and support program for its credit agents, the monitoring of microcredit applications made and granted, as well as visibility and communication actions aimed at commercial promotion of the product.

The following organizational schema was retained for MICRESOL:

- on one hand, a provision agreement between Fondem and the supplier K&K International, for the subsidized part, which concerns the provision of solar kits: photovoltaic modules, batteries, regulators, inverters, step-down regulators, lamps,
- on the other hand, a service contract between the Délégation des Caisses Populaires de l'Est (DCPE) – the RCPB's regional branch – and BETA, a proximity structure, for the part covered by the consumer through the solar microcredit granted by DCPE, which concerns:
  - The provision of the small equipment (battery boxes, module supports, wiring and interior installation),
  - the solar kit installation service,
  - the kit maintenance (preventive and curative) service for the duration of the microcredit.

Provision agreement

Following an international call for tender applying European Commission procurement rules, a framework agreement for the provision of photovoltaic components for autonomous electrification systems (individual solar kits), was signed between Fondem and Burkina Faso supplier K&K International, based in Ouagadougou.

The aim of the framework agreement was to define the terms and conditions for the provision of photovoltaic components for autonomous electrification systems, with a view to several subsequent contracts. The contract states no contractual amount but it indicates a maximum overall financial volume for all subsequent contracts to the framework agreement, in accordance with the European budget.

Following the signature of the framework agreement, several subsequent contracts were signed between Fondem and K&K International for the provision, in Ouagadougou, at the warehouse of K&K International, of photovoltaic components.

Service contract

Knowing that DCPE has no technical expertise in terms of individual photovoltaic solar systems, Fondem placed itself as technical advisor to DCPE for the preparation of this DCPE/BETA service provision contract.

BETA is a network of technicians-installers based in Koupela, in the heart of the area of operation.

This contract describes in specifically:

- the human and logistical means supplied by BETA to conduct its activities in the framework of MICRESOL,
- the technical and financial content of BETA's services, for the provision of electrical equipment and for the installation-maintenance service,
- the terms of payment by DCPE to BETA for the provision of the contracted services.

This contract was finalized once the supplier had been selected (in order to complete some parts concerning the interactions between the supplier and BETA, in charge of the provision of small electrical equipment for the assembly of the photovoltaic components, and of kit installation) and signed immediately afterwards, in September 2013.

WHY CHOOSE BETA?

Under the "Energy Credit" scheme implemented by Fondem, BETA, was selected as the structure in charge of kit installation and maintenance for the duration of the credits.

BETA is a relatively small structure governed by Burkinabe private law, based in Koupela, administrative seat of Kourittenga province. Its geographical proximity to the installation sites is an asset to ensure a high service quality while reducing transportation costs.

Its CEO, Boureima Kabre, is perfectly familiar with the area of operation's economic and sociological background and has a considerable experience in development. Indeed, for many years he was the coordinator of various projects in the fields of health, education and rural economic development.

BETA operates within a social entrepreneurship scheme, in the sense that it tries to reconcile economic viability and collective interest and/or social purpose.

Between 2008 and 2011, under the "Energy Credit" scheme, the work of BETA's local and proximity team made it possible to a cut back costs and delays between the granting of a microcredit and kit installation, and provided a regular and quality maintenance service. Moreover, his good interaction with the Caisses Populaires, already partnering this operation, had helped attain that past program's goals – both quantitative and qualitative.

Under MICRESOL, feedback concerning BETA being positive and since very few Burkinabe structures involved in individual photovoltaic solar systems professionally are based in the Est region, Fondem and the local operating partners chose to continue to work with BETA.

Fondem MICRESOL organizational diagram

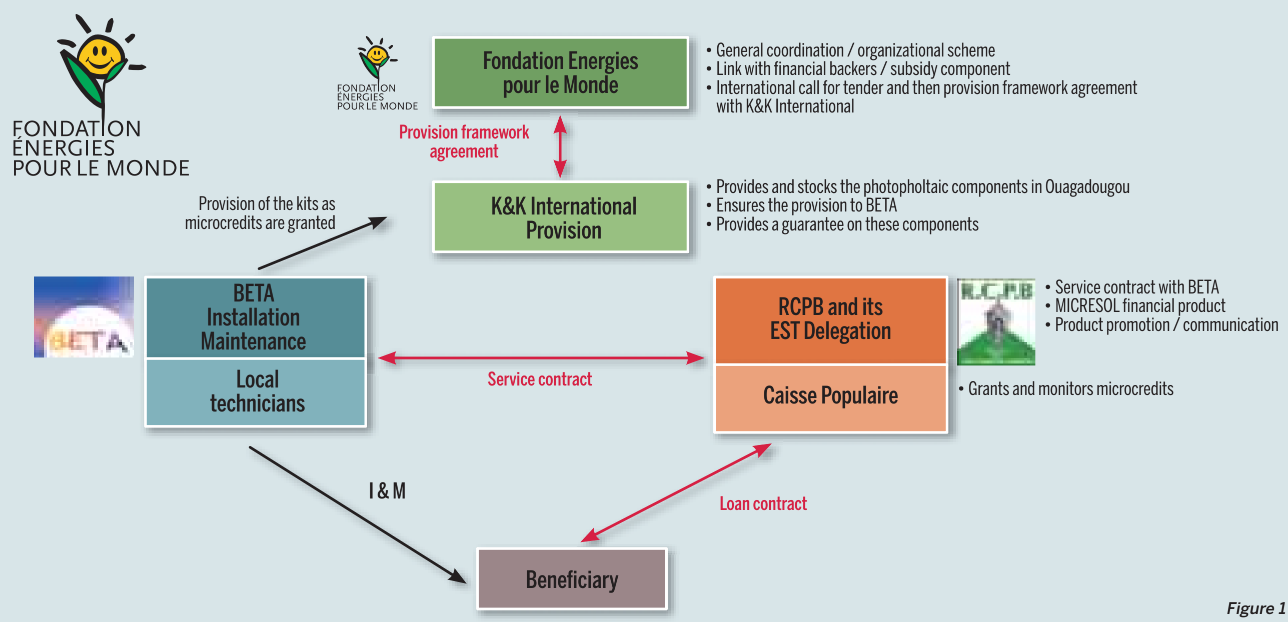


Figure 1

This diagram was chosen for the following key reasons:

- it complies with the framework agreement set by the main financial backer (the European Commission), for whom the only contractual contact is Fondem:
  - RCPB and DCPE being Fondem's partners,
  - K&K International being a contractor of Fondem for the provision of photovoltaic equipment, covered by the subsidy,
  - and BETA being DCPE's partner for the installation-maintenance service, which is a commercial operation (without subsidy);
- it separates contractual relations and thus clarifies/simplifies interactions between the program's various stakeholders;
- it enables setting up a warranty on the equipment, provided contractually by K&K International, which replaces faulty components that are the responsibility of the original suppliers (manufacturers).

The very reasons for this choice entail some restrictions / disadvantages:

- The supplier, K&K International and the installer, BETA, although working very closely (since, as the solar microcredit applications are made, BETA will procure from K&K International in Ouagadougou the photovoltaic components needed to create the kits), have no contractual relationship, which may create difficulties or delays in the smooth running of activities,
- DCPE has no contractual relationship with the supplier K&K International, so it may experience difficulties to manage possible delays in solar equipment procurement,
- Fondem has no contractual relationship with the installer BETA, and has therefore few means of applying direct pressure should installations not be strictly up to standard.

Furthermore, the fact that the supply of the equipment (photovoltaic components) is entirely governed by the procurement rules of the European Union (and in particular, the rules concerning equipment origin and contract award) has a direct impact on the cost of the equipment, making it necessarily higher.

1.2. MICRESOL TECHNICAL PRODUCT: A RANGE OF 4 SOLAR KITS

The program seeks to offer electrical equipment likely to meet the demands of:

- households, for domestic purposes: lighting, radio, TV, charging mobile phones, ventilation, refrigeration,
- micro-entrepreneurs, for economic uses: shops, hairdressing shops, dressmaking shops, video rental stores, sale of fresh products, etc.,
- social infrastructures: schools, colleges, health centers, community buildings.

In order to develop the range of photovoltaic kits to offer, a local market survey served to:

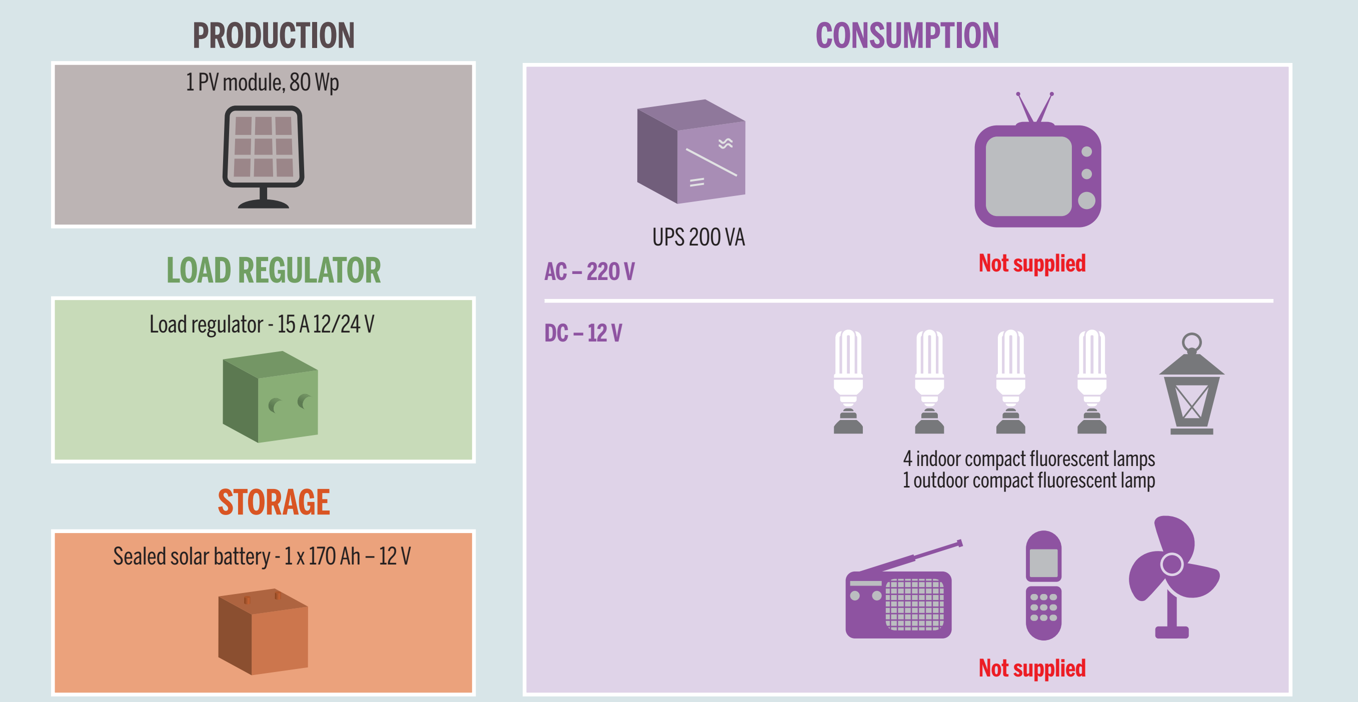
- provide feedback about the domestic and economic applications developed under the "Energy Credit" scheme,
- assess the type of photovoltaic equipment available in local markets,
- analyze the new domestic applications requested by the households in the east area (e.g. ventilation),
- identify new economic activities, presenting a good potential for development through the use of a photovoltaic kit.

"IT SEPARATES CONTRACTUAL RELATIONS AND THUS CLARIFIES/ SIMPLIFIES INTERACTIONS BETWEEN THE PROGRAM'S VARIOUS STAKEHOLDERS."

A range of 4 kits was selected:

- **an 8 Wp "mini-kit",** supplied with 3 portable LED lamps and a cigar lighter socket to recharge mobile phones. This kit was designed without external battery, but rather with built-in accumulators, thus reducing its cost of acquisition by potential customers. This makes it possible to reach out to part of the population with little capacity to pay.
- **an 80 Wp kit (Figure 2),** capable of supplying 5 low consumption lamps and various electrical appliances running on direct current or alternating current (by supplying an UPS). This kit can be used not only for domestic purposes (lighting, charging mobile phone, radio and TV), but also for economic uses (mobile phone charging center, hairdressing shop, dressmaking shops, etc.) or social purposes.
- **an 160 Wp kit (Figure 3),** capable of supplying 5 low consumption lamps and various electrical appliances running on direct current or alternating current (by supplying an UPS). This kit is designed for the development of video rental stores, but can be used to develop other economic activities, for domestic life by an affluent household, or by a community social infrastructure.
- **an 320 Wp kit (Figure 4),** capable of supplying 5 low consumption lamps and various electrical appliances running on direct current, and in particular, a refrigerator, supplied with the kit. It allows the development of activities related to the sale of fresh products or infrastructure services such as health centers (particularly for vaccine conservation).

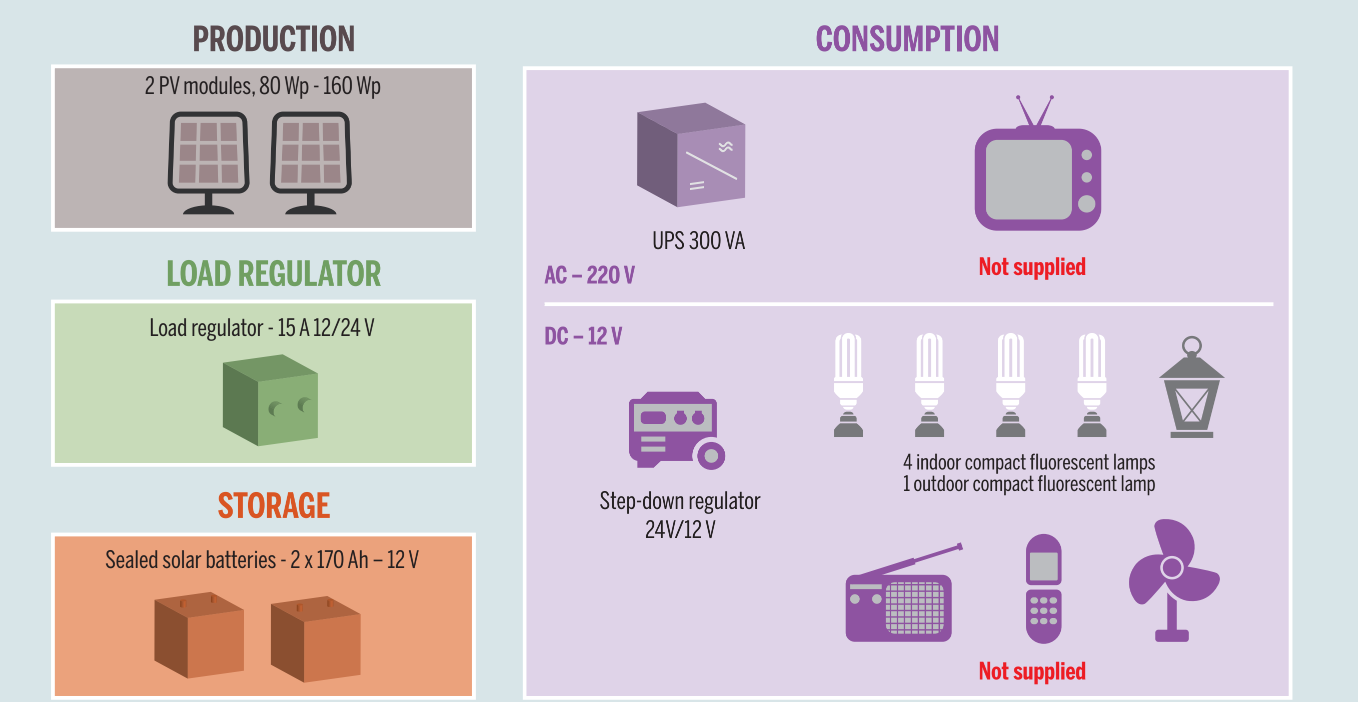
Illustration diagram of components of Kit 2 - 80 Wp



Source: Fondem

Figure 2

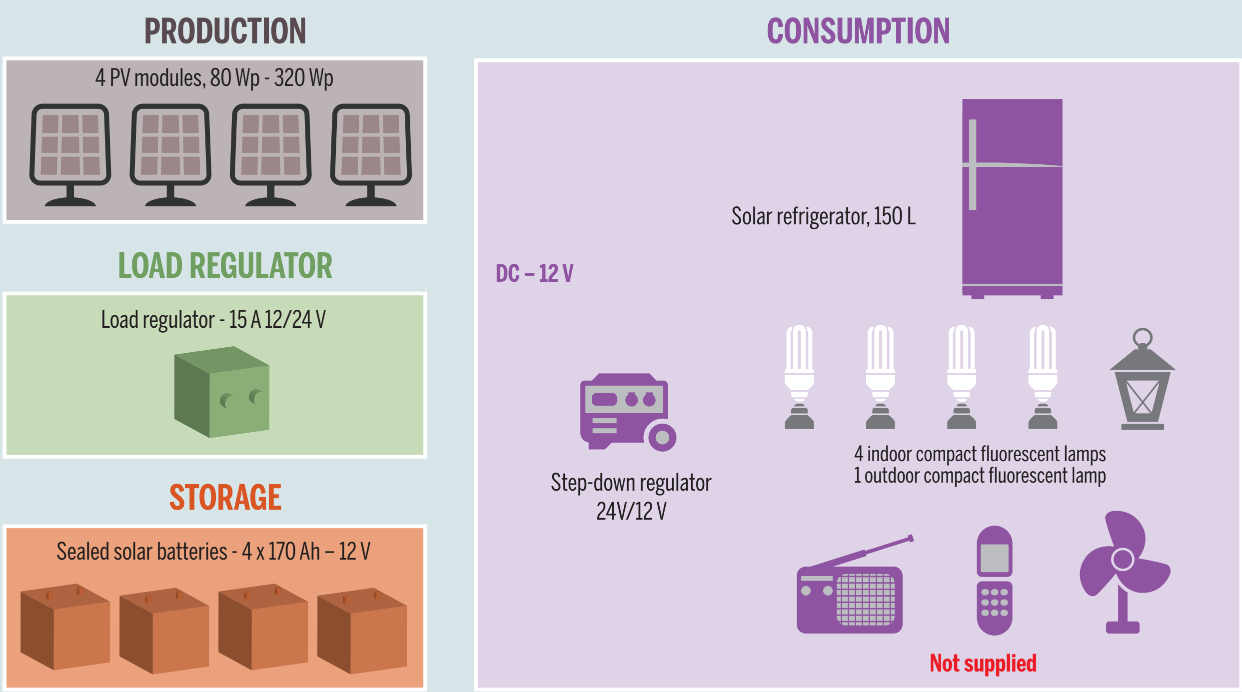
Illustration diagram of components of Kit 3 - 160 Wp



Source: Fondem

Figure 3

Illustration diagram of components of Kit 4 - 320 Wp with refrigeration



Source: Fondem

Figure 4

All components of the 4 kits of the MICRESOL range have been designed to be as standardized as possible, in order to be simply able to multiply them depending on the kit requested, since the pace at which the customers would decide to buy solar kits, the final number of kits subscribed to, and the distribution between the various kits of the range were unknown parameters.

To limit the risk (both in organizational and financial terms), it was considered unreasonable to sign a single provision contract at the start of the program. That is why Fondem chose to sign a framework agreement and then place successive orders in line with the dissemination of the kits in the field.

However, this option has some disadvantages: more administrative work due to placing several orders instead of a single one, and to the difficulties of setting up the supplier's terms of payment.

1.3. FINANCIAL PRODUCT: CONDITIONS FOR GRANTING A MICROCREDIT FOR THE ACQUISITION OF EACH KIT

The financial product indicates, for each kit of the MICRESOL range, the associated microcredit banking conditions:
- the total amount of the microcredit,
- the microcredit duration (12 to 36 months, depending on the kit it concerns and the microcredit amount),
- the interest rate,
- the amount required by the Caisse Populaire on opening the microcredit: application fee, credit insurance scheme, management fees, compulsory savings,
- the amount of the monthly installments payable by the client.

The financial product was finalized in October 2013 for the product launch at the end of 2013. It was subsequently revised to take account of the change in demand and promote faster kits sales.

"ALL COMPONENTS OF THE 4 KITS OF THE MICRESOL RANGE HAVE BEEN DESIGNED TO BE AS STANDARDIZED AS POSSIBLE, IN ORDER TO BE SIMPLY ABLE TO MULTIPLY THEM DEPENDING ON THE KIT REQUESTED."

The financial product currently in force is the following:

Table 1. MICRESOL financial product in Euros

MICRESOL financial product	Kit 1 8 Wp	Kit 2 80 Wp	Kit 3 160 Wp	Kit 4 320 Wp
Share Fondem - K&K International - Financial backers subsidy component				
Photovoltaic components: solar module(s), battery(ies), load regulator(s), possibly UPS	65%	60%	55%	45%
Share DCPE - BETA - Beneficiary microcredit component				
Supply of small equipment: module support, regulator/UPS support, battery box, wiring, small equipment (sockets, connectors, switches etc.) + solar refrigerator for Kit 4	€ 18.50	€ 180.00	€ 280.00	€ 1,870.00
Transport Ouagadougou to Koupela and then Koupela to installation site	€ 7.50	€ 30.00	€ 80.00	€ 110.00
Storage(intermediate) at Koupela	€ 4.00	€ 15.00	€ 35.00	€ 45.00
Installation	€ 0.00	€ 105.00	€ 135.00	€ 225.00
Maintenance during the microcredit refund period	€ 0.00	€ 70.00	€ 120.00	€ 250.00
TOTAL PRICE PER KIT TARGETED BY THE MICROCREDIT	€ 30.00	€ 400.00	€ 650.00	€ 2,500.00
Amount of monthly installments (for 3 years)	€ 1.00	€ 14.00	€ 20.00	€ 84.00

Source: Fondem-RCPB

The entire cost of the installation-maintenance services carried out by BETA is included in the amount of microcredit granted, and thus to the customer load.

