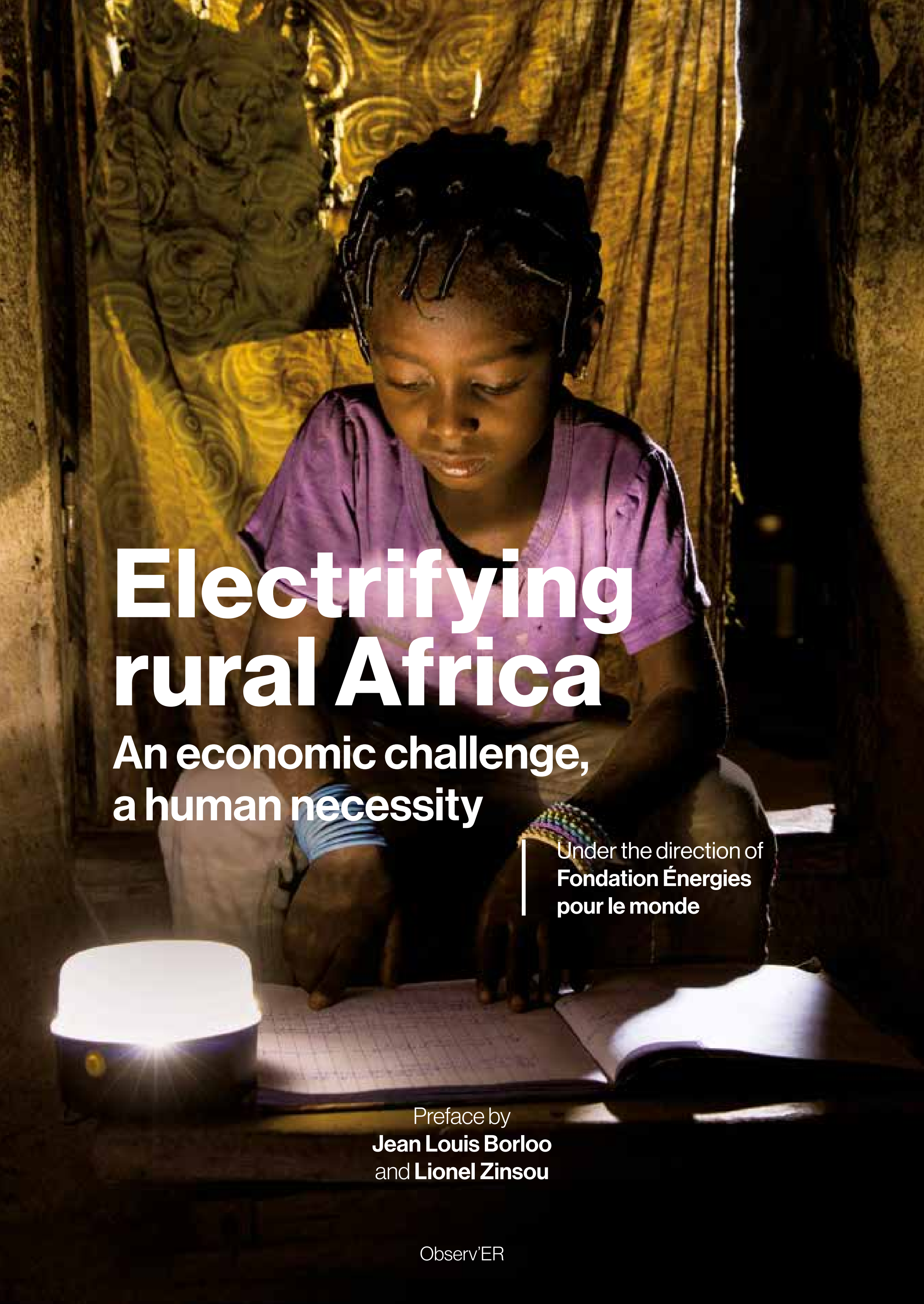


Electrifying rural Africa

An economic challenge, a human necessity

Under the direction of
Fondation Énergies pour le monde

Preface by
Jean Louis Borloo
and **Lionel Zinsou**

Observ'ER

Under the direction of
Fondation Energies pour le Monde

Electrifying rural Africa
An economic challenge, a human necessity.

Observ'ER

Warning

Responsibility for the opinions expressed in this book lies solely with the authors. Data collection was completed on 1 June 2019. Elements available after this date may have been included depending on their availability prior to completion of the draft.