2. IMPLEMENTATION OF THE PROGRAM

2.1. PRODUCT MARKETING AREA AND NETWORK OF TECHNICIANS-INSTALLERS

The DCPE savings bank participating in the dissemination of the MICRESOL product have been identified with the double goal of:

- disseminating the product in an area to achieve the long term quantitative target of 1,000 kits installed by mid-2016, meeting rural and peri-urban demand in the east regions,
- allow DCPE staff to adopt the solar microcredit product little by little, in particular through various training series.

Initially, 11 branches (savings banks) located in 4 areas of operation were selected. In addition to the initial 11, it was thought that new branches could be involved in MICRESOL over the course of the following years to follow changes in the demand of the potential customers.

Based on these 11 DCPE branches selected to disseminate the solar microcredit, the network of BETA technicians in charge of the associated installation/maintenance was defined. BETA set up the following team of technicians:

- 2 technicians based in Koupela, covering the areas of Koupela and Boulsa,
- 2 technicians based in Tenkodogo and Garango, covering in pairs the entire Tenkodogo area (up to Zabré),
- 1 technician based in Fada N'Gourma, covering the area of Fada.

In terms of geographic positioning, BETA first undertook to cover the following areas:

- a 50 km installation/maintenance area around the 4 main branches (Koupela, Boulsa, Tenkodogo and Fada N'Gourma),
- a 20 km installation/maintenance area around the branches slightly more distant and not covered in the previous areas (Mogtedo and Zabré).

In early 2014, the marketing area of the MICRESOL product was extended to covering the entire DCPE catchment area (i.e. 26 branches and points of sale), thus covering the south-east quarter of the country.

With the expansion of the area of operation, and the integration of all the DCPE agencies, even with no new recruitment, BETA deployed to cover DCPE's entire area of influence.

"WITH THE EXPANSION OF THE AREA OF OPERATION, AND THE INTEGRATION OF ALL THE DCPE AGENCIES, EVEN WITH NO NEW RECRUITMENT, BETA DEPLOYED TO COVER DCPE'S ENTIRE AREA OF INFLUENCE."

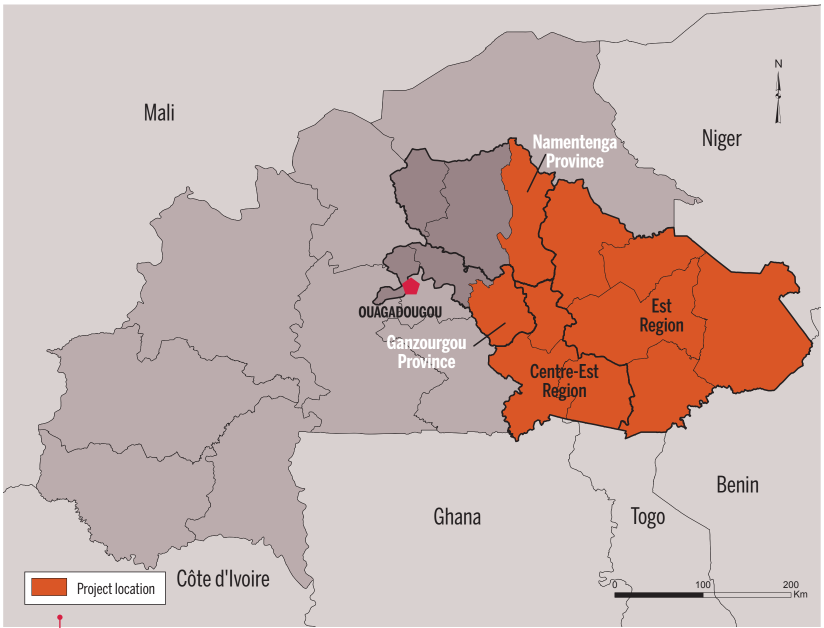


Figure 5. Project location - Source: FERDI

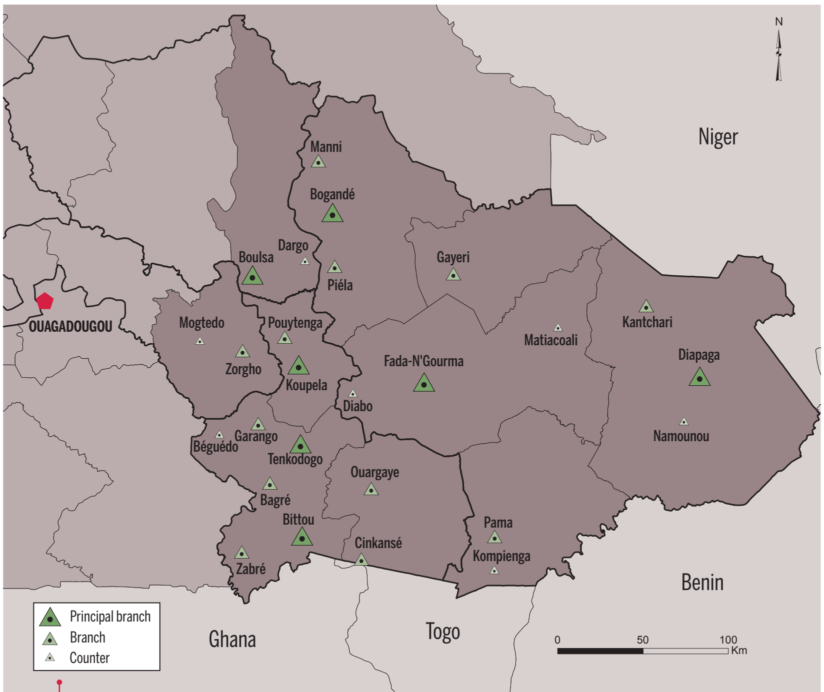


Figure 6. Network of the Délégation des Caisses Populaires de l'Est (DCPE)
Source: FERDI

2.2. TRAINING AND EDUCATIONAL TOOLS

2.2.1. Procedures guide and teaching workbook

A **procedures guide** was developed to define the roles, responsibilities and interactions between each stakeholder of the MICRESOL program, from the microcredit application to reimbursement of the credit by the customer.

Based on the feedback from the "Energy Credit" scheme, this guide was the result of a close consultation between all stakeholders: the DCPE, K&K International, BETA and Fondem.

"THE IDEA IS TO ENSURE A CLEAR AND COHERENT DISSEMINATION OF INTERNAL INFORMATION AND PROCEDURES IN ORDER TO SUPPORT THE CONCEPT AND THE SALES PITCH OF DCPE CREDIT AGENTS FOR THE CUSTOMERS."

The procedures guide is organized in sections presenting the program, its various stakeholders and the MICRESOL product, both technical and financial. It sets the rules for the situations related to implementation of the program: promotion and communication, microcredit application preparation, kit installation and maintenance, and monitoring of the solar microcredit beneficiaries.

The guide was completed following validation of the financial product and the selection of the supplier of the photovoltaic components. It was then disseminated widely to the program partners.

In addition, a **teaching workbook** was developed with various aims:

- present the operation of the MICRESOL project to credit agents,
- familiarize the credit agents with the product that they offer their clients,
- allow the credit agents to guide customers towards a product that suits them,
- allow them to give the customer basic information about the systems and their operation.

The idea is to ensure a clear and coherent dissemination of internal information and procedures in order to support the concept and the sales pitch of DCPE credit agents for the customers.

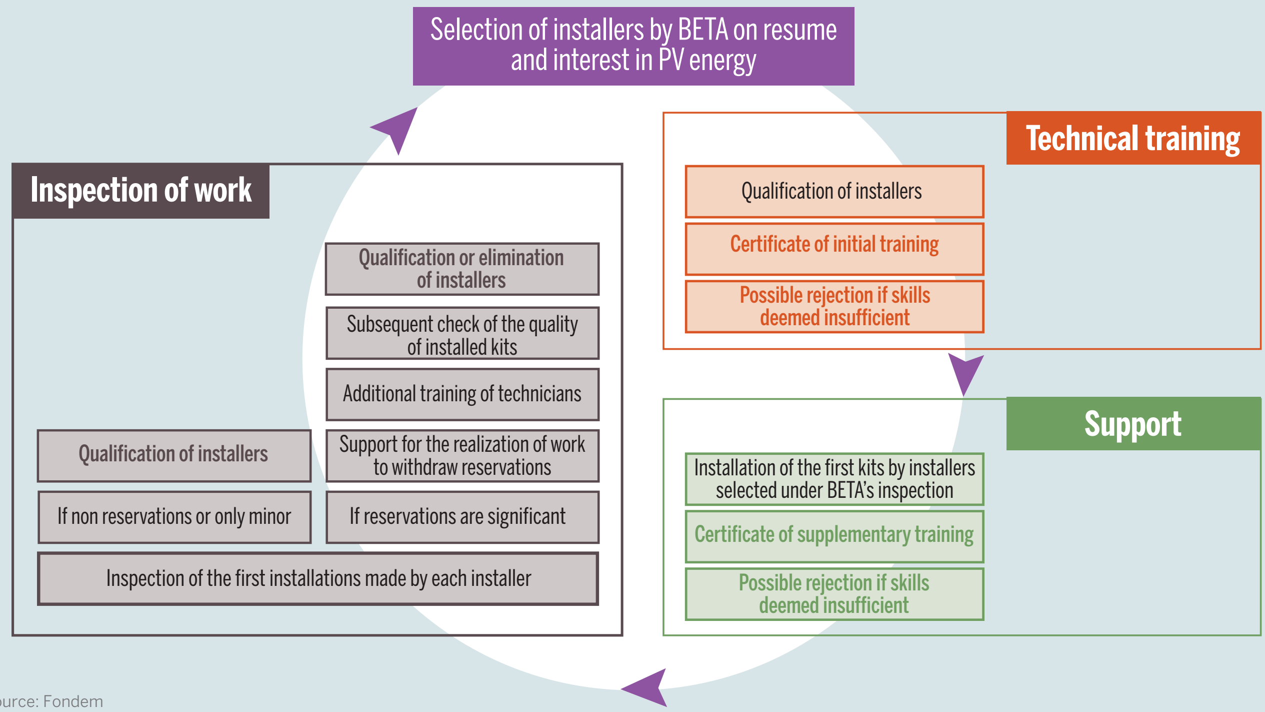
With this aim, the teaching workbook recaps the structure of the program procedures, presents the specific features of the solar photovoltaic electricity, the uses that customers can make of the energy and the MICRESOL technical range. It also sets forth a series of arguments to promote the MICRESOL product before future customers.

After exchanges and consultation focusing on MICRESOL within the DCPE staff, the teaching workbook was finalized in October 2013, and then released from November 2013 to all branches participating in the launch of the program.

2.2.2. Qualification procedure of technicians-installers

At the end of 2012, Fondem developed a qualification procedure with technical training and support to qualify skilled technicians for installation and maintenance of individual photovoltaic solar kits.

Qualification procedure of BETA technicians-installers for MICRESOL



Source: Fondem

Figure 7

On the basis of this qualification procedure,

■ An **initial technical training** was given to 5 BETA technicians by an international consultant in January 2013. This training concerned:
- some theoretical issues concerning solar photovoltaic electricity,
- practical exercises on demonstration solar components (modules, batteries, regulators, etc.).

At the end of the training session, the trainer assessed the technicians' skills according to a qualification grid, and then gave out "Certificates of initial training in photovoltaic kit installation and maintenance" to 5 BETA technicians involved in MICRESOL since they all had demonstrated the required skills.

■ A BETA **technician-installer support** service during the first kit installations carried out supplemented this "MICRESOL qualification" procedure between December 2013 and February 2014.

This installer support service was carried out by a Burkinabe consultant specialized in photovoltaic solar energy. The BETA CEO could have provided this support to his technicians himself (in terms of skills), but it was decided to go through an outside consultant in order to improve technical exchanges (since relations between employer and employee can be complicated), and because the outside consultant was readily available.

The support was carried out according to a two-step process:
- Strengthening of the technical training of the 5 BETA technicians,
- Support and assistance in the field during the first installations.

Initial technical training for BETA installations for MICRESOL
Source: Fondem

Signing of a solar microcredit application - Caisse Populaire of Tenkodogo
Source: Anne Mimault

This support was intended to help the technicians during their operations to improve their technical skills and enable them to deliver a quality service.

■ A "**quality control of the installation work of supplementary training**" service, conducted by an independent international consultant, in close partnership with a Burkinabe solar PV expert.

The service, which started in early 2015, was divided into 3 inspection missions, whose final aim was to validate the technicians' skills and hand out of certificates to the qualified technicians.

2.2.3. Training of DCPE banking staff

The MICRESOL product being atypical for a microfinance organization, one of the challenges of the program was to ensure a consistent concept among the banking staff of the DCPE branches. They had to be able to gain an understanding of solar photovoltaic technology, the technical range of kits on offer and the specific rules for the use of renewable electricity.

With this aim, the first step concerned training in the technical product of the DCPE "MICRESOL Project Leader" , who was recruited in mid-2012, to work specifically and full-time on MICRESOL.

The subjects covered during this training were: definition and operation of the "Solar microcredit" scheme, feedback of the "Energy Credit" scheme, basic technical training in individual photovoltaic solar systems, presentation of the MICRESOL program: goals and provisional work program.

Moreover, in 2012, Fondem contracted a Burkinabe consultancy firm for a service regarding "training in solar microcredit product for customer management staff".

This service was organized in two steps:
- First step, in mid-2013: presentation of the "Solar microcredit" scheme, feedback of the "Energy Credit" scheme, presentation of the MICRESOL program, its goals and its implementation methods (organizational diagram, stakeholders, etc.)
- Second step, just before the start of dissemination of the solar microcredit, at end 2013: presentation of the MICRESOL range of kits, description of a PV kit, presentation of the financial product associated with each kit, presentation of the installation/maintenance service performed by BETA.

The DCPE agents were then able to acquire the practical knowledge concerning the implementation of a solar microcredit through photovoltaic systems in the field.

They were thus capable of:
- informing and advising potential and existing customers of solar microcredits about its operation and terms,
- raising awareness of potential customers about solar photovoltaic,
- comparing the photovoltaic solution with conventional solutions (grid, line extension, generator),
- identifying the components of a solar system,
- ensuring that the system matched the use intended by the customer,
- advising the customer on the rational use of electricity and the routine service and maintenance tasks,
- promoting the MICRESOL product within the branches.

2.3. MICRESOL PRODUCT PROMOTION CAMPAIGNS

The information, awareness-raising and communication around the MICRESOL product were intended to:
- demonstrate the interest and relevance of the PV kits to solve a demand for electricity,
- show the interest of the solar microcredit as a tool to facilitate access to PV kits,
- show the quality of the components and products offered with MICRESOL,
- show the need for the rational use of the PV kit to extend its useful life.

As a reminder, RCPB is in charge of preparing, developing, and implementing all the information, awareness and communication tools concerning MICRESOL.

In mid-2013, RCPB developed a marketing plan, making it possible to set the targets to achieve in terms of marketing of the MICRESOL product and the means to achieve them.

In the framework of their marketing plan:
- RCPB and DCPE created a flyer about the MICRESOL product that was printed and distributed through the DCPE network in the east zone.
- DCPE created an advertising poster campaign. It was deployed on the main communication routes of the program area in December 2013, at the time of the launch of the solar microcredit within the Caisses Populaires.

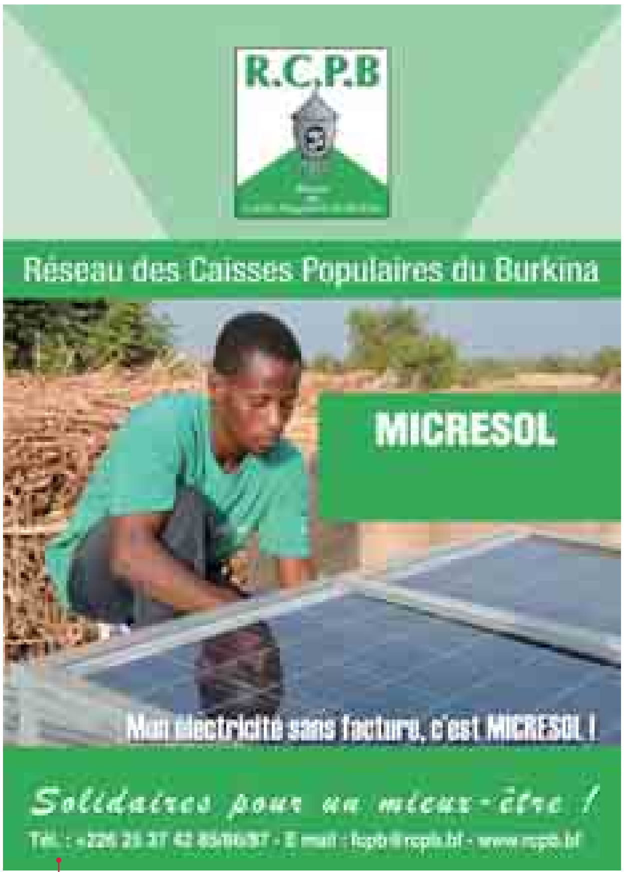


Figure 8. Solar microcredit promotional flyer
Source: RCPB

- A radio spot was also broadcast in French, Mooré, Bissa and Gourmantché by local radio stations in the east area, at the time of the effective launch of the MICRESOL product in early December 2013.

From mid-2014, and for approximately 9 months, a new promotion campaign was launched and supported by RCPB in order to revitalize marketing of the product:

- broadcasting the advertising spots on the radios of the entire area of operation,
- distributing promotional goods to MICRESOL product customers,
- strengthening internal communication to boost the marketing of kits, for instance through the distribution of photos of Kits 1 and 4 at the points of sale for a better knowledge of the technical product and optimal transmission of the information concerning the MICRESOL product to potentially interested members,
- boosting the skills of some stakeholders, including within the branches that had newly joined the product MICRESOL dissemination circuit (with the support of the procedures guide and the teaching workbook) for a better promotion of the kits.

3. RESULTS

3.1. DISSEMINATION OF SOLAR MICROCREDIT

From December 2013, the inhabitants of the east part of Burkina Faso were able to acquire a solar photovoltaic kit from the DCPE branches.

While the kit dissemination was encouraging during the initial phase (between December 2013 and June 2014), the pace of solar kit sales slowed down a little from June 2014.

Following several studies to identify the causes of this slowdown, and the gathering of several MICRESOL committees (steering committees bringing together operating staff of the Caisses Populaires, and possibly the assets: local coordinator, Fondem, etc.), some decisions were made:

- reduce the basis of the microcredit amounts, thanks to a significant effort from BETA to cut back the price of its own services,
- improve the financial product to make it more attractive while remaining viable for RCPB: relaxing the conditions for granting the credit (in particular by facilitating access to the Solar microcredit to persons not members of RCPB, and by cutting back the number of documents to provide to make an application), decreasing the rate of compulsory savings and the rate of interest,
- start a new promotion/communication campaign around the MICRESOL product, whose details are given in the previous paragraph.

The benefits of these new measures were quickly apparent, and the demand for kits, whose quality had been formally proven, has since grown apace.

In fact, from September 2014, demand has increased strongly, attaining **708 microcredit applications in early September 2015.**

The kits are intended not just for domestic but also for economic use, with the creation of video clubs, lighting of shops, the sale of mobile phone battery charging or the sale of fresh products thanks to the solar refrigerator.

As regards community social infrastructure, ten health centers (admittedly, in a vast area: 10 provinces of the east of the country) acquired kits in order to be able to offer care both day and night, but especially for 5 centers to offer new vaccination services (thanks to the purchase of a kit 4, equipped with a solar refrigerator, allowing vaccine conservation).
In the face of the success of the MICRESOL product, Fondem has initiated contact with the European Union in order to:

- increase the amount allocated to the provision of equipment, and thus reach out to a maximum of beneficiaries,
- carry out several budgetary adjustments to match actual situations in the field in order to be able to complete the project (mid-2016) in the best possible conditions.

708
microcredit applications in early September 2015

22%
of households had begun to develop at least one economic activity thanks to their new MICRESOL kit

62%
of children who study in the evening do so thanks to MICRESOL kits

38%
of households reported having stopped using batteries

Table 2. Distribution of microcredit applications in September 2015

	KIT 1 8 Wp	KIT 2 80 Wp	KIT 3 160 Wp	KIT 4 320 Wp	TOTAL
Nbr kits	455	75	157	21	708
Outstanding credit	FCFA 8,781,500	FCFA 20,122,125	FCFA 62,860,602	FCFA 34,541,661	FCFA 126,305,888
	€ 13,387	€ 30,676	€ 95,830	€ 52,658	€ 192,552

Source: Fondem

Examples of customers equipped with solar kits

Source: Fondem

Figure 9

3.2. MEASURE OF THE IMPACT OF THE NEW ACCESS TO ELECTRICITY

3.2.1. Methodology

In 2012-2013, a survey of the initial situation, before electrification, was carried out by a Burkinabe consultancy firm on the basis of a grid of impact indicators and adapted survey questionnaires in 6 "witness-communities" of the project's area of operation, with characteristics matching the socio-economic makeup of the program beneficiaries.

This survey was mostly reused for the impact survey of the MICRESOL program launched by Fondem in early 2015 and carried out by a Burkinabe consultancy firm:
- the grid of indicators was recovered,
- the results of that survey are used as reference situation.

Examples of activities that may be developed: sale of fresh products, charging of mobile phones, hairdressing shop, video store

Source: Fondem

Figure 10

This survey seeks to show how and to what extent the installation and use of a solar kit acquired through a microcredit induces a change or changes in the living conditions of the beneficiaries (households, small or micro-entrepreneurs, health centers).

The grid of indicators used focuses on poverty reduction, improvement of well-being and access to the means of communication and information, the involvement of women in domestic, economic and social life, the means for educational achievement, improvement of health and safety, economic and community development, and the environment.

A sample was selected of 100 beneficiaries representative of different social strata and the various professional categories.

Two surveys of these 100 beneficiaries were scheduled, the first in early 2015, the second in early 2016.

3.2.2. Results of the survey

The results of the first part of the survey carried out in early 2015, conducted when approximately 250 kits had been installed, show that, compared to all the households that before the MICRESOL project undertook no income-generating activity (IGA), **22% of households had begun to develop at least one economic activity thanks to their new MICRESOL kit**, mainly recharging mobile phones (a little over 80% of cases of IGA development), and also development of video stores (almost 15%) and sale of fresh products (5%).

In addition, **62% of children who study in the evening do so thanks to MICRESOL kits.**

The need for lighting is very high and the use of the kits replaces the excessive use of the batteries by the beneficiaries. Thus **38% of households reported having stopped using batteries** since they have a MICRESOL kit.

The changes most cited (spontaneously) during the qualitative surveys are:
- children can do their homework in the evening (85%);
- a more open outlook thanks to television and radio (75%);
- lighting makes it possible to work at night (60%);
- improved safety thanks to light - theft, snake bites (55%);
- health centers have become more effective (30%);
- electricity enables greater productivity and therefore increases revenue (25%).

"THIS SURVEY SEEKS TO SHOW HOW AND TO WHAT EXTENT THE INSTALLATION AND USE OF A SOLAR KIT ACQUIRED THROUGH A MICROCREDIT INDUCES A CHANGE OR CHANGES IN THE LIVING CONDITIONS."

CONCLUSION

After 4 years of project implementation, the MICRESOL product has won over all program stakeholders:
- *firstly, the beneficiaries; households that can improve their living conditions and their domestic comfort, micro-entrepreneurs who can develop income-generating activities (video stores, shops, hairdressers, sewing shops, sellers of fresh products, diners, etc.), infrastructures such as health centers,*
- *RCPB, the main operating partner, and its Délégation de l'Est (DCPE), for whom the MICRESOL product is a true loss leader, but allows it to further diversify its offer of cooperative financial services adapted to the Burkinabe rural and peri-urban areas, which often have a very limited capacity to pay,*
- *the local technical partners, the supplier K&K International and BETA, the installation-maintenance structure, who were able to develop their skills and activities through the project,*
- *the project financial backers.*

The MICRESOL product , intended for rural and peri-urban areas of Burkina Faso's east regions, appear to be relevant both technically and financially. The range of kits chosen matches the needs of the beneficiaries and has enabled the development of many economic activities, while remaining affordable for the most fragile populations.

In September 2015, more than 700 microcredit applications were made, allowing the installation and maintenance of quality kits. This result was achieved through the involvement of all the project stakeholders. The training of the banking and technical agents proved to be one of the key factors of its success.

Kit installation will continue until mid-2016 under the contract with the European Union, trying to reach the ambitious goal of 1,000 kits installed.

More widely, Fondem is currently working on upscaling this solar microcredit scheme to the Nord region, and then expanding nationwide. For this purpose, it is looking for:
- *the technical means to decrease the amount of the subsidy applied to the kits, the biggest restriction for replication of the model, while taking into account the technological developments of photovoltaic equipment and maintaining a competitive and quality product,*
- *financial partners to allow the coordination, training, and building up of the capacities of all the participants necessary to the proper operation of such a scheme.*

SOLAR LOANS THROUGH A PARTNERSHIP APPROACH: lessons from Africa

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Masai women discovering solar solutions during a demonstration session, Kenya - Source: PAMIGA

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PAMIGA (Participatory Microfinance Group for Africa) is an international NGO that aims to unlock the economic potential in Africa by promoting the growth of financial institutions that serve rural areas. It provides technical assistance to a network of 16 RFIs in sub-Saharan Africa.

KEYWORDS

- SOLAR ENERGY
- ACCESS TO ENERGY
- MICROFINANCE
- TWO-HAND MODEL
- RURAL SUB-SAHARAN AFRICA

Lack of financial resources is a key barrier to access to energy in rural Africa. Since 2013, PAMIGA has been assisting rural financial institutions in developing Solar Loans to overcome this barrier. The approach chosen was that of a "two-hand" model, where a financial institution and a solar solution provider decide to partner. This article presents the rationale and features of the model, its first results, and the key challenges and lessons learned from its implementation in Cameroon, Ethiopia and Kenya.

INTRODUCTION

In the recent years, great technological progress has been made, resulting in the design of solar solutions better adapted to the Bottom of the Pyramid (BOP), as well as in a decrease in the prices of solar product components. To make these technologies available to low-income rural populations on a sustainable basis, a variety of business models are currently being tested.

Since 2013, the Participatory Microfinance Group for Africa (PAMIGA), an international NGO providing technical assistance to a network of 16 rural financial institutions (RFIs) in sub-Saharan Africa, started to work with its member RFIs to develop financial products to facilitate access to quality pico-solar solutions for their vulnerable rural clients. The approach chosen was that of a "two-hand" model, where a financial institution and a solar solution provider (or several) decide to partner. This article first introduces the reasons that led PAMIGA and its partners to opt for a two-hand model. The methodology of implementation of the model and its first results are then presented. Finally, the article analyses the key challenges and lessons learned from implementation in Cameroon, Ethiopia and Kenya, among which emerged the necessity to develop networks of village-based "Energy Entrepreneurs" to reach the last mile more efficiently (the Energy Entrepreneur model is presented in more details in the following article Allet (2016), "Energy Entrepreneurs: an innovative model to reach the last mile").

1. WHY A TWO-HAND MODEL?

1.1. UNMET ENERGY NEEDS IN RURAL AREAS

The rural financial institutions that are members of PAMIGA's network offer credit and savings services to low income populations in sub-Saharan Africa. They mainly operate in rural areas, where access to electricity is still extremely limited. During field visits to rural areas, PAMIGA and its partner RFIs realized that rural poor populations were asking for their assistance to have access to clean energy solutions. To get a better understanding of rural microfinance clients' situation, PAMIGA and its partner RFIs conducted specific quantitative and qualitative needs assessments in Cameroon, Ethiopia and Kenya (between 2013 and 2015). Quantitative surveys were conducted with a sample of rural households. Since the RFIs first wanted to answer the needs of their clients, interviewed households were randomly selected in the areas of intervention of the institutions (generally focusing on 4 to 8 rural branches), mostly among existing clients (although a few non-clients were also interviewed). The quantitative surveys were completed with qualitative focus groups for a better comprehension of perceptions and expectations of rural poor populations. These needs assessments confirmed the high demand among RFIs' clients for improved access to energy, as illustrated in Table 1.

Table 1. Key findings of PAMIGA's energy needs assessments

	Cameroon	Ethiopia	Kenya
Nb of surveyed microfinance clients	86	152	110
Respondents NOT connected to the grid	82%	99%	88%
Respondents using kerosene lamps	84%	92%	79%
Respondents using torch lamps / flashlights	48%	88%	68%
Average monthly energy expenditures	€ 24	€ 12	€ 65
Percentage of average monthly energy expenditures out of household budget	10%	11%	15%
Respondents NOT satisfied with their current access to electricity	100%	100%	93%
Respondents interested in a solar solution	96%	97%	100%

The needs assessments furthermore showed that these vulnerable rural populations are aware of the existence of solar solutions and broadly perceive them as an adequate option for them. However, some key barriers remain: (a) the lack of accessibility to these solutions, as providers are often not present in rural areas; (b) the lack of information to select reliable solutions; (c) the lack of financing options for such investments.

Confronted to this unmet demand from their clients, the RFIs within PAMIGA's network believed that they could play a role to facilitate access to solar solutions. As it was a new area for them, they requested technical assistance from PAMIGA.

1.2. DRIVERS FOR RURAL FINANCIAL INSTITUTIONS' INVOLVEMENT

RFIs are often perceived as being in a good position to address some of the key barriers to access to clean energy. As mentioned by Levai et al. (2011), RFIs can have the advantages of: (a) having a wide outreach in rural areas, often more than any other distribution channel; (b) holding a position of trust with local households; and (c) offering access to adapted financial services to facilitate the purchase of new technologies.

For PAMIGA's partner RFIs, a first motive to get involved was that of fulfilling their social mission: by facilitating access to solar solutions, they could contribute to improve the living conditions of their clients and foster local economic development (Allet, 2014; Levai et al., 2011). These RFIs also decided to get involved in energy lending because they expected some strategic and financial benefits for themselves, such as differentiating from competitors, attracting new clients, retaining existing ones, diversifying their offer and portfolio, building a positive image as a socially and environmentally responsible institution, and attracting new sources of funding (similar to findings from Allderdice & Rogers, 2000; Allet, 2014; Levai et al., 2011).

1.3. HAVING SPECIFIC SOLAR PARTNERS OR NOT?

The core business of RFIs is to offer financial services (savings and credit). Following a "free market" approach (Groh & Taylor, forthcoming), RFIs could decide to just provide a loan and let clients find and purchase the energy solution they want. This is an approach that is more common in areas where the market of clean energy solutions is already well developed (for instance energy efficient devices in urban areas of Latin America). However, in rural areas of sub-Saharan countries, the supply chain for solar solutions is still limited. If RFIs were just to offer loans, they would help overcome the financial barrier to investment, but not the barriers linked to lack of information and lack of accessibility of solar solutions in rural areas.

Focus group discussions, conducted by PAMIGA with rural microfinance clients in Cameroon, Ethiopia, and Kenya, have revealed that rural households are worried about low quality solar solutions. As they trust their RFI, many of them actually prefer to get advice and guidance on which solar solution to choose. Even more surprisingly, in Ethiopia, microfinance clients who would have the capacity to purchase a small solar kit in cash, from their revenues or savings, clearly stated that they prefer taking a loan (and thus paying a bit more) in order to benefit from different services offered through the RFI, such as delivery of the kit at rural branch level and warranty for at least the duration of the loan.

Provided their context of intervention, PAMIGA's partner RFIs thus decided to opt for a "two-hand" approach, where they set partnerships with selected providers of solar solutions. The advantage of this approach is that, through such partnerships, RFIs are able to make quality solutions accessible to target clients in rural areas. Furthermore, they can control the use of the loan by disbursing the money directly to the selected partner, for the selected quality solution, and therefore mitigate credit risk linked to equipment breakdown. However, the two-hand model also implies a key constraint for RFIs: clients are likely to hold them directly responsible in case of problem with the technology since they will consider that the latter was promoted by the RFI, and they may stop repaying their loans. When opting for a two-hand approach, RFIs thus have to make a rigorous selection of solutions and partners to truly mitigate the reputation and credit risks (Morris et al., 2007).

2. THE TWO-HAND MODEL TESTED BY PAMIGA

Since 2013, PAMIGA has been testing this two-hand model of partnerships between RFIs and solar solution providers in three countries (Cameroon, Ethiopia, Kenya) with a total of six RFIs (A3C, ICS and UCCGN in Cameroon; Buusaa Gonofaa and Wasasa in Ethiopia; WPS in Kenya). Building on lessons learned from similar initiatives worldwide, PAMIGA has been applying a clear methodology, presented in the following sections.

2.1. SELECTION OF SOLAR SOLUTIONS AND PARTNERS

The energy and financial needs assessments, which had been conducted by PAMIGA and partner RFIs in a first step, were instrumental in identifying the types of solar solutions that would fit the needs and expectations of target microfinance clients. Building on these results, PAMIGA provided support in screening the offer of solar solutions and selecting quality technologies and reliable providers who were interested in starting contractual partnerships with a RFI.

For that purpose, PAMIGA has defined a list of criteria for pre-selecting adequate solar solutions and providers. For instance, solar solutions were evaluated along their capacities (what can they supply? does it fit the needs of various segments?), lifespan, quality of components (type of battery and solar panel, etc.), certification by Lighting Global and/or other relevant authority, easiness to use, warranty conditions, availability of spare parts, possibility to upgrade, and price. As for solar solution providers, they were evaluated along their local market presence, offer of adequate solar solutions, reputation, experience in and willingness to explore the Base of the Pyramid market and work in rural areas, capacity to import and manage a local stock, capacity to deliver the solutions to rural areas, capacity to provide efficient after-sales services and collect used material, willingness to partner with a RFI and provide training to the RFI staff, etc. (in line with recommendations formulated by Levai et al., 2011; Winiecki et al., 2008).

PAMIGA then organized a first workshop where the RFIs and pre-selected providers could meet. During these workshops, each actor would present its organization, activities, and motivation for engaging in such partnerships. The pre-selected providers would make a demonstration of their solar solutions and explain their services. Such workshops are crucial because, beyond a technical screening process, the success of a two-hand model lies in the capacity of partners to collaborate. It is thus critical that the RFI and solar solution provider have a good "feeling" about their capacity to communicate and work together. The decision was thus left to the partner RFIs and pre-selected providers, after a first meeting, to decide whether they wanted to pursue discussions and enter into partnerships.

Within this selection process, PAMIGA promoted a progressive approach, advising RFIs to first start with a limited number of solar solution partners (one or two), in order to test the new model and make it easier for loan officers to integrate the new financial product. Then, after a successful pilot phase, RFIs could decide to integrate additional partner providers in order to diversify the range of solar solutions proposed to clients. As part of this progressive strategy, most RFIs decided to start with solar lanterns for basic lighting and mobile phone charging needs, as "quick-win" entry products. Then, as the model and partnerships were strengthened, they progressively started to move towards larger solar home systems, for both domestic and productive use.

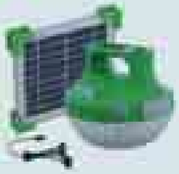
Following this approach, the three RFIs in Cameroon (A3C, ICS and UCCGN) first started a partnership with a local distributor in 2013 and integrated a second partner provider in 2015. In Ethiopia, both RFIs (Buusaa Gonofaa and Wasasa) also started with a single provider in 2013; in 2015, Wasasa decided to integrate two additional partners. In Kenya, WPS started partnering with a distributor in 2014, and then integrated a second partner for larger solar solutions in 2015.

2.2. DISTRIBUTION OF ROLES AND RESPONSIBILITIES BETWEEN PARTNERS

Lessons learned from field experiences always emphasize the importance of defining a clear distribution of roles and responsibilities between partners in such two-hand models (Levai et al., 2011; Morris et al., 2007; Rippey, 2009; Winiecki et al., 2008). In this model, the general idea is that each actor brings its respective competences and collaborates to jointly overcome the main barriers to access to clean energy: lack of available solutions, lack of information, and lack of financial resources to invest in a clean energy solution. On the one hand, the solar solution provider offers quality technologies, together with crucial customer services such as delivery, installation, customer education, warranty and after-sales services. On the other hand, the RFI gives access to its client base and offers financial services to facilitate investment in the solar solution. However, in each case, the

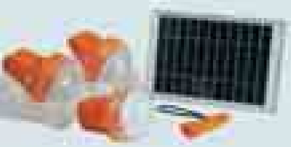
Figure 1. Solar solutions selected by partner RFIs

CAMEROON



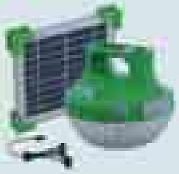
Mobiya (Schneider Electric)
2.5 Wp solar kit
1 lamp
+ mobile phone charging
FCFA 22,800

MB2-200 (Omnivoltaic)
2.5 Wp solar kit
1 lamp + 1 torch
+ mobile phone charging
FCFA 37,850



MB2-380 (Omnivoltaic)
5 Wp solar kit
3 lamps + 1 torch
+ mobile phone charging
FCFA 92,800

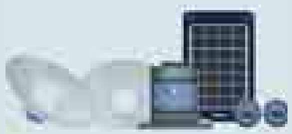
ETHIOPIA



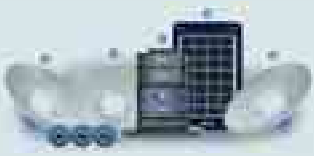
Mobiya (Schneider Electric)
2.5 Wp solar kit
1 lamp
+ mobile phone charging
ETB 1,262

S300 (d.light)
1.5 Wp solar kit
1 lamp
+ mobile phone charging
ETB 880

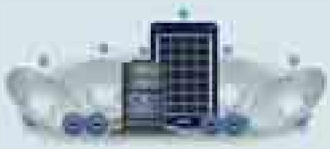
D20 (d.light)
5.5 Wp solar kit
2 lamps + 1 torch
+ mobile phone charging
ETB 2,300



Home 200 X2 (NIWA)
5 Wp solar kit (upgradable)
2 lamps
+ mobile phone charging
ETB 2,519



Home 300 X3 (NIWA)
5 Wp solar kit (upgradable)
3 lamps
+ mobile phone charging
ETB 3,261



Home 400 X3 (NIWA)
5 Wp solar kit (upgradable)
4 lamps
+ mobile phone charging
ETB 3,261

KENYA

SunKing Mobile (Greenlight Planet)
1.5 Wp solar kit
1 lamp + mobile phone charging
KES 2,350

SunKing Pro2 (Greenlight Planet)
3.3 Wp solar kit
1 lamp + mobile phone charging
KES 3,150

Solectric 15 (Orb Energy)
5 Wp solar kit
2 lamps
+ mobile phone charging
KES 8,990

Solectric 30 (Orb Energy)
10 Wp solar kit
4 lamps + mobile phone charging / radio playing
KES 14,990

Solectric 120 (Orb Energy)
40 Wp solar kit
4 lamps + TV (included) + mobile phone charging / radio playing
KES 59,990

exact demarcation of roles can slightly differ, in order to find the most efficient model according to the capacities and expectations of each partner, as well as their context of intervention. For instance, in some contexts, the RFI may be willing to take over the responsibility of delivering the solar solutions from their branches to end-customers; while in other contexts this task will be performed by technicians contracted by the solar solution provider.

To help partners define a balanced and optimal distribution of roles, PAMIGA organized additional participatory workshops where RFIs and solar solution distributors could discuss the terms of partnerships (respective roles and responsibilities of each party, procedures to be followed during implementation). The workshops also had the objective to make sure that each partner has a clear understanding of each other's constraints and responsibilities. This process then resulted in the signing of Memorandums of Understanding (specifying the respective roles and responsibilities of each partner, as well as cost-sharing aspects for joint activities) and the development of detailed Memos of Procedures.

Table 2. Typical distribution of tasks in PAMIGA's two-hand model (some variations exist from partner to partner)

	RFI	Solar solution provider
Promotion	JOINT RESPONSIBILITY The RFI usually focuses more on promoting the financial products.	JOINT RESPONSIBILITY The provider focuses more on promoting the solar kits.
Loan application/appraisal /approval	EXCLUSIVE RESPONSIBILITY	
Delivery of solar kits	FACILITATION The RFI facilitates the delivery of solar kits from rural branches to end-customers.	RESPONSIBILITY The provider delivers the solar solutions to the RFI rural branches.
Installation of solar kits		RESPONSIBILITY When installation is needed
Customer education	JOINT RESPONSIBILITY	JOINT RESPONSIBILITY
Loan repayment collection	EXCLUSIVE RESPONSIBILITY	
After-sales services	FACILITATION The RFI may facilitate the contact between clients and providers.	RESPONSIBILITY

2.3. ADAPTING THE FINANCIAL PRODUCT TO THE TWO-HAND MODEL

In parallel to the setting of partnerships, the RFIs worked on developing a specific financial product dedicated to finance access to clean energy: the Solar Loan. PAMIGA provided technical assistance in this financial product design process, using a risk management approach. This methodology consists in identifying with the RFI staff the specific risks linked to energy lending and therefore identify the loan features and procedures that should be adapted in order to mitigate these risks. RFIs can thus develop a new loan product that is fully in line with their existing procedures: for instance, if they only provide group lending, the Solar Loan will also be a group loan; if they do individual lending, the Solar Loan will be an individual loan; if they have maximum loan amounts per loan cycle, the same will apply to Solar Loans, etc. Only a few specificities are defined.

For instance, in Ethiopia, partner RFIs decided to keep the same type of collaterals on the Solar Loans as for other loans (15% mandatory savings and group joint liability); but in order to reduce the credit risk specifically linked to Solar Loans (i.e. clients refusing to repay due to equipment breakdown), they decided to request a down-payment amounting to 10% of the cost of the solar solution, in order to build a better sense of ownership of the solar kit among clients (assuming it would reduce risks of misuse or bad care). In Kenya, the MFI kept the same lending methodology and possible loan duration as for other loans; but, because most clients who want to invest in a solar solution still need to have access to a loan for their business, the RFI decided to allow the provision of Solar Loans in parallel to another business loan (which is not allowed for any other type of loan). To mitigate the risks created by allowing parallel loans, the RFI then strengthened the loan appraisal process for Solar Loans and defined repayment schedules tailored to the monthly energy savings allowed by the solar kit (making sure the Solar Loan does not come as an additional burden for the household but can be repaid thanks to the energy savings).