Webpage

This book is available online:
http://www.fondem.ong/electrifier-lafrique-rurale/
Updated data and additional content are available on the book's website:
http://www.fondem.ong/electrifier-lafrique-rurale/

Design and production

Publisher : Observ'ER

146 rue de l'Université – 75007 Paris
Tél.: 01 44 18 00 80 – Fax: 01 44 18 00 36
www.librairie-energies-renouvelables.org

Publishing Director:
Vincent Jacques le Seigneur
Authors: Gérard Madon, Yves Maigne, Etienne Sauvage, Sarah Vignoles
Page makeup: Alice Guillier
Translation: Shula Tennenhaus

ISBN-978-2-913620-63-6
This book is not for sale.

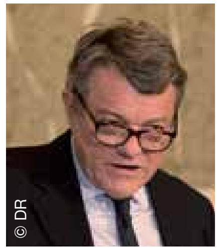
Cover: © Cyril le Tourneur d'Ison

Electrifying rural Africa

An economic challenge, a human necessity.

Foreword

Africa – a triple revolution



Making access to energy easier in the developing countries, starting with those of Africa will not only guarantee the success of our climate policies, but also crucially forestall a challenge for peace and world stability. Why? Because in Africa, a triple revolution is underway and the speed and impacts of each one of its facets is unheard of in humanity's history.

The first revolution... the demographic shock

Africa's population should double in the next thirty years. The continent, whose inhabitants have increased tenfold since the access to independence and/or the creation of new states, will need to feed, house, look after, train and employ more than a billion extra people by 2050. A billion youngsters under 30 – who haven't even been born – will number one in every four members of the labour force across the world. Their lifestyles – staple consumer goods, transport, habitat... – and their working and production methods will obviously be decisive for the success or failure of climate policies applied elsewhere on the planet.

The second revolution... communications

The speed at which mobile telephony and smartphones are spreading almost beggars belief. There are now 995 million telephone subscribers and 362 million Internet users. There are hardly any homes without cell phones even though many miles have to be covered on foot to charge them wherever there is an electricity supply... In less than a decade or generation, Africa in its entirety has made a technological leap and, in so doing, has turned its perceptions, ideas, lifestyles and production methods upside down.

It constitutes both a threat and an opportunity. Nowadays, populations who have no access to the absolutely essential services to development cannot be expected to sit tight while they are connected with the rest of the world and see Paris, Addis-Ababa, London or Lagos aglow at night. And tomorrow, even more, its youth will continue to take to the road, attracted by the pull of the city's lights and music. It also constitutes a chance, because modern ways are within reach all over the territory with communication, which makes it possible to bring forward harvests, get the weather forecast, alert or prevent risks, pay or get paid. What is more, electricity can now be purchased on demand*, as dictated by needs and the money in your pocket, on a par with communication units that we are already familiar with. This is called pay-as-you-go – a term that sums up this on-the-go world and constant communication that we have entered as part of the whole global village.

The third revolution... access to energy

Access to energy is a universal challenge. It is what enables fundamental rights to be achieved: drinking water, and also wastewater treatment, education and health, employment and security, stability, in a nutshell the right to live decently in one's village or neighbourhood. And it is one of the sustainable development goals adopted by the General Assembly of the United Nations in 2015, which seeks to "Ensure access to affordable, reliable, sustainable and modern energy for all by 2030".

Yet Africa is in darkness although it is possible to allow access to electricity to some 620 million Africans who are deprived of it... namely almost 80% who are rural dwellers. The pay-out would be double as Africans would thus have access to development. At the same time, Africa would become the first continent to call massively on renewable energies, and thus pave the way for a decarbonized world, which is a prerequisite for humanity's survival. It is not a wager, it may be a crazy bet, a challenge it is for sure, but it is within reach. Why? As with telephony, the absence of the grid is an opportunity to grasp, to develop community- or canton-wide mini-grids just about everywhere fuelled by small photovoltaic or hydropower plants. Technology's progress and the scale effects now make renewable energies competitive. In most cases they are cheaper than those produced by small diesel-powered generator sets*. The technologies are robust and suited to this continent that is blessed by nature... here for its solar radiation, there for its rainfall patterns or latent wind and everywhere for its huge biomass potential.

The need to act is urgent

While this triple revolution – demographic, communication and access to energy – is engrossing it causes concern. It is obviously a humanitarian duty, because we cannot just leave one out of every four earthlings in the dark, but it is also a duty for humanity, whose very survival is at stake. We have no choice in the matter, we must act as a matter of urgency.