Within such two-hand model, a key adjustment is linked to the disbursement of the loan: instead of disbursing cash to the clients, the RFIs make a direct payment to the solar solution provider, who then delivers the solar kit. The clients thus receive their Solar Loan "in-kind", under the form of the solar solution, and will still have

> ***"EACH ACTOR BRINGS ITS RESPECTIVE COMPETENCES AND COLLABORATES TO JOINTLY OVERCOME THE MAIN BARRIERS TO ACCESS TO CLEAN ENERGY."***

Table 3. Examples of Solar Loan key features

	Cameroon	Ethiopia	Kenya
Local name	Crédit Lumière	Liqaa Solaarii	Mkopo wa Sola
Lending methodology	Individual lending	Group lending	Group lending
Personal contribution / down-payment	No	10% of the total cost of the solar kit	No
Minimum loan amount	FCFA 10,000	ETB 500	KES 1,200
Maximum loan amount	FCFA 90,000	ETB 15,000	KES 60,000
Loan duration	3 to 12 months	4 to 24 months	6, 9 or 12 months
Instalment frequency	Monthly, quarterly, biannually or term	Monthly with different amounts	Monthly
Interest rate	24% flat per annum	13 to 18% flat per annum (according to loan size)	24% flat per annum
Collaterals	30% cash collateral, pledge on assets, personal guarantors	15% cash collateral, joint liability	15% cash collateral, joint liability, pledge on assets

to repay their loan as usual, with the RFI. For the RFI, it may imply adjusting internal cash flow management, since payments to partner providers are made by head office, whereas loan disbursements are often managed at branch level. It also implies some adjustments in the loan application forms and loan agreements signed with clients, and possibly in the Monitoring Information System too. Some RFIs were actually already used to such disbursement processes (for agricultural loans linked to the purchase of inputs or equipment loans for instance); for others, it was an innovation, specific to this two-hand model.

This approach of adapting only a few loan features to the specific risks of energy lending thus facilitates the integration of a new financial product within the institution, making it easier for loan officers to assimilate only a few specificities.

2.4. PREPARATORY PHASE AND KICK-OFF

During the preparatory phase, PAMIGA also assisted RFIs in defining the roles and responsibilities of each staff internally, writing an adapted manual of procedures for Solar Loan, working on financial projections to set the right pricing and identify the break-even point, adjusting the existing staff incentive scheme, defining the marketing strategy, developing a monitoring plan, and training staff on new financial product.

On the other hand, partner providers and distributors had to work on their own financial projections, anticipate adequate stock management, set their internal organization, define their marketing strategy and communication tools, develop User Guides and warranty cards adapted to the target populations (in local language, with illustrations), and provide training on their solar solutions to the RFI field staff.

Operations then started with demonstration sessions conducted jointly by RFI and partner providers' field staff with groups of microfinance clients. Between the initial needs assessments and these first promotion activities, the preparatory process lasted 4 to 9 months, depending on the country. The two-hand model has been tested since August 2013 in Cameroon, September 2014 in Ethiopia, and July 2015 in Kenya.

3. MAIN RESULTS AND LESSONS LEARNED

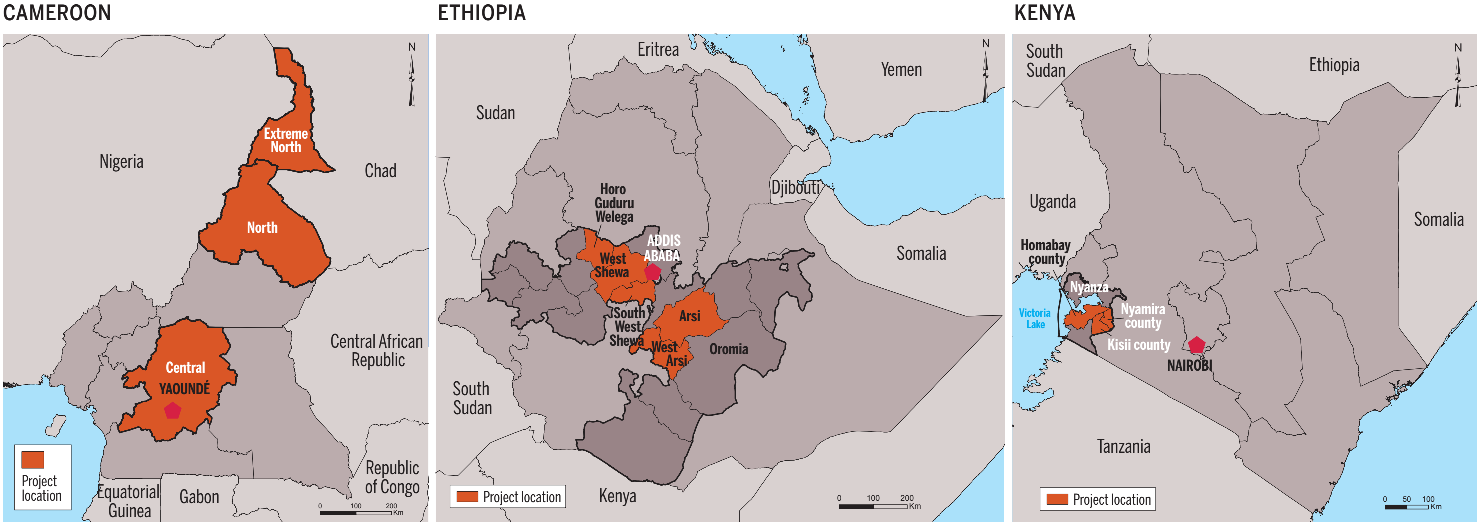
3.1. FIRST RESULTS

As of the end of December 2015, a total of 1,993 solar kits in Cameroon, 1,124 kits in Ethiopia and 446 kits in Kenya have been distributed through this two-hand model.

Table 4. First results

	Cameroon	Ethiopia	Kenya
Number of solar solutions distributed	1,993	1,124	446
Number of months of operations	28 months	15 months	5 months
Geographical coverage	40 branches in Central region + 8 branches in Northern-Extreme North regions	11 branches in Oromia region	15 branches in Kisii, Nyamira and Homabay counties, Nyanza Province
Percentage of pico-solutions	97%	78%	91%
Percentage of solar home systems	3%	22%	9%

Figure 2. Project locations



Source: FERDI

Even though these results are positive, they are much lower than what all partners initially expected. In Cameroon and Ethiopia, operations started rather slowly despite a great initial enthusiasm from both RFIs and solar solution providers. Moreover, results have showed important fluctuations from one quarter to the other, as illustrated in the three following figures. Indeed, the implementation of the two-hand model faced various challenges (detailed in Section 3.3), which negatively impacted the uptake of Solar Loans. Partners progressively had to find solutions to address these challenges (cf Section 3.3), which then had a positive effect on results.

3.2. FIRST IMPACTS MENTIONED BY RURAL CLIENTS

To assess the first impacts of Solar Loans on rural clients, PAMIGA conducted focus group discussions with over 200 clients in Cameroon (in June-July 2014, as part of a client satisfaction survey) and 75 clients in Ethiopia (in March and October 2015). The interviewed households were randomly selected among microfinance clients who had invested in a solar solution thanks to this two-hand model. These qualitative interviews revealed that, rather quickly after having purchased their solar solutions (1 to 3 months), clients already mention some positive impacts:

Improved access to quality solar solutions

As obvious as it may sound, the partnerships between RFIs and solar providers first enabled rural households to invest in a quality solar solution more easily. In Ethiopia, in September 2013, 97% of surveyed households stated to be interested in solar energy for their

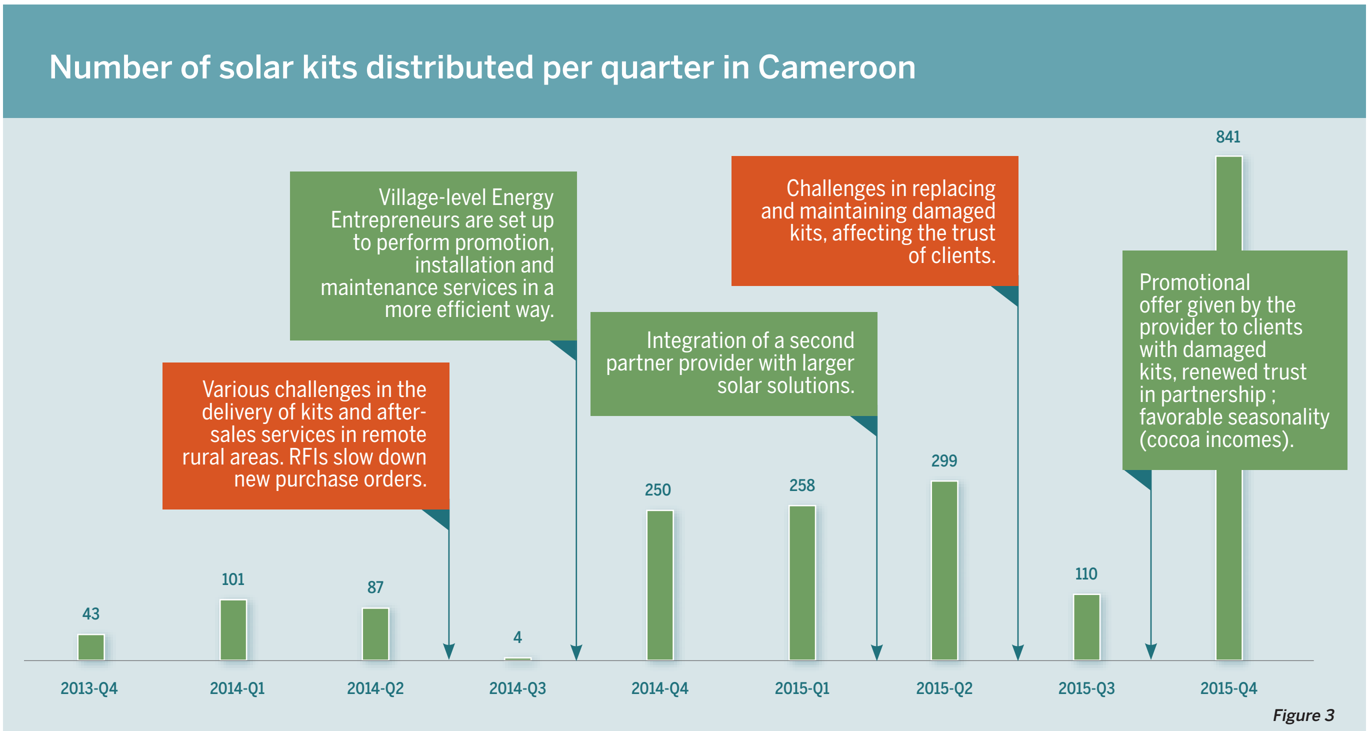


Figure 3

Number of solar kits distributed per quarter in Ethiopia

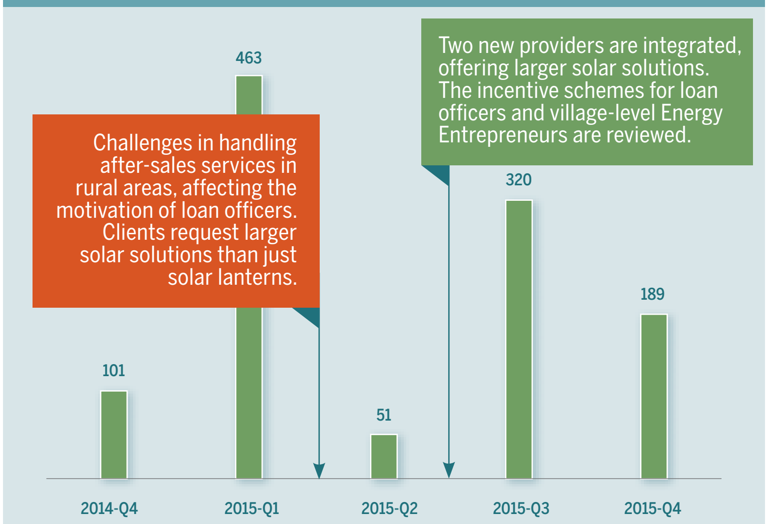


Figure 4

Number of solar kits distributed per quarter in Kenya

Figure 5

house; but only 1 respondent out of 152 was actually using a solar solution (cf needs assessment results). In 2015, when asked why they did not invest earlier, Solar Loan clients generally answered that they did not have enough information on available solar solutions; some of them mentioned that they could have bought one in cash, from the marketplace in some nearby town, but they were afraid to end up with a low quality product, with no warranty. The RFI thus played an instrumental role here in bringing information to rural households, pre-selecting for them a range of quality solar solutions with warranty and after-sales services, and therefore making them feel more confident to invest in solar.

Interestingly, the same mechanism seems to apply in Cameroon. Most of the solar lanterns distributed through the two-hand model have actually been purchased in cash by rural clients, and not through a Solar Loan. As solar kits are more widespread there than in Ethiopia, these clients could have opted for buying a solar lantern themselves, directly from some local traders. Yet, they preferred to order their solar kit through the RFI and pay a small service fee for that, because the RFI was bringing some guarantee that the solar kit would be of good quality and that the provider would perform after-sales services and respect the warranty period. A more rigorous quantitative study is however still needed to assess more precisely how Solar Loans and partnerships between RFIs and solar providers increase the overall uptake of solar solutions in rural areas.

Improved lighting and living conditions

In Cameroon, the study revealed that Solar Loan clients on average increased their daily lighting duration by 2 hours, with the solar kits allowing them to have lighting for up to 5 hours per day. In both countries, many clients also mention that the solar solution has improved the quality of lighting of their house (higher brightness) and allowed them to have lighting in several rooms at a time.
"We used to use kerosene lamp for lighting, in particular when cooking. Now, we have good light since it gets dark, at 6:00pm, until we switch off, at 10:00pm." (Female client, Bivouna, Cameroon)
"We used to have lighting only in one room, we always had to stay together in the same room. Now, with solar, we parents can be in the living room, and the children play in their bedroom." (Male client, Tuli village, Ethiopia)

Reduction of energy expenditures

In both countries, interviewed clients have experienced a significant decrease in their energy expenditures, as the solar solution enabled them to reduce or even stop the use of kerosene lamps, as well as to stop paying for mobile phone charging services in town.
"Before, we would use 2L of kerosene per week. Now, we only use 1L per week." (Female client, Bivouna, Cameroon)
"Before my solar kit, I used to pay FCFA 58,000 for lighting my bar and my house. Now, I only pay FCFA 28,000, it is a miracle!" (Couple, Bivouna, Cameroon)
"We are a family of six. Before the solar kit, we used to spend Birr 20 per week for kerosene, and Birr 6 per week for charging our mobile phones. Now, we do not use kerosene anymore, we can save that money." (Male client, Bola village, Ethiopia)

Some first social effects

Other impacts are also regularly mentioned by interviewed clients, such as the possibility for children to better study in the evening at home (thanks to more lighting hours and better quality of lighting), the reduction of health issues linked to the use of kerosene lamps, or even more socializing opportunities in the village.

"Before, when I was sneezing, it was all black and dirty [because of kerosene lamps' emissions]. Now, it is not black anymore!" (Male client, Tulu Habib, Ethiopia)

"I am proud, I have lighting like people in Addis! Many neighbors come to our place in the evening, we all enjoy chatting together." (Male client, Yeron Ama Tole, Ethiopia)

3.3. KEY CHALLENGES AND LESSONS LEARNED

Even if the context of intervention is rather different from one country to the other, some key lessons have emerged from these experiences:

Adaptation of solar solutions to local needs is a key success factor.

Solutions that had proved successful in Asia did not systematically encounter the same uptake in Cameroon or Ethiopia. For instance, in areas where people have extremely limited experience with electrical devices, some solutions, initially thought to be user-friendly, still turned out too complex to handle by target clients alone. To address a slow uptake of the solution, partners had to develop a service of installation for clients who did not feel comfortable with the solar solution at first; this implied a slight adjustment in the pricing of the solution, to include the cost of this additional service.

In Ethiopia, several clients complained that the cables to connect the lamps to the battery were not long enough to reach all their rooms. In reality, the solar solutions may not have been adapted to the traditional features of rural Ethiopian households, which are often composed of 2 to 3 small houses. In this case, to avoid frustrations on clients' side, partners had to put emphasis on customer education at the time of promotion, making sure that they would order a solar solution adapted to the layout of their rooms and houses.

In all three countries, many clients also quickly wanted to graduate from small solar lanterns and climb the energy ladder up, requesting solar solutions with more lamps and other applications. To respond to these needs, RFIs, who usually started with solar lanterns only, then decided to progressively include larger solar solutions and partner providers.

In a context of fast technological innovation, evolving needs and fierce competition from low-quality products, having the capacity to offer a range of adapted solutions is thus crucial both for the solar solution providers and for RFIs.

It is essential to facilitate synergies between the worlds of microfinance and energy.

Building strong local partnerships between RFIs and distributors of solar solutions is essential for the successful roll-out of such a model. The first months of operations have shown that it is important not to underestimate the time needed to build understanding and trust between the different actors. RFIs and solar solution providers indeed come from two different sectors that are not used to working together. They may decide to collaborate along similar objectives (improving access to clean energy solutions for low-income populations), but they each have their own vision, procedures and technical language. For instance, local distributors seek to maximize the sales of solar solutions, and thus push the demand as much as possible; whereas RFIs want to have a high outreach, but also have to manage good customer relationships and credit risk. RFIs need to go through a learning curve, integrate new products and practices, in addition to careful appraisal processes that could appear as lengthy and inefficient in the eyes of distributors.

Furthermore, RFIs and local distributors do not understand well the constraints that can be faced by each partner (such as minimum volumes for delivery for distributors, or seasonality of loan applications in rural areas for RFIs). These differences in expectations and misunderstanding of each other's constraints have sometimes led to tensions between the partners. The pilots showed that for the two sectors to understand each other, communicate and work together effectively, it is essential to have an organization that can act as a facilitator during the startup phase, to ease the tensions and progressively make partners better understand each other (through regular workshops, exchange visits, adjustments of detailed procedures, moderation, etc.). However, one cannot expect such type of two-hand model to be fully functional and sustainable since the beginning: building partnerships between RFIs and solar solution providers remains a learning process that requires strong motivation, commitment, patience and perseverance from all partners.

Motivating solar distributors and RFI field staff is instrumental in achieving good results.

Solar solution distributors are typically located in urban areas and have a very limited knowledge of the needs of the BOP and the challenges of working in rural areas. In Cameroon, the partner distributor was at first enthusiastic at exploring this new market segment. However, its level of motivation and commitment decreased quickly when the company realized the specificities and complexities of working in rural areas and started to question the market potential behind access to clean energy for poor rural populations, which hindered the progress of the pilot. In Ethiopia, the situation was very different: the partner distributor has shown very high interest and commitment, which has allowed to build trustful relationships with RFIs more easily. However, the distributor is mainly motivated by its social responsibility and still rather skeptic on the business case in addressing this new market. Lack of successful business cases and slow returns on investment are key challenges in keeping national distributors motivated.

Motivating **RFI field staff** is also of critical importance. Loan officers often perceive Solar Loans as complex and time-consuming. Managing these products required a greater involvement of field staff, in particular to coordinate purchase orders and deliveries,

Solar panel installed on the roof of a rural house, Kenya
Source: PAMIGA

support clients to install kits, and educate them in the proper use of the solutions. At times, loan officers even had to act as a facilitator for after-sales services. The risk then is that loan officers prioritize more conventional loans, at the expense of Solar Loans. The pilots made it clear that it was essential to clearly communicate to the teams on the financial and strategic benefits expected for their institution, as well as to have an adapted incentive system (financial or otherwise, dedicated to Solar Loans while at the same time fully integrated in the overall incentive scheme of the RFI), while adjusting the allocation of roles between RFIs and local distributors.

RFIs cannot do it all.

Quite quickly, it appeared that the initial distribution of roles and responsibilities defined between the microfinance and energy actors could not be applied. Solar solution distributor, historically located in urban areas, did not have the decentralized representatives in rural areas to perform the required tasks of marketing and after-sales services. They even tended to assimilate RFIs to retailers of solar solutions, expecting them to be actively promoting the solar solutions and distributing them on their behalf. As a consequence, RFIs' field staff had to assume a variety of additional activities, ranging from delivery of the kits to education of clients on the use of the solar solution and management of after-sales services. This goes far beyond what microfinance institutions usually do and had a direct impact on staff motivation: the new financial products were then perceived as too complex, costly and time-consuming for the rural outlets. With no local presence of the solar solution distributor and low motivation from microfinance field officers, the marketing of solar products and Solar Loans was thus very limited, resulting in low demand from clients.

The pilots made it clear that RFIs alone cannot do it all: they are not in a position to act as a retailer and handle all technical services (i.e. marketing, delivery, installation, customer education, after-sales services). Loan officers cannot become "sales agents" getting commissions for each solar unit sold. Such positioning would actually represent a mission drift which could put at risk the whole institution. To bridge the gap between urban-based solar solution distributors and rural target clients, PAMIGA and its partners then decided to set up networks of Energy Entrepreneurs, located in the villages. These entrepreneurs are responsible for promoting solar solutions and offering local high quality services to clients (delivery, installation, after-sales services). A business model has been defined so that the Energy Entrepreneurs are profitably and sustainably integrated into the partnership between the RFIs and solar solution distributors *(please refer to the following article Allet (2016), "Energy Entrepreneurs : an innovative model to reach the last mile).*

3.4. POTENTIAL FOR UP-SCALING AND REPLICATION

Building on these lessons, PAMIGA is now supporting partner RFIs in Cameroon, Ethiopia and Kenya in scaling up, by rolling out Solar Loans to their whole networks of rural branches and diversifying the offer of solar solutions (from solar lanterns to larger solar home systems, from domestic to productive use of energy). The two-hand model is also being replicated in new countries where PAMIGA has partner RFIs, such as Benin and Senegal, each time with specific attention given to adaptation to the local context and with a long-term vision aiming to build a sustainable, efficient and scalable business model.

"RURAL FINANCIAL INSTITUTIONS ALONE CANNOT DO IT ALL."

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ENERGY ENTREPRENEURS: an innovative model to reach the last mile

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Delivery of solar lanterns at the last mile, Ethiopia
Source: PAMIGA

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PAMIGA (Participatory Microfinance Group for Africa) is an international NGO that aims to unlock the economic potential in Africa by promoting the growth of financial institutions that service rural areas. It provides technical assistance to a network of 16 RFIs in sub-Saharan Africa.

KEYWORDS

- LAST MILE
- SOLAR ENERGY
- ACCESS TO ENERGY
- RURAL DISTRIBUTION
- RURAL SUB-SAHARAN AFRICA

Today, reaching the last mile in remote rural areas remains a big challenge for many solar solution providers. Since 2014, PAMIGA has been testing a new model to bridge the gap between urban distributors and rural clients: the Energy Entrepreneur model. This article presents the unique features of the model, its first results and impacts, as well as the key challenges and lessons learned from its implementation in Cameroon and Ethiopia.

INTRODUCTION: THE CHALLENGE OF LAST MILE DISTRIBUTION FOR SOLAR SOLUTIONS

Access to electricity in rural areas in sub-Saharan Africa could be greatly improved thanks to off-grid, solar solutions. A range of technologies exist today. However, many providers and distributors of solar solutions face a clear challenge of reaching the last mile, i.e. reaching out to customers located in rural, off-grid, remote areas. Shukla & Bairiganjan (2011) indeed identify some key challenges to the distribution of energy products for rural Base of the Pyramid (BoP): the sparse population density, lack of infrastructures, variety of local languages and low literacy level. These features of the BoP market make it difficult for providers of solar solutions to develop standard, cost-effective marketing and communication material, to disseminate quickly knowledge and experience, and to manage distribution and as well as customer and maintenance services in a cost-effective way (Winiecki & Kumar, 2014). The challenge is even more acute since manufacturers or distributors who have the capacity to import and/or assemble solar solutions are systematically located in urban centers. Within this specific context, PAMIGA has been testing a new model to bridge the gap between urban distributors and rural clients: the Energy Entrepreneur model. This article presents the unique features of the model, its first results and impacts, as well as the key challenges and lessons learned from its implementation in Cameroon and Ethiopia.

1. A VARIETY OF LAST MILE DISTRIBUTION MODELS

To distribute their products in rural areas, solar solution manufacturers and distributors have to find intermediaries between them and the customers. In the very dynamic market of clean energy for the Base of the Pyramid, a variety of strategies are being tested in this perspective:

DEVELOPING OWN NETWORK OF LAST MILE AGENTS (PROPRIETARY DISTRIBUTION MODEL)

Some solar companies have opted for developing their own network of employees (sales agents and technicians). This is for instance the case of Mobisol, who has created its own network of "market huts" in small towns of Tanzania (Linder, 2014), and of Simpa Network, who has set up a network of sales agents and technicians to ensure installation, maintenance, repair and education on solar solutions in India (Needham, 2014). This strategy however implies high upfront investments. Very few manufacturers actually choose this option due to the complexity and prohibitive costs related to channel development, control, monitoring and management (Shukla & Bairiganjan, 2011).

PIGGYBACKING ON EXISTING NETWORKS

Solar solution companies have been very innovative in identifying existing decentralized networks and piggybacking on them. SolarAid-SunnyMoney, for instance, opted for penetrating the rural BoP market in East Africa through rural school teachers, starting with entry-level solutions at special price in school (Miller et al., 2015). This strategy has proved efficient to build trust and get the market started, but can only be considered as a first step before developing a network of agents or shops.

Other solar solution providers have opted for piggy-backing on existing networks of gas stations, such as OneDegree Solar (Stout, 2015), or telecom retailers (such as d.light in Ethiopia). Yet, these intermediaries are usually limited to pico-solutions (lanterns) that do not require any strong technical knowledge, since they would not have the mandate and capacity to provide more complex installation and repairing services.

Most solar companies also try to work through small retailers, such as OneDegree Solar, BBOXX, d.light, Light4All Cameroon, etc. However, they widely agree that the model presents some key challenges. First, small retailers in rural areas often lack the capacity to pre-finance a small stock of solar kits. Some companies have tried to consign products or provide credit facilities to the retailers, but the experience did not always turn out well. For instance, Light4All, in Cameroon, faced repeated cases of fraud from retailers who had sold the kits but refused to pay the distributor back. Second, solar distributors, being based in urban areas, have difficulties to identify reliable small retailers in rural areas and to closely monitor their activities. Several solar companies emphasize that these retailers are often very active in marketing and selling the solutions, but lack capacities to properly handle their stock and do not have the right mindset when it comes to providing customer services, in particular after-sales services (Hamayun, 2014; Mercy Corps & d.light design, 2013; Shukla & Bairiganjan, 2011).

Finally, several providers have also opted for partnering with rural financial institutions (RFIs) to reach the last mile, such as banks or microfinance institutions' networks. RFIs indeed have a good knowledge of their clients and the capacity to offer financial services to facilitate investment in the solar solutions. However, experience has showed that not all microfinance institutions have the capacity to reach out to rural areas (Linder, 2014), that many were reluctant to actively enter in this market that appeared risky in their eyes (Hamayun, 2014), and that one cannot expect financial institutions to take over full responsibility for marketing, delivering, installing and maintaining solar solutions (PAMIGA, 2014; Shukla & Bairiganjan, 2011; Allet, 2016).

FOSTERING LOCAL ENTREPRENEURSHIP

Another strategy tested has been that of fostering the creation of local microenterprises or microfranchises, as tested by Orb Energy in India or Solar Sister in East Africa (Lucey, 2015). This model slightly differs from that of small retailers, since the microentrepreneurs are not necessarily involved in retail selling beforehand. These microentrepreneurs may become sub-retailers of solar solutions (Lucey, 2015) or manage solar battery charging stations and charge small fees to their local customers (Vermot-Desroches & André, 2012). This model has proved efficient in certain contexts but seems to require a high level of technical support to help the microentrepreneur build their skills and capacities. Furthermore, similar to the model of small retailers, a main challenge remains the lack of financing capacity of these microentrepreneurs.

USING TECHNOLOGIES

Finally, some companies involved in "pay-as-you-go" models are using technologies (like SMS or mobile money) to facilitate payments, customer education, impact data survey and customer support services (Hamayun, 2014; Stout, 2015). This strategy is very cost-effective once the clients have received their solar solution. Technologies cannot however fully replace the need to have last mile agents for the promotion, delivery, installation and maintenance of the solar solutions.

The different strategies implemented to reach last mile populations all seem to have their own advantages and limitations. Within its specific context of intervention, PAMIGA has been testing a new hybrid model in the past years: the Energy Entrepreneur (EE) model.

2. THE ENERGY ENTREPRENEUR MODEL TESTED BY PAMIGA

2.1. ORIGINALITY OF THE MODEL

The model tested by PAMIGA is innovative in that it tries to combine different strategies of last mile distribution in order to take the best from each and mitigate their respective risks. More specifically, the Energy Entrepreneur model seeks to develop a network of independent last mile agents while piggybacking on RFIs' structures.

EEs are independent individuals, from local communities, who are selected and contracted by solar solution distributors to perform activities of promotion, installation, customer education and after-sales services at the last mile level.

The model is innovative in that it involves various stakeholders who each play a key role in setting and managing the network of EEs. Similar to some "sales agents" or "sub-retailer" models, the solar distributor signs contracts with the EEs, provides them with specific training on their solar solutions (technical and marketing training), pays them a commission for their work, and ensures technical and after-sales support. However, in PAMIGA's model, the distributor is not the only entity in relation with the EEs. RFIs, who are partnering with the concerned solar distributors (refer to Allet, 2016) are also involved in developing and monitoring the network of EEs. Thanks to their existing decentralized structures, RFIs help address several of the challenges and risks faced by solar energy companies who try to develop last mile agent networks, but without having to perform themselves the role of these last mile agents.

More specifically, the hybrid model tested by PAMIGA seeks to manage the following risks:

- **EEs are carefully selected with the support of RFIs' field staff,** who already know the local people and communities and can easily ensure the selection of candidates with good reputation (honest). This can **limit the risk of fraudulent or irresponsible behaviour** from last mile agents.
- **EEs are service providers. They do not hold a small stock or directly buy from the distributor and sell to clients**. EEs are indeed in charge of: (a) promoting solar solutions among the rural communities to which they belong; (b) assisting clients in installing their solar solutions, when needed; (c) raising clients' awareness on the good use and maintenance of the solar solution; and (d) facilitating after-sales services by responding to clients' questions or complaints, making a diagnosis in case of technical problem, fixing the problem when it is due to inadequate installation or maintenance, informing clients about the warranty conditions, and coordinating with the solar distributor when defective kits have to be replaced. In a first phase, PAMIGA and its partners thus decided to limit the role of EEs to that of village-based service providers, rather than a role of sub-retailers who hold a small stock of solar solutions and buy and sell them directly to end-customers. With this approach, it becomes easier to select adequate profiles among a wider range of candidates, since EEs do not need to have a small shop or warehouse. Furthermore, **capacity to pre-finance a small stock at local level is not an issue anymore.**
- **EEs do not directly handle cash**. EEs do not handle any cash payment between the clients, RFIs and distributors. They are not remunerated on a margin that they would make by buying and selling solar kits themselves (sub-retailer model), but are paid a commission for each unit sold (more similar to some proprietary agent models). As agreed within the partnerships between RFIs and solar solution distributors, **payments of the solar solutions are made by RFIs directly to the solar solution distributors** (refer to Figures 1 and 2 for more detailed processes). This strategy has two clear advantages for the distributors: (i) the purchase orders are compiled at RFIs' level, making it easier for the distributor to optimize its deliveries to rural areas; and (ii) the **risks of default on payment and fraudulent behaviours are drastically reduced for distributors.**
- **EEs are monitored with the support of RFIs' field staff.** Thanks to their network of branches and rural outlets, RFIs are indeed in a much better position than urban-based solar distributors to check if EEs are performing well and **make sure that any risk of fraud or drift is quickly and effectively mitigated**. Additionally, by approving and supervising the EEs, the RFIs play a crucial role in making Energy Entrepreneurs appear as trustable in the eyes of clients.

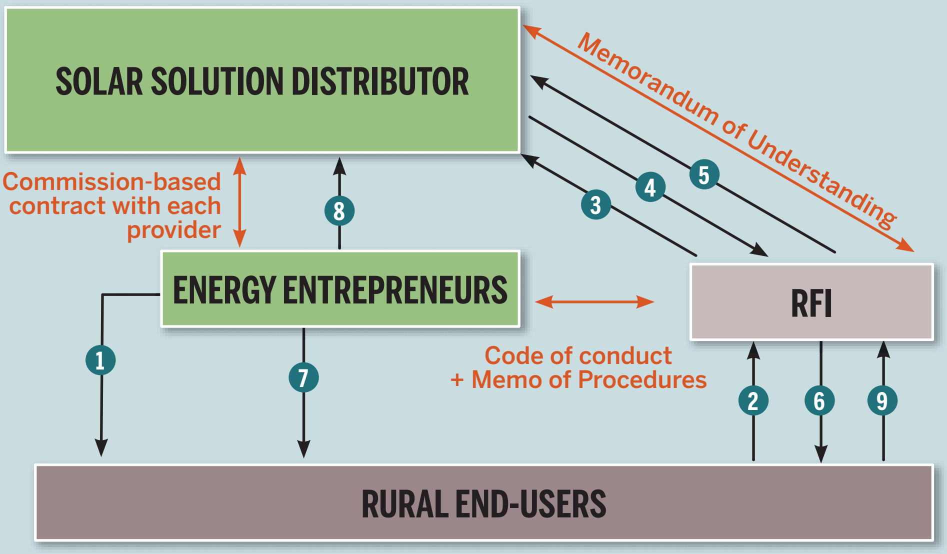
2.2. INSTITUTIONAL FEATURES OF THE MODELS IMPLEMENTED IN ETHIOPIA AND CAMEROON

This innovative model has been tested by PAMIGA since 2014 in Ethiopia and Cameroon.

In Ethiopia, the partner RFIs not only offer financial services to end-users who would like to invest in a solar solution; but they also play a key role in making the network of EEs successful. Indeed, if contractual relations of EEs are with the distributor, operational relations are mostly handled by partner rural RFIs. The latter are in a better position to manage, supervise and monitor the EEs, thanks to their presence in rural areas. Branch managers and loan officers are thus in charge of: (a) coordinating with EEs for conducting joint demonstration sessions; (b) organizing the schedule of EEs for installation of the solar solutions at clients' houses; (c) facilitating the commission payment to EEs on behalf of the distributor; and (d) monitoring the performance of each EE and providing feedbacks to the distributors.

"THE ENERGY ENTREPRENEUR MODEL SEEKS TO DEVELOP A NETWORK OF INDEPENDENT LAST MILE AGENTS WHILE PIGGYBACKING ON RURAL FINANCIAL INSTITUTIONS' STRUCTURES."

Energy Entrepreneur model implemented in Ethiopia

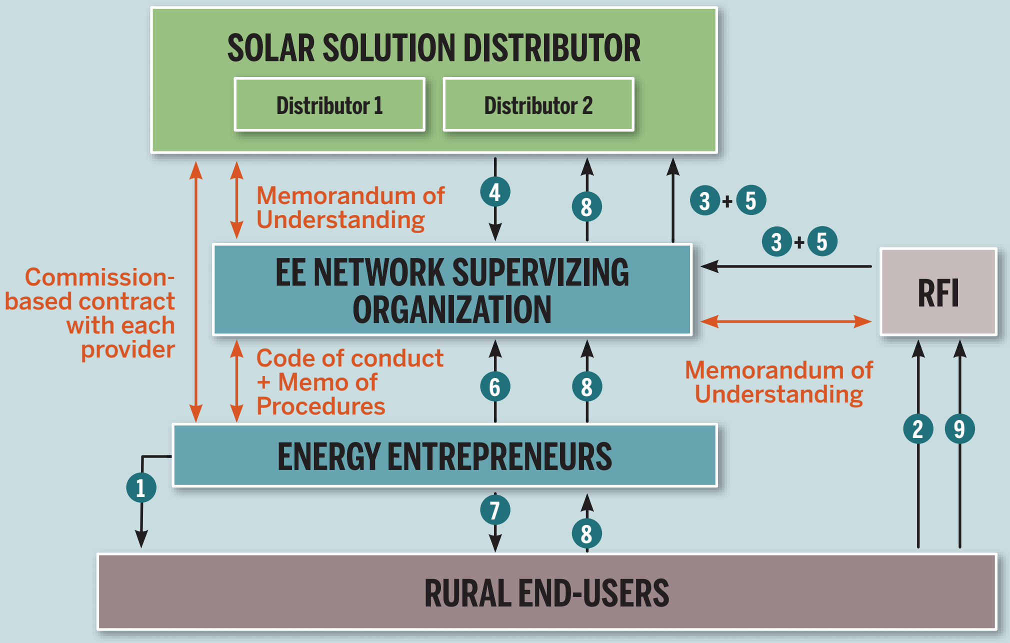


1. EEs conduct promotion activities (together with RFI field staff as well as independently); during these activities, they collect names of interested clients and refer them to the RFI branches.
2. Clients apply for a loan.
3. Once the loan is approved, the RFI places an order with the solar solution distributor.
4. The solar solution distributor delivers the solar solutions to the RFI branches.
5. The RFI pays the solar solution provider on behalf of the clients.
6. The RFI hands over the solar solutions to clients.
7. EEs provide customer services: client education, assistance in installation, after-sales services.
8. EEs coordinate with the distributor if the warranty has to work.
9. Clients repay their loans to the RFI.

Figure 1

In Cameroon, the model was slightly different, with the introduction of a local NGO, MIFED[1], to play to role of supervising organization of EEs. In this model, MIFED plays a key intermediary role between all partners (solar solution distributors, rural RFIs, and EEs), compiling purchase orders, centralizing kit deliveries, facilitating payments of EEs on behalf of the distributors, coordinating after-sales activities, and monitoring EEs' performance. The organization furthermore provides strong technical support to EEs regarding marketing techniques and business management. To play this role of coordination, supervision, animation and monitoring of the EEs, MIFED has been granted specific funding from PAMIGA.

Energy Entrepreneur model implemented in Cameroon



1. EEs conduct promotion activities (together with RFI field staff as well as independently); during these activities, they collect names of interested clients and refer them to the RFI branches.
2. Clients apply for a loan.
3. Once the loan is approved, the RFI places an order with the solar solution distributor, through the EE network supervising organization.
4. The solar solution distributor delivers the solar solutions to the EE supervising organization.
5. The RFI pays the solar solution provider on behalf of the clients, through the EE network supervising organization.
6. EEs pick up the solar kits from the EE supervising organization.
7. EEs hand over the solar solutions to clients and provide customer services: client education, assistance in installation, after-sales services.
8. EEs coordinate with the distributor if the warranty has to work, through the EE network supervising organization.
9. Clients repay their loans to the RFI.

Figure 2

1 MIFED (Microfinance & Développement) is a Cameroonian NGO that provides technical assistance to microfinance institutions in Cameroon. It has been a historical partner of PAMIGA.

This difference between the Ethiopian and Cameroonian models is directly linked to the context of intervention in each country: in Ethiopia, RFIs were initially working with a single partner distributor who expressed strong motivation in directly developing and supervising such a network of EEs; while in Cameroon, RFIs were planning to work with two different distributors and identified the involvement of a third party as a better option to develop a brand-agnostic network of EEs which could be used by both distributors (thereby fostering synergies and economies of scale).

2.3. SELECTION OF ENERGY ENTREPRENEURS

In Cameroon and Ethiopia, criteria for selecting EEs were defined during participatory workshops gathering representatives of the RFIs and solar solution providers. In general, participants agreed that the ideal profile of an EE is that of a young dynamic person, well settled in the target rural area, well known and appreciated by the community. Requirements regarding the level of education remain basics (being literate) since it is not realistic, in these rural areas, to expect to find graduates from technical schools in all villages. Rather, what is favoured is the high motivation, willingness to learn and perform, and capacity to handle things.

ENERGY ENTREPRENEUR SELECTION CRITERIA DEFINED IN ETHIOPIA

- √ Target: between 18 and 35 year-old
- √ Must speak the local language
- √ Must know how to read and write
- √ Hight interest / willingness / motivation in promoting access to solar solutions
- √ Settled in the village or area
- √ Should already have a source of revenue – EE activity only as additional
- √ Available for an extra activity / not involved in too many activities
- √ Good reputation, trusted by the community
- √ Good physical condition (to walk distances and carry the kits)
- √ Ability to talk / convince / communicate / market
- √ Knowledge or experience in technology-related businesses: mobile phone charging, mobile maintenance, radio repairing, etc.
- √ High school / technical training education is an asset
- √ Having received training on solar energy through the Ministry of Energy program is an asset
- √ Owning own means of transportation (horse, mule, bike, etc.) is an asset

"RURAL FINANCIAL INSTITUTIONS PLAY A CRUCIAL ROLE IN MAKING ENERGY ENTREPRENEURS APPEAR AS TRUSTABLE IN THE EYES OF CLIENTS."

As they have a good knowledge of the rural communities where they work, the RFIs' loan officers and branch managers were asked to identify candidates with the right profile in their area of intervention. The solar solution distributor then conducted interviews with each candidate to assess the adequacy of their profile and their level of motivation. The coordinator of clean energy activities within the RFI (referred to as "Energy Champion") also participated in the interviews. The final decision was then jointly made by the solar solution distributor, RFI branch manager, and RFI Energy Champion. In general, between 2 and 4 EEs were selected per branch or rural outlets, depending on the areas to be covered.

In both countries, the typical profile of selected EEs was that of a young man, aged between 20 and 35, usually engaged in farming activities and developing (or seeking to develop) a small business to get an additional source of income. Despite efforts to promote female candidates, very few women applied to this opportunity because the job of EE, which implies frequent visits to households and community groups, was often perceived as not "suitable" for woman (although in reality, the few women selected to become EEs have proved to be among the most active and performing EEs so far).

Training graduation of the first Energy Entrepreneurs in Cameroon
Source: MIFED

2.4. TRAINING OF ENERGY ENTREPRENEURS

Selected EEs then received a two-day training on the following topics:

- Introduction to solar energy and selected solar solutions (products, components, functioning, installation, capacity, autonomy, limitations, etc.);
- Role and responsibilities of the EEs;
- Supervision / relation with the RFI and solar solution distributors;
- Procedures to follow;
- Marketing messages and techniques;
- Installation of the solar solutions and basic trouble-shooting / maintenance;
- Key messages and techniques for customer education on the good use of the kit;
- Business management;
- Sales price and commission payment;
- Objectives, evaluation and incentive system.

In Ethiopia, the trainings were exclusively conducted and financed by the solar solution distributor, with technical support of PAMIGA to develop the training module. A total of 48 EEs received training in June 2014. In Cameroon, the trainings were conducted by MIFED, with technical support from the partner solar distributors. A first round of 23 EEs was trained in September 2014 (followed by a second round of 19 EEs in May 2015).

In both countries, at the end of the trainings, the EEs who proved to have sufficient motivation and capacity were invited to sign a contract with each solar distributor, as well as a Code of Conduct describing the responsibilities of the EE and his moral commitments towards clients and partners. Contracts were signed with 44 Energy Entrepreneurs in Ethiopia and 40 Energy Entrepreneurs in Cameroon. They were also given a Memo of Procedures presenting in details the procedures to follow for each activity under the EE responsibility (what should be performed, by whom, when).