Firstly, Africa is currently responsible for a negligible amount of greenhouse gas emissions, yet it already pays the heavy price of climate change impacts with its water shortages and devastating cyclone periods, resurgence of diseases, malnutrition and serial famines, extreme weather events...

Secondly, while Africa is hardly responsible for these emissions, the situation is set to change, for in the last five years, 30% of the world's fossil resource discoveries have been made in Sub-Saharan Africa. The Southern Hemisphere countries will be unable to resist this treasure trove hoarded in their sub-soil any more than their Northern Hemisphere counterparts in the last century, unless something is done to dissuade them.

Giving moderate support, helping out to enable humanity's first decarbonized continent to emerge calling on 100% renewable energy, will be taking the one step ahead in the race against time that we absolutely need to win because Africa will not wait.

Jean-Louis BORLOO,
President, Fondation Énergies pour le Monde

"It is time to be optimistic"
Interview with Lionel Zinsou


© DR

Fondem : ***A number of years ago, you prefaced an esay by Christine Heuraux on the challenges of electrification in Africa. What is essential about this topic?***

Lionel Zinsou : During my years in office in Benin, we ran the "Light for all" project distributing solar lamps to equip households, health centres and schools. The project gave me first-hand insight into the access to electricity issue and convinced me that it had to demonstrate that a widescale initiative was possible and that it would bring many benefits to purchasing power, public health, education and security.

For governments, taking action for access to electricity is an issue of credibility. Make no mistake about it, electrification is not making progress and every day we fall behind another ten years, which means that 70% of Africa's rural population has no access to electricity. While the heavy rural exodus continues, demographic trends are such that there are still more people living in the countryside, right where there is no electricity and where the population no longer believes in electrification, even though it is a mainstream demand, a social right.

The benefits of access to energy are obvious. In the poorest districts of Benin, free access to solar lamps and cell phone charging generate annual savings of 100 000 FCFA (€ 153). This saving, far from being trifling, has a strong macroeconomic effect on purchasing power. That's an initial outcome. But over and above the financial impact, the intangible benefits are also extremely perceptible. The link between access to electricity and education is clear as borne out, yet again in Benin, by the distribution of solar lamps in Benin's schools that resulted in a wave of admission applications. There are other impacts – the independence and community life of women, security and public health.

Fondem : ***You say that Africans no longer believe in electrification, yet it is a mainstream demand. Can the situation change?***

Lionel Zinsou : Education, health, water and electricity are the population's four fundamental demands. They are basic public assets that now need to be supplemented by connectivity, which has become essential. These services, that were previously confined to the wealthy, have become requirements for everybody. It is a mass phenomenon. Africans, who have entered a democratic process, have growing expectations that the public authorities meet these needs... and if they are unresponsive, they intend to punish them. This is a new situation.

Some people viewed the “Light for all” programme that I mentioned and was funded by several financial backers as an initiative motivated by electoral ambitions. This attitude actually shows the deep indifference of people who already have electricity towards those who do not. We are far from being an equalization society, and what makes matters worse, we were in denial.

The context has dramatically changed. When I was a child, the country had no electricity and we thought we would never have it. There were no roads, no harbours... We had nothing and that was that. Now the port of Lomé is Africa’s biggest port. And today, the norm is that this dearth of services is intolerable... we cannot live without electricity. It has become a basic need, just like the telephone. This radical change in attitudes has come about over the last fifteen years. The non-existence of public assets is unacceptable. And that’s what made us act when we set up the “Light for all” programme.

Many programmes can be built from this notion of the right to essential services, with the populations and naturally the NGOs who are pioneers in the field. Innovative systems and new economic models need to be devised. But I think that the movement is relentless and will be decided in the next ten years.

Fondem : ***Senegal is contemplating harmonizing electricity prices to foster rural access to electricity, but is not thinking of an equalizing mechanism that is hard to maintain... How can the demand for electricity in the rural environment be met to satisfy both the affordability and economic viability criteria?***

Lionel Zinsou : That’s the crux of the matter. You cannot pay the real cost of electricity in the rural context. Thus, this electrification cannot be developed by going through the national grid. In 1980, they said that rural electrification in Africa would be universal and completed by 2000. In 1990, they said that it would be achieved in 2010, today, in 2030... In fact, it is impossible because the financial resources are just not there – and even less so if electrification is privately managed – to go right to the last village that has hardly any resources and uses very little electricity. That is why decentralized off-grid systems must be developed to reduce costs, line losses and make them accessible even if they will always need aid or credit for investment from public or private funders.