2.5. MARKETING MATERIAL

In Cameroon, partners identified very soon that it was crucial to create visibility and sense of identity for the EEs. In this perspective, a logo was created and printed on T-shirts, each EE being granted 2 T-shirts. The objective was dual: (a) to create a sense of ownership, a pride to be an EE, a feeling of belonging to a group and a collective project; and (b) to give visibility to the EEs, making them "legitimate" representatives of the solar solution providers in the eyes of local communities. Each EE was also provided with a demonstration kit and with a first pack of 300 flyers promoting the solar solutions and Solar Loans. The demonstration kits were granted by the solar solution provider, while the T-shirts and flyers were financed with the support of PAMIGA.

In Ethiopia, the network of EEs was developed under the supervision of the partner solar distributor. The latter decided that for an initial phase, providing one demonstration kit at the RFI branch level, to be used by the EEs operating around that branch, would be sufficient. No marketing material was thus provided to the EEs at that time.

2.6. COMMISSION PAYMENT

To perform their tasks of promotion, installation, customer education and after-sales services, EEs are paid a commission for each unit sold. This commission was included in the price of the solar solution, in order to ensure the sustainability of the model. The level of commission for each type and unit of solar solution was discussed among partner RFIs and solar solution providers, with inputs from loan officers and EEs themselves. The objective was to define a commission that is attractive enough to keep EEs motivated, while not increasing too much the price for the end-client. In Cameroon, the commissions were set between FCFA 500 (EUR 0.75) for solar lanterns and FCFA 4,000 (EUR 6) for larger solar home systems, representing 2% to 4% of the price of the solution. In Ethiopia, the commissions were defined between ETB 50 (EUR 2) for solar lanterns and ETB 120 (EUR 5) for larger solar home systems, representing 3% to 4% of the price of the solution. It was decided that the commission will be paid after EEs have assisted clients in installing the solar solutions and brought back satisfactory reports signed by the clients.

Entrepreneur
Energie

Figure 3. Example of Energy Entrepreneur logo from Cameroon

In both countries, there were intense debates on the relevance to provide separate commissions for the performance of after-sales services. Most partners were however concerned that EEs could perform unnecessary or false after-sales services in order to charge additional commissions to the distributor. It was thus decided to keep a single commission per unit sold, which includes the remuneration of after-sales services (as a flat rate), and to clearly communicate to EEs that they still remain responsible to perform after-sales services during the warranty period, making them aware that if clients face a technical problem that is not properly solved, it will generate negative word-of-mouth that will finally impact the demand, and therefore the potential business for the EE. To make this mechanism work, it is then crucial to make sure that clients are fully aware that EEs should perform these after-sales services "free-of-extra-charge" during the warranty period and that proper client complaint mechanisms are in place to enable proper monitoring.

2.7. INDIVIDUAL TARGETS DEFINITION AND MONITORING

During the trainings, selected EEs were also asked to set their own goals (in terms of number of solar solutions) for the coming 6 months. They could define (a) minimum targets they are sure to achieve; and (b) more ambitious objectives that they would do their best to achieve. The trainers provided them some guidance when they believed that the self-defined objectives were not realistic or too modest. Making EEs define their own goals, rather than imposing targets, was a way to create motivation and ownership.

Monitoring of performance for each EE was then facilitated by MIFED, the EE supervising organization, in Cameroon. In Ethiopia, this role was given to RFIs' loan officers, who are in a better position than the distributor to follow up what is going on in the field – checking the number of clients brought by the EE, clients' feedbacks on after-sales and other customer services, etc. In case of problem, the RFIs then report to the solar solution distributor, who is responsible to follow up with the concerned EEs.

EEs already receive a commission per unit sold: this already constitutes an "incentive" for them to perform on promotion and after-sales services. However, as solar energy was a new area for most selected EEs, partners agreed that it would be useful to set some exceptional rewards during the first year of operations in order to boost EEs' motivation and make them realize that, once they have overcome the challenge of starting a new activity, solar energy could be a good business opportunity for them. In both countries, the partners jointly define some "thresholds" (in terms of number of solar solutions) that would allow the EE to get a special reward. Possible rewards, according to the EE performance, were the following: certificate of good performance, additional T-shirts and hats, free demonstration kit, selection to be trained on larger solar solutions, and exceptional cash reward.

"THE UPTAKE INCREASED FROM 20 SOLAR KITS PER MONTH BEFORE THE INTRODUCTION OF ENERGY ENTREPRENEURS, TO 117 KITS PER MONTH AFTER."

3. MAIN RESULTS AND LESSONS LEARNED

3.1. FIRST RESULTS OF THE PILOT IMPLEMENTATION

A higher uptake of solar solutions

In Cameroon, the results were quite fast and impressive in terms of uptake. Two weeks after the first training (September 2014), a couple of EEs had already sent a first purchase order. Within 3 months (October to December 2014), a total of 468 solar kits were ordered, multiplying monthly performance by almost 17. The trend however decreased slightly in the following months, as the solar solution distributor had not anticipated such a larger uptake and had to renew its stock of solar kits. On average, the uptake increased from 20 solar kits per month before the introduction of EEs (October 2013 to September 2014), to 117 kits per month after (October 2014 to December 2015). This trend could thus hint to a positive effect of EEs on the uptake of solar solutions, thanks to their active promotion activities at the last mile level. However, this data should be interpreted with caution since it is difficult to attribute this positive change to the sole introduction of the EE model: many other factors, such as the evolution of the partnerships between the RFI and distributor, range of solar solutions offered, seasonality of income, etc., may also have influenced these results. In Ethiopia, it is indeed even more difficult to attribute the impact of EEs to the global uptake of solar solutions, since EEs were included in the partnership model between the RFIs and distributor since the beginning.

Some positive effects identified by the various stakeholders

Partner RFIs in both countries seem to clearly appreciate the role performed by EEs. In Cameroon, RFIs have expressed that the introduction of EEs and the involvement of MIFED in supervising them have clearly reduced the burden on field staff, who were released from most promotion, education and follow up activities linked to the solar solutions, and could focus on the financial services provided to the clients. In Ethiopia, the RFIs' field officers have identified a clear contribution of the EEs in terms of client education: in areas where EEs have been actively involved, the rate of client complaints due to misuse of the solar solution clearly decreased (i.e. from 100% to 18% in Tulu Habib rural outlet, Ethiopia). This had overall a positive impact on the image of the solar solutions and the RFIs.

Rural clients themselves, interviewed by PAMIGA during focus group discussions (conducted with over 200 clients in Cameroon in June-July 2014 and 75 clients in Ethiopia in March and October 2015) similarly seem to appreciate the presence of EEs at village level. In particular, they value the fact that the EE is from the community, which has several advantages in their view: (a) he/she can speak the local language; (b) clients know where to find him/her quite easily; (c) clients can use social pressure in case the EE is not performing his/her tasks properly. Overall, clients mostly appreciated the support that they received from EEs in terms of installation, customer education and facilitation of after-sales services.

As for distributors of solar solutions, they seem to be less aware of the impacts brought by EEs. In Cameroon, partner distributors have seen the positive change in the uptake of solar kits following the introduction of EEs. In Ethiopia, it is more difficult, as already mentioned, to identify a separate effect in solar kit uptake. As they are far from the field, distributors do not get regular feedbacks from end customers themselves regarding the role of EEs. As a result, they seem to be less convinced of the added value of EEs for their own business. This is also linked to a common misbelief among solar solution distributors: the idea that RFIs' field officers could actually perform the same job as EEs... However, many experiences have proved that one could not expect RFIs to play this role (PAMIGA, 2014; Shukla & Bairiganjan, 2011; also refer to Allet, 2016).

Opinion from Energy Entrepreneurs themselves

EEs interviewed by PAMIGA as part of regular follow-up activities (focus groups with 5 EEs in Cameroon in January 2015 and 7 EEs in Ethiopia in March 2015) have expressed mixed feelings regarding their own activity as EEs. On the one hand, they identified some challenges that they were facing and that could be possible areas of improvement for the model. In Cameroon, for instance, EEs mentioned that rural customers were putting high pressure on them to deliver the solar solutions in a very short period of time, which would be less challenging if EEs were allowed to manage small local stocks. In Ethiopia, many EEs requested to get more training and technical support to adequately perform their tasks. On the other hand, interviewed EEs also perceived great potentials. In Cameroon, several of them still expressed high ambitions:

> *"I see great opportunities here. I want to develop this activity, make it my main business, and maybe soon have one or two people work for me!"* (EE, Cameroon),

Rural woman displaying the solar panel that she uses for lighting her house, Ethiopia - Source: PAMIGA/Ries Engineering

"IN AREAS WHERE ENERGY ENTREPRENEURS HAVE BEEN ACTIVELY INVOLVED, THE RATE OF CLIENT COMPLAINTS DUE TO MISUSE OF THE SOLAR SOLUTION CLEARLY DECREASED."

In Ethiopia, even though EEs said that the commission was slightly lower than what they initially expected, the majority still perceived this job as a good opportunity for them to make some extra income in rural areas where job opportunities are scarce.

3.2. KEY CHALLENGES AND LESSONS LEARNED

Building a last mile EE network still remains a complex and progressive process. Various challenges were encountered during the testing phase of the model, bringing valuable insights for practitioners:

Managing the relationships between RFIs' field staff and Energy Entrepreneurs.

Field staff from partner RFIs has sometimes perceived EEs as competitors that have "stolen" a business opportunity away from them. Pricing of the commissions had to be defined making sure that it would not appear as "unfair" (too high) in the eyes of the RFI staff, while still being attractive enough for EEs. In some areas, some credit committee members or loan officers tried to become EEs despite the clear conflict of interest it would create. Indeed, EEs are incentivize to sell as many solar kits as possible; while loan officers have a dual objective, that of reaching out to many clients, while ensuring that the quality of their portfolio remains high and therefore rejecting applications for clients with insufficient capacity to repay. Furthermore, when PAMIGA and solar solution distributors suggested allowing the most dynamic EEs to hold a small stock and directly handle cash sales, the RFIs expressed clear disapproval, as they were concerned that the EEs would start providing credit and distort the market. By not allowing EEs to handle cash sales directly, RFIs have however put constraints on the EE business model. Balancing the respective interests of each stakeholder thus constitutes one of the clear challenges of this model.

Defining a viable model to supervise and monitor Energy Entrepreneurs.

In Cameroon, MIFED has been mobilized to provide technical support to the network of EEs, to facilitate the relations between EEs, the RFIs and the solar solution distributors, and to

Rural Ethiopian family in front of their house equipped with solar energy - Source: PAMIGA

supervise and monitor the performance of the EEs. MIFED has been playing a crucial role in animating the network in a very successful way. However, MIFED's involvement still depends on donors' grant (channeled through PAMIGA). A more sustainable model needs to be developed to ensure the institutional viability of the value chain.

In Ethiopia, the network of EEs has been supported directly by the solar solution distributor, with the assistance of the RFIs. The direct involvement of the distributor in the supervision of EEs could logically entail a better outlook for sustainability than having a donor-funded external support organization performing this role. Yet, the experience in Ethiopia also revealed the limitations of this approach. First, EEs have been much less active in Ethiopia than in Cameroon, because it was more challenging for the distributor to allocate enough internal resources to ensure the required close monitoring of EEs[2]. Second, EEs in Ethiopia have not been able to work with other energy companies so far, contrarily to Cameroon, whereas the EE business model would be stronger if EEs were able to work with several energy companies at the same time, diversifying the catalog of clean energy solutions that they can offer to rural populations.

Keeping Energy Entrepreneurs motivated.

Experience has showed that EEs are extremely motivated right after receiving training. However, this motivation quickly decreases if they lack adapted technical support from the solar company or other partner[3]. In Cameroon, for instance, out of 40 EEs who had received training and signed a contract, 18 only were active in December 2015. To keep EEs motivated, PAMIGA and its partners tested various strategies, such as building an identity as EE (through a local name, a logo, branded T-shirts and hats, etc.), defining targets in a participatory way and monitoring them, setting a performance-based incentive scheme, organizing refresher trainings and peer learning workshops, defining a graduation model, etc. The pilot experience showed that strong support and close monitoring are needed when developing such a model, such as regular refresher trainings and peer-learning activities, frequent interactions with a supervisory organization or person to monitor promotion activities and performance, etc.

Building a market for Energy Entrepreneurs.

EEs tend to perform high in the first months, as they catalyze the low-hanging fruits, from customers close to them and who were already ready to invest in solar. However, they find it more difficult to reach out to other customers, slightly further from their social circles (families, friends, neighbors, church groups, women groups, children school, etc.) or with lower awareness of solar. A risk could

2 Some organizations, like Solar Sister or Frontier Markets, have also identified that manufacturers or distributors may not necessarily have the capacity or willingness to supervize a network of last mile agents. Both organizations have thus developed dedicated services to promote, manage, and monitor such networks of last mile solar agents. They have initiated interesting models but are only operational in a limited number of countries today.

3 Similar findings from Mercy Corps & d.light design (2013).

be that they quickly saturate their local market and lose interest in this activity.

Similar to other experiences (Lucey, 2015; Miller et al., 2015), some EEs in Cameroon and Ethiopia have stood out as "super agents", generating most of the sales. These EEs have showed high motivation and strong innovation and entrepreneurship skills. For instance, in Cameroon, a couple of EEs created stamps with their name and EE function that they used on the flyers and warranty cards provided to clients. Another EE had the idea to use his demonstration kit to light up a wedding ceremony, attracting a lot of attention from the rural community. As mentioned by Lucey (2015), in this type of model, it is not surprising to have a high attrition rate: some entrepreneurs become superstars, while others are active for 3, 6 or 12 months, hit a wall after the "easy market", and lose interest. Even if one cannot expect to keep all EEs active over the medium to long term, a variety of actions can be taken to help the most motivated EEs expand their market, such as: diversifying the range of clean energy solutions that they can promote, building their marketing and business management skills, making them progressively graduate to more complex solar solutions, or supporting them to develop larger businesses employing staff to cover broader markets.

3.3. THE WAY FORWARD

PAMIGA and its partners are now building on these lessons learned to make the EE model more efficient and sustainable. The vision is, after a first testing phase, to make the role of the most engaged and performing EEs evolve as follows:

- **Direct distribution of solar lanterns and other pico-solutions.** From mere "service providers", the most performing EEs would become independent entrepreneurs who could manage a small stock and handle cash sales directly with end customers (when the latter do not need a loan). They could receive a loan from the partner RFI to finance their working capital.
- **Installation and maintenance of larger solar solutions.** Performing EEs could progressively upgrade to the installation and maintenance of larger solar solutions, which would be purchased by end customers through Solar Loans obtained from the partner RFI. One step further, one could even envision that the most performing and ambitious EEs could become operators of solar mini-grids at community level.

This strategy would enable EEs to diversify their market and, potentially for some of them, make their EE activity evolve from an extra, part-time job, towards a full-time, profitable business. This evolution would of course require removing the reluctances of partner RFIs to see EEs handle cash sales, adapting the existing selection and monitoring processes to make sure that the risks of fraudulent or irresponsible behaviors are still managed, and identifying the adequate pricing and realistic break-even point to guarantee the profitability of the business for EEs. This is with this vision that PAMIGA is now working on improving the implementation of the EE model in Cameroon and Ethiopia, and expanding it to other countries (Senegal, Benin, Kenya).

"STRONG SUPPORT AND CLOSE MONITORING ARE NEEDED WHEN DEVELOPING SUCH A MODEL."

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Source: HERi Madagascar

4. SUMMARY AND REVIEW

15 YEARS OF DEVELOPMENT IN ACCESS TO OFF-GRID RENEWABLE ELECTRICITY: insights from the Ashden Awards

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379 organisations providing access to renewable electricity, who applied for Ashden Awards during the past 15 years, mostly used solar home systems and solar lamps. Trends found are that the number of applicants and the scale of their work have increased; East Africa has overtaken South Asia as the region with most applicants; and most applicants are now for-profit enterprises. Case studies of Ashden winners illustrate benefits and challenges.

Off Grid Electric's Agent Success Coordinator Jessica Paul showing the components of the Off Grid solar home system
Source: Ashden/Anne Wheldon

Ashden is a charity that promotes the use of sustainable energy at a local level. This paper was researched and written by members of Ashden's international team. Lead author Anne Wheldon (MA, PhD, FEI) supports assessment of applicants, research and writing; Chhavi Sharma (BA, MSc) runs the international awards and post-awards support programme; Ellen Dobbs (BA, MSc) leads on research and monitoring of Award winners.

KEYWORDS

- ELECTRICITY ACCESS
- MINI-GRID
- HYDRO POWER
- SOLAR HOME SYSTEMS
- SOLAR LAMP
- MOBILE MONEY
- PAY-AS-YOU-GO SOLAR

INTRODUCTION

Ashden is a UK charity that promotes the use of sustainable energy at a local level, because of its human and environmental benefits. A core part of Ashden's work is to highlight successful sustainable energy practitioners through the annual Ashden Awards, and support them to take their work further. Ashden's largest Award programme focuses on developing countries, in particular on the provision of energy access. This international programme has received about 1,400 applications and made over 90 awards during the 15 years since the Awards were launched.

This paper reviews internal information held by Ashden on the 379 applicants (and 41 winners) working on sustainable electricity access, to identify trends in access to sustainable electricity in the work of applicants and winners, and provide insight into the wider sustainable electricity access sector.

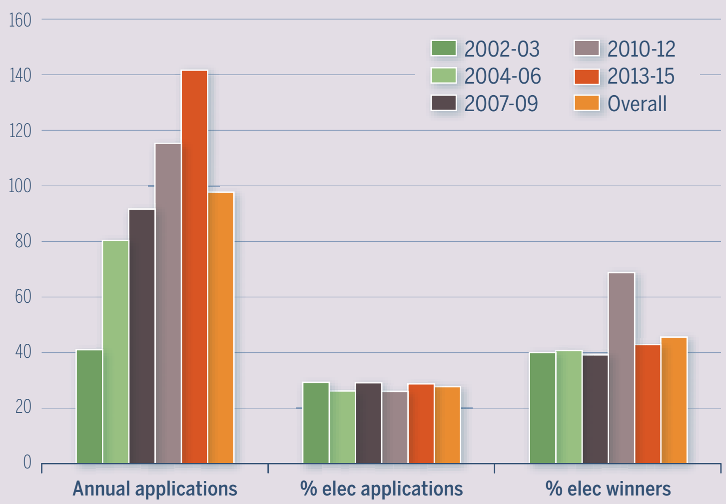
1. ANALYTICAL FRAMEWORK

1.1. SELECTION CRITERIA

Ashden Awards are for organisations that can show existing achievement in providing sustainable energy at a local level, along with innovation and potential for growth and replication. All winners must be delivering significant social, economic and environmental benefits. They must be on a path to achieving financial sustainability, and have the capacity and commitment to take their work further. Winners in specific Award categories (for example "Clean energy for women and girls", "Innovative finance for sustainable energy" and "Increasing energy access") must meet additional category-specific criteria. The application process has changed somewhat over the years, but broadly follows the following steps.

- Applicants put themselves forward for an Award by filling in a standard form. Any organisation may apply. A "longlist" of around 20 is selected from these initial applications. All longlisted applicants are sent more detailed questions tailored to their specific work, and must also provide financial information and references. Specialist assessors review all materials submitted, and an expert judging panel selects about ten finalists from the longlist.
- An essential part of the application process is to see the work of finalists on the ground. All finalists are therefore visited by an Ashden assessor who meets the people involved in the organisation, reviews the work in action, interviews people who are benefitting from it, and obtains answers to questions from the judging panel. Assessors report back to the judging panel who select winners in each Award category. The Ashden team prepares a detailed case study on each winner which is made available on the website (www.ashden.org/winners) along with a short video and photos of the Award-winning work.

Average annual applications for Ashden International Awards, and percentage of applicants and winners providing access to sustainable electricity



Source: Ashden

Figure 1

- Winning an Ashden Award brings a cash prize and publicity. Ashden also provides a tailored support package to each Award winner, and follows their post-Award progress.

1.2. DATA

The application and assessment process generates detailed information on the work of individual applicants (both quantitative and qualitative). This collated information forms the evidence base for this paper.

1.2.1. Sample size

Ashden Award applications were initially screened to select those that provided access to sustainable electricity, and whether the applicant became a winner. Applications were analysed in three-year groups, to smooth the year-to-year variations inevitable with small numbers (although the earliest group contained just 2002 and 2003 applications, because those for 2001 could not be located).

Figure 1 shows that the number of applications for Ashden Awards has increased substantially over time, from about 40 per year in 2002-03 to 140 per year in 2013-15. Despite this significant increase in numbers, the proportion of applicants providing access to electricity from renewable energy stayed the same, at around 28% (overall 379 out of 1,369 applications). Most other applicants provided cleaner and more efficient cooking, also heating and water supply. Applicants providing access to electricity were generally judged to be stronger than others, and produced about 46% of final winners (41 out of 90).

The 379 applicants and 41 winners providing access to electricity from renewable sources form the sample on which the quantitative analysis in this paper is based. The data used is that provided to Ashden at the time of application, because this provides a common reference point for all applicants.

"THE NUMBER OF APPLICATIONS FOR ASHDEN AWARDS HAS INCREASED SUBSTANTIALLY OVER TIME, FROM ABOUT 40 PER YEAR IN 2002-03 TO 140 PER YEAR IN 2013-15."

1.2.2. Possible biases of the sample

The Ashden application process is designed to highlight achievement, rather than as a tool to overview the energy access sector. One possible bias in relating the findings of this paper to the wider sector is that Ashden is less well-known outside the Anglophone world (although all materials for making an application are translated into other widely-used international languages, including French, Spanish and Chinese). Another is that businesses and not-for-profit organisations might anticipate more benefit from winning an award than public sector bodies would do, thus making public sector bodies less likely to apply. As we make clear throughout this paper, Ashden rewards achievements specifically in *sustainable* energy, so organisations increasing energy access through the use of fossil fuels would not be eligible for an Award.

2. QUANTITATIVE ANALYSIS

2.1. WHERE DOES THE WORK ON ACCESS TO SUSTAINABLE ELECTRICITY TAKE PLACE?

The 379 applications were coded into the broad geographical categories: South Asia, Rest of Asia, East Africa, Rest of Africa and South and Central America. A few applicants were coded as ‘global’ if their work spanned several geographical regions.

Figure 2 shows that most applicants providing access to electricity worked in South Asia (32%), East Africa (21%) or elsewhere in Africa (17%) – the regions that are home to about 90% of the people who currently lack access to electricity (World Bank, WDI, 2012). Some of this geographical spread may relate to Ashden being less well-known outside the Anglophone world, as noted above.

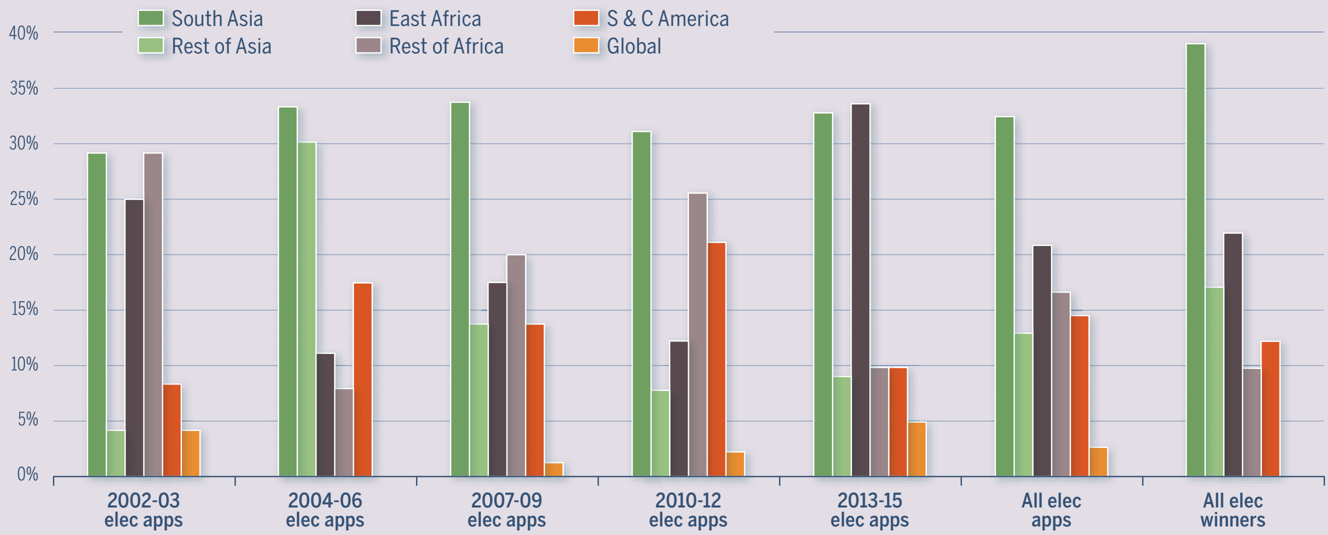
South Asia had the largest share of applicants until 2013-15, when it was overtaken by East Africa. In terms of winners providing access to electricity, South Asia has the largest share followed by East Africa. One reason for the growing importance of East Africa in recent years is the widespread use of mobile money, which has enabled new ways of paying for electricity: this will be discussed further in the case study of Off Grid Electric.

2.2. WHAT TECHNOLOGIES ARE USED?

An initial review of the 379 applications identified three broad categories of technology used by Ashden applicants to provide sustainable electricity access: renewable-powered mini-grids, individual home systems (nearly all solar powered), and solar-powered lamps. The latter are mainly lamps supplied with an individual PV module, but in a few cases are lamps or batteries charged at a central point like a shop or kiosk with PV modules.

Figure 3 shows solar home systems are the main technology used by both applicants (42%) and winners (51%). However, solar lamps have increased in popularity, and have been the dominant technology since 2010. Renewable-powered mini-grids maintain a fairly constant representation among applicants, averaging 27%, and account for a similar proportion of winners (29%).

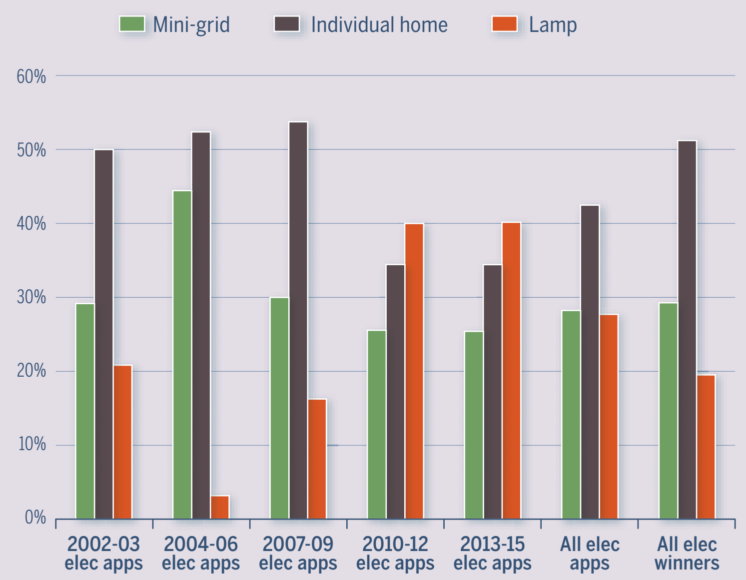
Location of work on access to sustainable electricity: applicants and winners



Source: Ashden

Figure 2

Technologies used to provide access to sustainable electricity



Source: Ashden

Figure 3

"SOUTH ASIA HAD THE LARGEST SHARE OF APPLICANTS UNTIL 2013-15, WHEN IT WAS OVERTAKEN BY EAST AFRICA."

Developments in these technologies and their use, that Ashden has observed, are summarised below.

2.2.1. Renewable powered mini-grids

Renewable-powered mini-grids can provide electricity access to a group of homes, public buildings and small businesses. A thousand or more customers can be connected if the power is sufficient, but all need to be quite close to the power source (typically within a few kilometres), otherwise the cost of cable to connect them becomes prohibitive.

Obviously the choice of renewable source depends on location. Small hydroelectric schemes work well in areas with high rainfall, for example providing power to remote mountain villages in Indonesia (IBEKA, 2012). A wide range of biomass can be used for power generation: gasifying waste biomass and using the gas to run an engine and generator is one example (HPS, 2011). Wind turbines are also a possibility. Solar photovoltaics (PV) have decreased rapidly in price over recent years and their low maintenance requirements make them particularly attractive for remote areas, like in rural Kenya (SteamaCo, 2015). PV mini-grids require rechargeable batteries for storage because power is supplied only during daytime, which is often not the time when electricity is used. Among Ashden applicants, hydro (61%) and PV (26%) are the main renewable power sources for mini-grids, with PV becoming more important in recent years.

Mini-grids require complex planning, construction and long-term management. A particular management challenge is finding an acceptable way to share out and pay for the electricity. Fifteen years ago, many systems were under community management, and electricity sharing was fairly informal, often with only token payments (for example: AKRSP, 2004). Increasingly, to keep systems performing well, paid operators are used for day-to-day management. Electricity payments are set at a level to cover salaries and maintenance, and, for fairness, are increasingly based on metered electricity consumption (for example in Afghanistan: GIZ-INTEGRATION, 2012). In East Africa, the use of mobile phones and mobile money is widespread, and mobile money payment is starting to be used for mini-grid electricity (SteamaCo, 2015). This cuts the cost of collecting payments.

2.2.2. Individual home systems

In many places, electricity access can be brought more quickly by providing renewable power systems to individual buildings, rather than using mini-grids. Individual systems also avoid complex long-term management, and can serve buildings in areas that would be too remote for mini-grid connection.

In Ashden's experience, individual systems are nearly always powered by PV ("solar home systems"), although in a few cases individual wind turbines or very small hydroelectric generators have been used. Solar home systems use a PV panel to provide power for two or more lights and, increasingly, for phone charging too. Depending on size they can also power other small appliances like radios, fans, TVs and laptops. All require rechargeable batteries for storage.

In 2007, a basic solar home system like those sold by SELCO (2007 winner) used around 35 Wp of PV, a lead-acid battery and an electronic controller to supply four ~200 lumen fluorescent lights. It had to be installed by a trained electrician, and cost around USD 400 (USD 460 in 2015 money).

Much has changed since then. PV prices have fallen dramatically. A recent analysis by the Fraunhofer ISE (Fraunhofer, 2015) showed that during the 14 years from 2000 to 2014, PV module prices on the world market fell by about 90% from EUR 5 to 0.5 per Wp (and that followed a fall of 80% during the preceding 16 years). LED lights are now more efficient and long-lasting than fluorescents, and available in a wide range of output and configuration. Long-life lithium-ion batteries are now widely used, particularly in very small systems. Electronic controls have improved enormously.

Taking advantage of these developments, several businesses now sell solar home systems as Pay-as-you-go (PAYG) kits for DIY installation. System prices are significantly lower (although not to the same extent as PV modules, because other contributors to cost like batteries, lights, cables, manufacture and distribution have not changed as much). For example, the current entry-level kit from 2012 winner Barefoot Power (including a 6 Wp PV panel, four 75 lumen LED lights, battery, controller, two USB charging points, cables and connectors) retails for only about one-third of the price of the 2007 system above.

Such price decreases mean that more households can now afford a solar home system, but having to pay all the cost upfront is still a barrier. Pay-as-you-go (PAYG) using mobile money, described in the case study of Off Grid Electric, significantly reduces the upfront payment required from the customer and can make solar home systems affordable to many more.

2.2.3. Solar lamps

A modern solar lamp has a single high-efficiency LED light and a rechargeable battery, usually lithium-ion technology, in a case which is small enough to carry around. Solar lamps are designed to replace kerosene lamps or candles and provide better quality, and (on a lifecycle basis) cheaper light. They can also replace battery-powered LED lamps that are becoming increasingly popular in a number of African countries (Bensch et al., 2015), avoiding the need for frequent replacement of dry-cell batteries.

The recent developments that have changed solar-home-systems have also led to a growing number of solar lamps on the market, which are usually packaged and sold as “fast moving consumer goods”. The “Lighting Global” initiative of the IFC has had a major impact on the sector, bringing in quality standards and accepted methods to measure performance (Lighting Global, 2015). In parallel there are growing numbers of cheaper, uncertified solar lamps of varying quality.

Ten years ago, most solar lamps that Ashden encountered used fluorescent bulbs. The cheapest (for example: NEST, 2005 winner) cost around USD 35 (USD 42 in 2015 money) and needed 3 Wp of PV. Businesses like d.light (2010 winner) now sell solar lamps that meet Lighting Global standards, with prices that start at around USD 5. Such lamps provide modest light levels, around 20 lumens, but can be afforded by many more households than in the past (although they are not as cheap as some battery-powered LEDs). The cheapest modern solar lamps have integrated PV panels, and thus the disadvantage that the whole unit has to be left out in the sun to charge up.

In Ashden’s experience, the distinction between a solar home system and a lamp has blurred over time. Solar home systems have become smaller and cheaper, while top end lamps with detachable solar panels (costing around USD 42) now provide 150 lumens of light, different brightness settings, and one or even two USB charging sockets. Phone charging is important for many low-income households in remote areas, since mobile phones increasingly bring not just communication but financial service and knowledge.

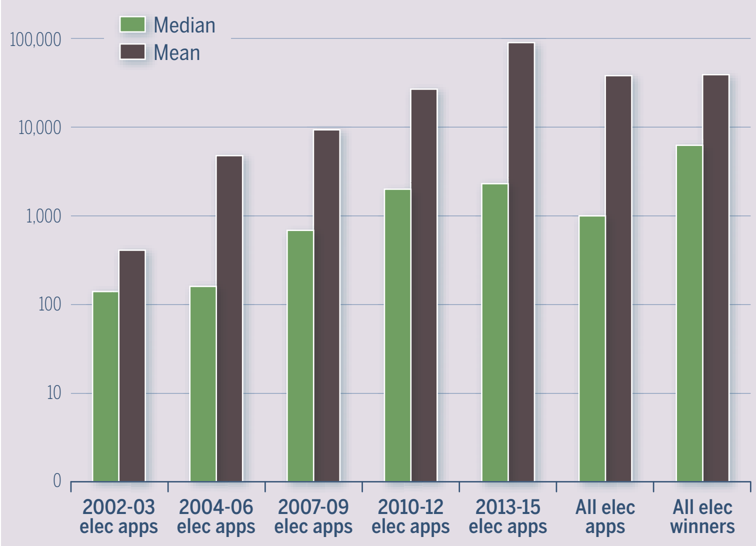
2.2.4. Tiers of access

The different technologies above obviously provide different levels of access to electricity. In order to track global progress in providing access, the Sustainable Energy for All initiative categorises access into broad “Tiers” (SE4ALL, 2015). A simple solar lamp is ranked at Tier 0, or at Tier 1 if it includes a charging socket. Solar home systems are typically ranked between Tier 1 and Tier 3, depending on size and functions. Tier 4 access, which provides enough power for tools and equipment for businesses as well as a wide range of domestic appliances, can be achieved with mini-grids.

2.3. SCALE OF OPERATION

We define “scale” of an application for an Ashden award as the number of households or equivalent that had been provided with access to electricity by the applicant, at the time of application. For mini-grids this is the number of households connected to a mini-grid, for individual home systems and lamps it is the number of systems sold or installed. In a few applications this information was not clear and estimates were made from the number of beneficiaries cited by the applicant.

Number of households supplied by Award applicants: mean and median values

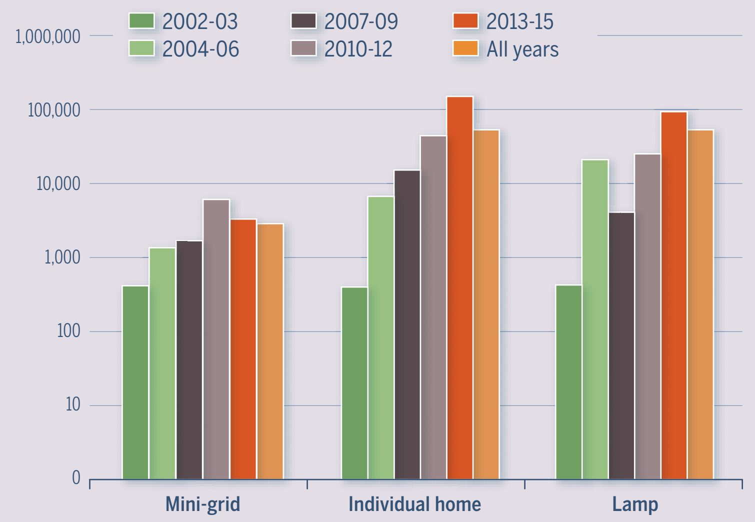


Source: Ashden

Figure 4

Applicants operate at widely differing scales, from tens up to millions of households. Given the relatively small number of applicants, it is difficult to choose the right averaging technique to indicate trends in scale. Figure 4 therefore shows two measures of the average number of households: the arithmetic mean and the median. It uses a logarithmic scale to cover the large range of scale. Both measures show that the scale of operation of applicants has increased substantially with time, from a mean of about 400 households in 2002-03 up to over 90,000 in 2013-15 (median from 140 up to 2,300).

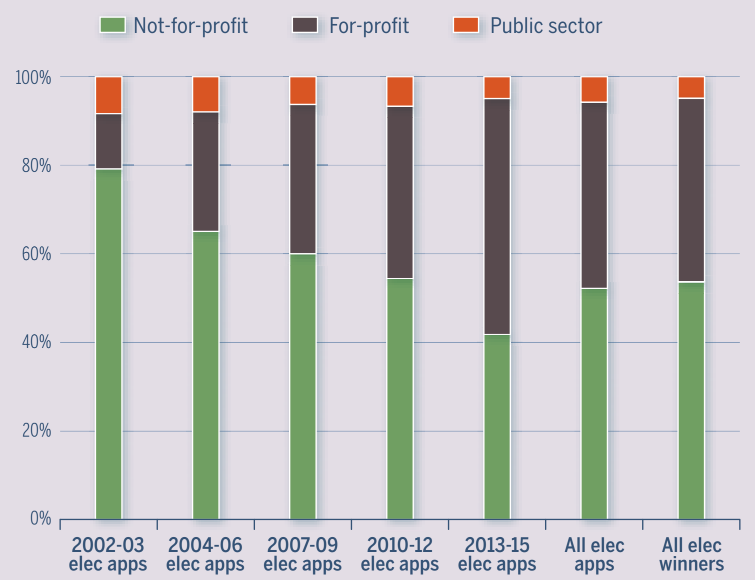
Number of households supplied by different technologies: mean values



Source: Ashden

Figure 5

Types of organisation applying for and winning Ashden Awards



Source: Ashden

Figure 6

In each time period the mean is higher than the median, showing that the data is skewed by a few very large numbers. This skewing has increased over time, which we think is caused partly by real change in the sector. Several renewable energy businesses and programmes have deliberately grown large, rather than focussed their work within a limited geographical area which was more normal 15 years ago, in our experience. However, the skewing also relates to our specific data set, which is applicants for achievement Awards. Some organisations defer making an application until their scale exceed that of previous winners, and thus over time have an ever-increasing bar to exceed.

Scale of operation varies with technology. Figure 5 shows that applicants reach many more households with solar home systems and solar lamps than with mini-grids. This is not surprising given that solar home systems and, in particular, lamps are small and easy to transport to individual homes. Mini-grids, by contrast, are complex projects. For each technology, the scale of operation has increased over time.

Note that the scale of *impact* of an organisation depends on the level of benefit to a household, as well as the scale of operation. Solar lamps providing Tier 0 or 1 access cannot provide the same benefits as Tier 4 access from mini-grids. This will be discussed more fully in the case studies below.

2.4. WHAT TYPES OF ORGANISATION APPLY FOR ASHDEN AWARDS?

Applicants were coded as for-profit; not-for-profit or public sector. A growing number of applicants identify themselves as "social enterprises", but because this term has different interpretations in different places they were all included in the "for-profit" category.

The profile of organisations applying for an Ashden Award has changed considerably over the past 15 years, as shown in Figure 6. In 2002-03, nearly 80% of the applications working on sustainable electricity access came from not-for-profits, but by 2013-15, the majority were for-profit organisations. Only a small number of applications come from public sector organisations: this may not reflect their importance in the sustainable electricity access sector as a whole, because – as noted earlier – such organisations might be less interested to win awards.

Several factors may have contributed to the shift from not-for-profit to for-profit applicants. One likely factor is experience from a number of government and not-for-profit programmes in the 1980s, which showed that "giveaways" tend not to lead to lasting uptake of new technologies. Another is the growing availability of private investment to the sector, both loans and equity. A third is that businesses can often change and adapt more quickly than not-for-profits, taking up new technologies and exploring new markets.

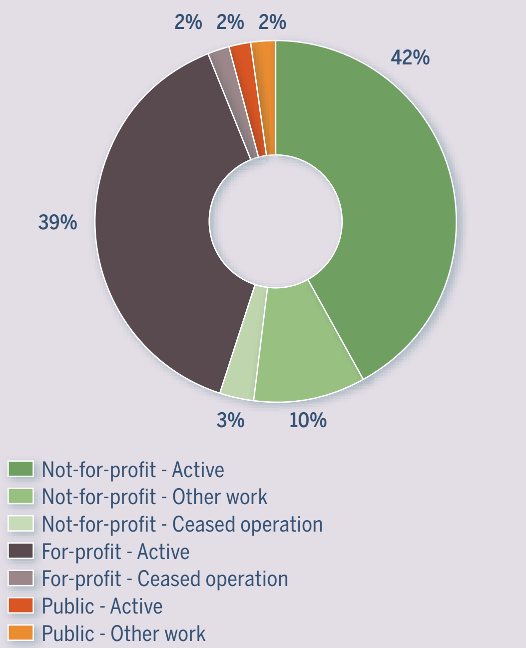
Here again, categories are somewhat blurred. Many for-profit businesses that provide access to electricity receive grant funding, at least in their early years. Equally, many not-for-profits are selling products or services in an increasingly "business-like" way. The case study of SolarAid below is an example of this.

2.5. CURRENT STATUS OF WINNERS

Ashden internal records and internet checks (November 2015) were used to identify whether winners remain active in the electricity access sector (Active); are active but now doing other work (Other work); or have ceased operation (Ceased operation). Figure 7 summarises the findings, and shows also the division into not-for-profit, for-profit and public sector categories.

Numbers are too small to draw strong conclusions from this, but it is clear that a large majority of the 41 winners (83%) are still active in the sector and very few have ceased operation (5%). Most of the 12% who have moved on to other work are not-for-profit organisations.

Current status of Award-winning electricity access organisations



Source: Ashden *Figure 7*

3. CASE STUDIES AND IMPACTS

Three recent Award winners have been selected as case studies to highlight trends that were identified above. The studies also look in greater depth at other aspects of providing access to sustainable electricity, including the context and social impact of the work and the challenges faced.

3.1. SOLAR AID - SOLAR LAMPS

Although solar lamps can have significant impact in off-grid homes, it is still an enormous challenge to get lamps and backup services to the remote areas where they can bring the most benefit. UK-based not-for-profit SolarAid (2013 winner) took on this distribution challenge, using a "business-like" approach.