Fondem : ***What is the role of the international funders in this process?***

Lionel Zinsou : I think the funding bodies are feeling contrite. They have not really helped improve the continent’s situation and have nothing to do with energy mix developments because they did not consider them as a priority. It’s hardly surprising as for thirty or forty years they have neglected agriculture – linked to the electrification issue – which is the leading rural sector activity and even though it is agriculture that keeps the rural population in place. The number of World Bank initiatives in agriculture has been halved. Although agriculture accounts for 25% of Africa’s GDP and employs 50% of the working population, it represents just 8% of the African Development Bank’s portfolio. Since the Green Revolution, the issue of agriculture has taken a back seat, which means that rural electrification has effectively been overlooked. This situation, which penalizes the rural world, is also bound up in the fund raisers’ financing model. They pass through governments and implicitly convey an intensive model: “The future does not lie in family farming, but in processing, the service sector...”

Fondem : ***How could this situation change?***

Lionel Zinsou : The game plan is different now, because we are in democratic transition and the populations are coming forward, voicing their desiderata. Yet, democracy is stronger at local level than at national level because it is always more important for the central powers to control the presidential election than that of the mayor. Admittedly, the latter are still deprived of own resources, but the situation is beginning to move on. It’s interesting because the territorial institutions are those under the citizens’ direct control and surveillance, so corruption has less hold there because there are fewer resources to misappropriate. So, the territorial institutions will be able to sort out and overcome the inherent problems of setting up and conducting projects in the rural context.

Fondem : ***Do you think that local finance actors have a place in this context?***

Lionel Zinsou : Of course. I think everything is going to take place at local level, in a decentralized manner. If proof were needed that things are changing, microfinance is contributing the most working capital to trade and households. It is naturally subject to social control, and reports recovery rates of 95% compared to 50% by any traditional banking operator. Likewise, local firms and microfinance structures will be able to bring energy and water services to territorial scale. They are inseparable. Subscription to energy services will work through the same rationale as microlending, controlled by the interdependent community, as opposed to how it happens in peri-urban districts where the community supports not paying the public utility for its consumption...

Fondem : ***Is there anything left for the industrialized countries' local communities to do?***

Lionel Zinsou : Obviously. Decentralized cooperation is better at achieving its goals than centralized cooperation, primarily because it does not use state funding. So much less money is lost along the line. I also believe that Africa's territorial institutions are starting to change and claiming their economic identity and that decentralized cooperation will do them a lot of good. It is fairly easy, fruitful, sound, practical and more ethical than centralized cooperation, because a state-to-state project invariably uses 50% of the funds assigned to it. If you imagine twinning between small towns, such as Komé or Bopa, with the territorial institutions of another country, there will be many more results, less bureaucracy, better performance with much lower transaction amounts.

Fondem : ***Should the next French parliamentary development law debate be used to recommend fast-tracking this cooperation on small local projects rather than on major national programmes?***

Lionel Zinsou : I think it is easier today to finance major energy infrastructures than small, delocalized ones. That is the very reason why the latter should be the priority, in that the market mechanisms are much less finely tuned. There is no slick answer to the question of funding small electricity infrastructures. The economic models need to be adapted to the local context. Some local mini-grid projects require subsidies, because the income from payment for electricity will only cover the overheads and maintenance, not the project cost, whereas elsewhere the economic model will be very different because there are one or two major industrial users. However, that does not mean that co-funding large-scale projects should be abandoned.

Fondem : ***What then would the institutional funders' role be in that case?***

Lionel Zinsou : If we return to the funders, they have no vested interests or demands from sovereign states to support their farming sectors and thus the rural populations. Moreover, they are unequipped to understand small-scale projects. The banks can intervene in mass funding by refinancing the microfinance associations and should refrain from offering microcredits of € 200 or € 500 above all, as they will lose their money anyway. The same applies to fund raisers. They need to find programme refinancing bodies rather than finance them directly. They will be more effective, for less outlay.

Fondem : ***How should the change of scale be dealt with?***

Lionel Zinsou : Small projects need to be grouped together to attract financing. And the private or voluntary sector capable of setting up and managing these projects in conjunction with the local institutions should be refinanced. I am convinced that we will change scale fairly fast, that many projects are viable, even if the sustainability factors – the local environment, type of demand, etc. – are external. I think the fund raisers' role is readily found. Attijari, for instance, the first commercial bank to get Green Climate Fund accreditation, is mobilizing all its branches to report projects. It will be quite interesting to see the outcome. As an Attijari board member, I will make a point of following up these questions directly with the CEO: see what the network brings up, and whether a bank network can help set up projects, not only renewable energy ones. The projects and solutions should come in all sizes, just like the experiment.