SolarAid set up a trading subsidiary, SunnyMoney, to develop a rural market for solar study lamps. SunnyMoney teams travel to different parts of a country and run sales campaigns through trusted head teachers who act as local agents. In this way, households in rural areas get access not just to the products but to backup services too.

Lamps are sourced from global suppliers, and have to meet Lighting Global standards. They are sold with warranties at prices between about USD 10 and USD 40, depending on size and features.

Several formal studies have been undertaken of the impact of solar lamps, and find different combinations of benefits. For example, a randomised-control-trial (RCT) in Bangladesh by Kudo et al. (2015) found decreased expenditure on kerosene and increased study time by children, in households with solar lamps. This study found no impact on school grades or on health. Grimm et al. (2015) conducted an RCT in Rwanda on the impact of PV lamps with chargers ("pico-kits"). They found that the lamps were intensively used and led to significant reductions in expenditure on kerosene, candles and dry-cell batteries, along with increased lighting hours in the day and more flexibility in how time was used. However, they found no impact on total study time, or time spent on domestic chores. A pilot study by Furukawa (2013) in Uganda found that children with solar lamps studied for longer but, somewhat surprisingly, achieved slightly lower school grades.

A SolarAid in-house study (Harrison, 2013) found that lamps were mainly used for study, also for cooking and general household lighting. Crucially, over 90% of households surveyed were satisfied or very satisfied with the lamps. The money saved on kerosene means that the cost of a basic lamp is recovered within three months. A large-scale RCT, initiated by Solar Aid, is currently in progress to determine the impacts of solar lamps on poverty alleviation.

Head teachers interviewed by the Ashden assessor said that they tried out the lamps in their own homes before becoming involved with the SunnyMoney campaign, to confirm the benefits. They

"IN 2002-03, NEARLY 80% OF THE APPLICATIONS WORKING ON SUSTAINABLE ELECTRICITY ACCESS CAME FROM NOT-FOR-PROFITS, BUT BY 2013-15, THE MAJORITY WERE FOR-PROFIT ORGANISATIONS."

Head teachers try out solar lights at a meeting with a SolarAid sales team
Source: Ashden/Anne Wheldon

highlighted the value of having lamps in school dormitories, as well as in homes, for both study and safety.

At the time of the Ashden assessment visit (March 2013) SolarAid had sold over 400,000 solar lamps in Tanzania, Kenya, Zambia and Malawi. By March 2016 this number had increased to 1.7 million. The SunnyMoney programme continues in Southern Africa, and recent pilot sales in Malawi have shown the potential for reaching lower-income households using PAYG technology in solar lamps (SolarAid, 2016a).

However, SolarAid's recent experience in Tanzania shows how quickly the sector can change. Tanzania was the country where SunnyMoney was most successful in building a market for solar lamps, and accounts for over 0.9 million of its sales. But during 2014-15, there was a rapid increase in competition from uncertified solar lamps (some of them fakes of popular certified models), also cheap lamps powered by dry-cell batteries, and SunnyMoney sales fell substantially. SolarAid decided to wind up operations in Tanzania, but the SunnyMoney Tanzania brand has been taken over by local enterprise ARTI energy (SolarAid, 2016b).

3.2. OFF GRID ELECTRIC - SOLAR HOME SYSTEMS

Off Grid Electric (2014 winner) is a for-profit business based in Arusha, Tanzania. Its founders wanted to make solar home systems a mass-market option. However, they recognised two major barriers to customers: the initial cost of buying a system, and low expectations of after-sales service.

The growing availability of mobile money in East Africa helped provide a solution to the first barrier. Off Grid Electric provides an agreed level of electricity service from a 5 or 10 Wp solar home system installed in a customer's home, with an entry-level service of two bright lights and a phone charger for eight hours per day, and the option to add further appliances at an additional cost. Customers pay a deposit of around USD 8 and then a daily fee of between USD 0.20 and USD 0.60. These PAYG fees are paid using mobile money, with a minimum payment of one day's use.

Incentivising local agents provided a solution to the second problem. A network of local agents is paid not just to find customers and install systems, but also to provide ongoing aftersales service.

The PAYG approach removes the upfront hurdle of what would have been a roughly USD 100 purchase cost and makes the service accessible to lower income households. Equity investment has enabled Off Grid Electric to grow rapidly. At the time of the Ashden visit (March 2014) systems were in use in about 10,000 homes. The programme has expanded rapidly and is currently (October 2015) reaching over 10,000 more customers every month.

Users of solar home systems have reported many benefits to Ashden assessors, including increased study time for children, increased ease and time-flexibility for household chores, greater safety at night, and savings on kerosene. Many also report how charging mobile phones at home is both cheaper and more convenient than going elsewhere. An impact survey has been made of the successful World Bank/GEF-financed credit scheme for solar home systems in Bangladesh, which has led to about 3 million installations. This survey found that having a solar home system increased the time that children study in the evenings, decreased kerosene consumption, and provided health benefits, in particular for women (Samad et al., 2013).

Off Grid Electric customers interviewed in their homes by the Ashden assessor identified many benefits, including increased safety at night from lights outside homes; more customers attracted to well-lit shops; and children spending more time on study in evenings. Phone charging at home was really appreciated, particularly by women who spent more time than men in the home. The money saved on kerosene covered the PAYG charges.

3.3. SARHAD RURAL SUPPORT PROGRAMME (SRSP) - MINI-GRIDS

It is a huge challenge to provide electricity to regions like North-West Pakistan: isolated, often cut off by snow or earthquakes and plagued by political instability. Private businesses will not take the risk of working in such a region.

Local not-for-profit SRSP (2015 winner) has worked for many years with local communities, and seen first-hand how lack of electricity held back development. It saw the potential for producing electricity from hydro-power, because there are plentiful rivers and streams in the

Washing machines are powered by SRSP's micro-hydro system in the Bumboret Valley, Pakistan. This greatly reduces the drudgery of housework for women.
Source: Ashden/Martin Wright

region, but knew from experience that for a hydro scheme to succeed, the local community must take the lead. So in 2004, SRSP started working with communities to develop village-scale micro-hydro power schemes with mini-grids. All SRSP installations use high-quality turbines, made in Pakistan (hence able to be maintained locally), and include metered connections to homes, businesses and community facilities.

By the time of the Ashden visit in March 2015, SRSP had installed 189 micro-hydro schemes with a total capacity of 15 MW, bringing power to about 40,000 homes. The impact on home comforts, economic opportunity, and wider community development, reported to the Ashden assessor has been substantial. Electric light makes homes more pleasant, study easier, and health care safer. Phones, TV and internet provide access to new skills and a window on the world, reducing isolation.

Teachers told the Ashden assessor that electric light improves both academic performance and attendance because children can complete their homework, and are no longer afraid to go to school!

Crucially, the level of power available from a hydro-based mini-grid means that domestic appliances like washing machines and irons can be used, cutting the drudgery of housework for women. The level of power also enables new income generation, through a wide range of activities. Many like fruit-drying, craft work and hotels bring in much needed income from outside the region.

4. DISCUSSION

Ashden's experience of the development of the sustainable electricity access sector over the past 15 years is positive, because – as detailed above – a growing number of organisations apply for awards, their work is at an increasing scale, and most winners stay active in the sector. Trends identified are the growth in use of solar lamps; the increasing importance of for-profit businesses; and the rise in the significance of East Africa. Applicants have adopted global technological developments to offer better and cheaper services. Lower cost PV, better quality LED lights and mobile money PAYG are reaching rural homes. Although the Ashden application process was not designed to survey the sustainable electricity access sector as a whole, the trends identified in this paper may apply more broadly.

But despite these encouraging trends, 1.3 billion people still lack access to electricity (IEA, 2016), and most of these are in the poorest and most remote parts of the world. There are substantial challenges in providing access to all.

In our experience, businesses have a growing role to play, although we know from research with Ashden winners (Haves, 2014) that they face challenges, including access to working capital and developing appropriate sales and marketing.

However businesses – including socially-focussed ones – need customers who can pay, and tend to gravitate to where people have money and are easy to reach. There is continuing role for government and philanthropic funding, to support work in places where businesses will not venture (like the region served by SRSP) and to provide the groundwork for business-like operation (like SolarAid's grant-funded distribution approach).

There is also a dilemma about where to focus effort in terms of level of access. Rightly, there is a global ambition to bring everyone to Tier 4 or higher, to reduce domestic burden and enable economic opportunity. But our experience, from talking to winners and others, is that mini-grids to achieve Tier 4 are hard work to develop and, in particular, to manage long term. It seems unlikely that their use can be expanded sufficiently reliably and rapidly to achieve the SE4ALL goal of universal access by 2030.

For Ashden it is crucially important that no-one gets left behind, without access to electric light. Inability to charge a mobile device is, increasingly, part of being "left behind". Ashden therefore sees a continuing role for solar home systems and lamps to rapidly expand access in the immediate future, alongside efforts on mini-grid and grid-connection to offer greater opportunities.

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SOLAR OFF-GRID MARKETS IN AFRICA

Recent dynamics and the role of branded products

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Lighting sources of non-electrified populations. Kerosene-driven tin wick lamp. Source: Gunther Bensch

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KEYWORDS

- RURAL ELECTRIFICATION
- ENERGY ACCESS
- ENERGY POVERTY
- TECHNOLOGY ADOPTION

The UN electricity for all initiative promotes branded solar products based on the argument that otherwise households won't have access to such technologies. We argue that non-branded products have already reached households; hence access is not an issue, at least for richer households. Yet, a justification of branded products can be made based on their durability and thus reduced electronic waste. Subsidies can be paid to reach also the poor.

INTRODUCTION

Spearheaded by the United Nations' Sustainable Energy for All (SE4All) initiative, the international community is striving to provide electricity to all non-electrified households around the world by 2030. Achieving this by extending national electricity grids would require enormous investments. Solar off-grid technologies such as solar home systems (SHSs), solar lanterns, and pico-PV kits are a lower-cost alternative. Production costs for these technologies have decreased sharply in recent years and various branded and non-branded products have become available all over Africa. Under the auspices of the Lighting Global program, donor organizations and some African governments currently promote branded solar products arguing that high quality standards are necessary to establish self-sustaining markets. Lighting Global endorses a market-based dissemination approach that requires end users to pay cost-covering prices (see Lighting Global, 2016).

The present note challenges this policy and the role of branded solar products in meeting the SE4All goals. We provide evidence that the vast majority of the rural poor will not be able to bring up the required investment costs, even if the devices can be purchased with credit. We call attention to the lighting transition in rural Africa that is already ongoing before branded products might reach a certain area: dry-cell battery driven LED lamps and non-branded solar products are replacing kerosene and candles as dominating lighting sources. We show that the somewhat better off strata obtain non-branded solar products on local markets, *while the poorer strata use LED torches that can be easily scaled from one diode hand-crafted lamps to larger sizes. Durability of non-branded products is likely to be shorter than for branded products, but this is overcompensated by the lower upfront costs. Given the availability of these alternative technologies, branded products are not necessarily the most rational choice from the poor's perspective.*

In the following, we first present the data underlying our assessment, second we provide evidence on the lighting transition to LED and non-branded solar products, and third we carve out the affordability problems of the majority of rural households.

1. DATA SOURCES

The data we use in this note was collected in various household surveys that we conducted between December 2006 and December 2014 in Benin, Burkina Faso, Mozambique, Rwanda, Senegal, Tanzania, and Zambia. The studies were commissioned by development agencies such as Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) and the Netherlands Ministry of Foreign Affairs to evaluate the effects of their electricity access interventions. All surveys were designed to collect detailed information on energy consumption and lighting usage, which is not available in secondary data sets like the Demographic and Health Surveys (DHS) or the Living Standard Measurement Surveys (LSMS). More details on the surveys and their representativeness as well as the underlying evaluations can be found in Bensch et al. (2015) and Peters and Sievert (2016).

2. THE LIGHTING TRANSITION: NON-BRANDED SOLAR PRODUCTS AND DRY-CELL BATTERIES

Table 1 shows adoption rates for off-grid electricity sources in the absence of governmental programs or promotion activities by branded solar product companies. The surveyed areas are representative for the rural population in the respective countries. They are not particularly well-off. It can be seen that – with the exception of Rwanda – solar technologies are already used by considerable parts of the rural population. It is important to emphasize that the products found in such non-program areas are virtually only non-branded ones. Non-branded products are not quality verified and are sold by non-licensed vendors on local markets or in local shops[1].

To the extent that these observations can be transferred to other African countries the message that can be taken away from Table 1 is that households in rural areas do have access to solar technologies, also without any promotion of branded products. It is sometimes argued that these non-branded products are of an inferior quality, since they are not quality verified and marketed via licensed vendors (see Lighting Global, 2016). Bensch et al. (2016) examine the difference in lighting performance, user satisfaction, and durability between informally obtained SHS and high-quality SHS promoted by an international NGO. No sizeable differences were found. To the contrary, the available evidence suggests that these non-branded SHS meet expectations in terms of durability and lighting quality.

Table 1. Electricity sources in off-grid regions (in percent of surveyed households)

		solar panel	pico-solar lamp	other
Burkina Faso	2010	26	-	7
	2012*	34	-	7
Rwanda	2011	1	-	2
	2013*	2	4	2.3
Senegal 1	2011	18	-	5
Senegal 2	2014	16	2	5
Tanzania	2014	15	16	10
Zambia	2011	34	-	17

Note: Senegal 1 refers to surveys in the Bassin Arachidier and Casamance region, Senegal 2 to surveys in the Thiès region. Other sources include car batteries and generators.
* refers to surveys that were conducted after an electrification intervention. Numbers reported in this table are based on the control group part of the sample, i.e. households that were not served by the electrification program.

Bensch et al. (2015) show that lighting consumption patterns in Africa have also changed in off-grid households that do not possess a solar home system or a solar kit. Off-grid households are increasingly using dry-cell battery LED lamps. As can be seen in Table 2, in particular in West Africa kerosene and candles have almost vanished completely. But also in countries in which we encountered lower dry-cell battery LED usage rates some years ago, they have gone through double-digit annual growth rates since then.

"GIVEN THE AVAILABILITY OF NON-BRANDED TECHNOLOGIES, BRANDED PRODUCTS ARE NOT NECESSARILY THE MOST RATIONAL CHOICE FOR THE POOR."

1 See also Lighting Global (2016).

Table 2. Lighting sources of non-electrified population in our survey samples

		Lighting usage rates among non-electrified households, in %		
		candles	kerosene	Dry-cell batteries
Burkina Faso	2010	0	29	100
	2012*	0	10	99
Rwanda	2011	26	65	24
	2013*	32	36	47
Senegal 1	2011	21	9	97
Senegal 2	2014	0	1	97
Tanzania	2014	9	61	68
Zambia	2011	69	17	85

Note: Senegal 1 refers to surveys in the Bassin Arachidier and Casamance region, Senegal 2 to surveys in the Thiès region.
* refers to surveys that were conducted after an electrification intervention. Numbers reported in this table are based on the control group part of the sample, i.e. households that were not served by the electrification program.

This transition from kerosene and candles to dry-cell battery LED has been largely unnoticed, one reason being that official censuses do not account for dry-cell battery LED lights as a lighting option. The lighting quality of these lamps is comparable to small solar devices, depending on the number of diodes. The poorest households use hand-crafted LED lamps; the cheapest options are made of one or two diodes, wired to a set of dry-cell batteries. Components are obtained in rural shops for less than EUR 1. Multi-diode lamps are available at between EUR 2 and 5 and can be as bright as regular energy saver lamps. Figure 1 shows some pictures of kerosene lamps as well as hand-crafted and ready-made LED lamps.

3. THE AFFORDABILITY PROBLEM

The last section has argued that solar markets in rural Africa are taking off already without external support and presence of licensed vendors of branded products. This section argues that the challenge is indeed not to sell solar products per se in Africa: the better off stratum is ready and able to pay cost covering prices, some of them even for more expensive branded products. But to increase coverage rates considerably and to iterate towards the SE4All goals, the poorer strata have to be reached. Using our data sets from rural Burkina Faso we show that the rural poor can hardly be expected to make the upfront investment that is required if cost-covering prices are charged for solar products. For this purpose, we take the perspective of a rural Burkinabè household that hitherto does not possess a solar product and that ponders the investment decision for a solar home system. Since it is often argued that financing schemes will help the poor to overcome the investment burden, we assume availability of a credit scheme at a modest 10 percent interest rate. The average price for a non-branded 40-50 Watt SHS bought on the local market is at EUR 100. Figure 2 shows the cash flow that results from this investment for different repayment periods (1-4 years). An important parameter are the savings potentials on the household's current energy expenditures for energy services to be replaced by the SHS. Since wealthier households have higher ex-ante energy expenditures and have thus higher savings potentials, Figure 2 shows cash flows by expenditure quartiles.

It can be seen that for the most likely scenario of a one-year repayment period the investment into an SHS entails an additional burden for the monthly cash-flow of all expenditure strata. For the poorer 50% of the population this burden weighs heavily: servicing the loan creates additional costs of around EUR 6 per month. For comparison, the poorest stratum has monthly total expenditures of EUR 25 per month, the second poorest around EUR 58, so the monthly installment payment would consume a considerable share

Figure 1. Lighting sources of non-electrified populations

Kerosene-driven hurricane latern — Dry-cell battery-driven hand-crafted light — Dry-cell battery-driven LED flashlight — Dry-cell battery-driven LED lamp

Source: Gunther Bensch and Maximiliane Sievert

Expenditure effects of SHS adoption under different credit repayment periods

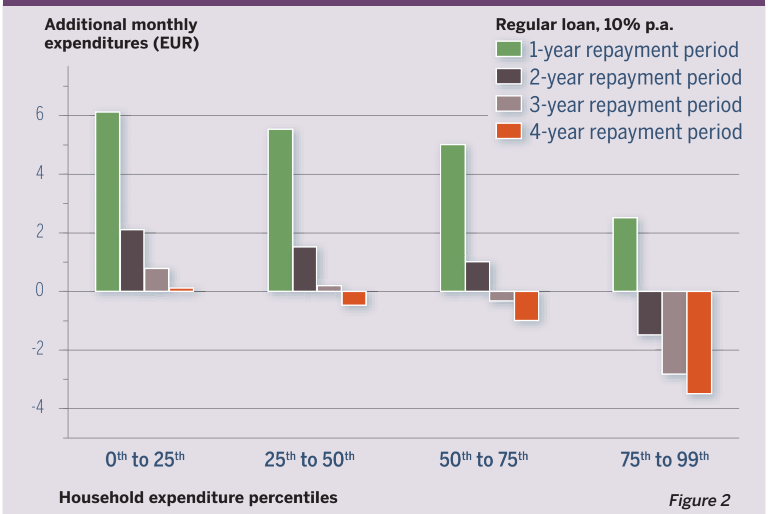

Figure 2

of total expenditures (between 10 and 24 percent)[2]. The monthly burden obviously decreases for longer repayment periods. Moreover, Figure 2 also shows that affordability is much less of an issue for the upper stratum. For a one year repayment period additional expenditures are at slightly more than EUR 2, which corresponds to only 1 percent of their total monthly expenditures (around EUR 210).

It is worth noting that all parameters in this hypothetical calculation are set in a very conservative way and hence the factual cash-flow can be expected to be more onerous. Among others, optimistically, we assume all kerosene, candles, and dry-cell battery expenditures to be replaced, which is typically not the case, since some traditional lighting is used complementarily. While we use data from Burkina Faso in this example, these calculations can be replicated in all of the other countries we collected such data without significant changes in the findings[3].

2 A more profound analysis of this case can be found in Bensch et al. (2016).

3 In Rwanda, for example, the amortization period of a 1-Watt branded solar kit is around 18 months given the real-world lighting expenditures of rural households (Grimm et al., 2015).

CONCLUSION

What are the implications of the above observations for public policies in general and the branded solar sector and promotion programs like Lighting Global in particular? For starters, it raises the question whether there is a target group at all for branded solar providers given the market-based paradigm that is prevailing. One part of the rural population does already have access to non-branded solar products. These devices might be of lower quality in terms of durability, but not necessarily in terms of service levels. In addition, the shorter durability is also compensated by considerably lower market prices, so non-branded products in fact seem in many cases to be worthwhile investments from the customers' perspective. Those households who do not use a non-branded solar product are much more difficult to reach, because they are already using electric light powered by dry-cell batteries and, more importantly, because they will not be able to afford the required up-front investment. Financing schemes might help to reach more customers, but considerable parts will remain to be excluded. In this situation, the role of branded solar products in achieving the SE4ALL goals is particularly unclear, at least if the current SE4ALL-paradigm of no-end-user-subsidies is maintained. If a political decision is taken that access to electricity is defined as access to high-quality solar energy, more direct promotion schemes like end-user subsidies are required. In fact, branded solar products might justify public support not by an energy access argument but by a life-cycle management argument: the shorter durability of non-branded products and the surging consumption of dry-cell batteries in rural Africa is leading to more and more electronic waste, which is becoming a growing environmental burden. It might indeed be possible to implement a reasonable waste management system through licensed vendors, but probably not through non-licensed vendors on local markets or in local shops.

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ACKNOWLEDGMENTS

Peters gratefully acknowledges the support of a special grant (Sondertatbestand) from the German Federal Ministry for Economic Affairs and Energy and the Ministry of Innovation, Science, and Research of the State of North Rhine-Westphalia.

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“Identifying best practices in all matters related to decentralized electrification in developing countries – whether they be technical, economic, environmental, financial or organisational – is essential if we are to achieve our goal of universal access to electricity.”

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