Funds from different origins should be combined, with a pinch of private liquid assets, a pinch of World Bank lending, the AFD, etc., to cushion the budgets and then continue working through these partnerships with the private sector. Operators need these supports that call for hybrid funding. I am quite confident and think that this approach will become accepted. It is time to be optimistic. But I am still talking about "customized" not "off-the-shelf" financing. It is a more complex environment, tailored, where the actors who are unable to recover their debt claims must refinance those who do.

Fondem : ***Will the "customized" financing take place locally rather than at central level? Will the complexity reduce as a result?***

Lionel Zinsou : Yes, indeed. If that were not already the case in microfinancing, I would say that it would take twenty years to get there. But the tools are there, and we have the experience. We could also encourage the microfinance institutions to develop financing projects worth about 100-200 000 USD to handle an electrification project for a locality with about 500 inhabitants.

Lionel ZINSOU,
economist, former Prime Minister of Benin

Team

Editorial team

Yves Maigne worked in industry for twenty years for Leroy-Somer and Photowatt, on developing micro hydro and solar photovoltaic power plants in developing countries, before joining Fondation Énergies pour le Monde (Fondem) as its director. He partakes in the design and performance of field projects of the NGO dedicated to access to electricity services and renewable energies, by encouraging all the stakeholders, the financial partners, local councillors and users to work very closely together, not to mention the operators and national and regional institutional actors. The book was inspired by bringing these partners together, whose roles are both essential and complementary. He is a member of the National Academy of Technologies of France and contributes to the work of the Energy Division.

Gérard Madon started his career in 1975 as a research engineer in renewable energies in Senegal. He continued from 1982 as a specialist sustainable development, domestic energy and rural electrification consultant in engineering offices, and is the cofounder and associate of MARGE Energy, Environment and Sustainable Development (Toulouse). He has worked in more than 50 countries, mainly in Africa. He has been the chair of the governing board of Enercoop Midi-Pyrénées since 2015. Enercoop Midi-Pyrénées is an Enercoop network cooperative that supplies 100% renewable electricity in France.

Etienne Sauvage is an ESPCI/ENSAM engineering graduate, who started his career in 2000 in the Comoros on an electrification programme using solar kits. He then worked for the Transénergie design office engineering electrification programmes for the Indian Ocean area, based in Madagascar. From 2005 onwards he worked as a consultant engineer specializing in the issue of access to water and electricity in rural areas, mainly in the island territories of the Pacific, in Africa and the Indian Ocean. In 2007, he founded the HACSE engineering office that he directs, that specializes in decentralized rural electrification, and has been a preferred partner of Fondem for many years.

Sarah Vignoles provided the editorial coordination of this book. She has put her multidisciplinary training and experience at the service of a number of public and voluntary sector organizations since 2002. She has contributed to several publications on the theme of sustainable development.

The authors thank their families, whose support has enabled them to work on this book undisturbed, making the appropriate time and spaces available for thinking and writing. They also express their gratitude to Vincent Jacques Le Seigneur, the General Director of Fondation Énergies pour le Monde, for his support and patience throughout this project.

Acknowledgments

This collective opus was made possible thanks to the advice, eye-witness reports and expertise of many contributors.

Iconography and graphic coordination
Marion Cubizolles

Contributors
Christian de Gromard, Marie-Christine Zelem

Case studies
GRET/Juliette Darlu ; GERES/Marie-Noelle Reboulet ; ESF/Hervé Gouyet ; MARGE / Robert van der Plas, Maurice Pigaht et Samuel Martin ; FONDEM/ Celia Creff

Interviews
Jean-Louis Borloo et Lionel Zinsou
Camille André-Bataille, Jean-Pierre Bresson, Arnaud Chabanne, Samy Chalier, Yann Chauvelin, Juliette Darlu, Guilhem Dupuy, Bernard Equer, Grégoire Gailly, Hervé Gouyet, Caroline Frontigny, Elodie Hestin, Sarah Holt, Boureima Kabre, Jean-Baptiste Lenoir, Olivier Oriol, Olivier Rasoldier, Stéphane Redon, Rodolphe Rosier, Vincent Renaud, Mamadou Saidou Diallo, Nicolas Saincy, Boubacar Sow

Proof-readers
François-Xavier Albouy, Bernard Equer, Abdou Fall, Iris Nicomedi, Bernard Tardieu, Marin de Viry

Experts
Renée Chao-Béroff, Alexandre Chavanne, Jean-Paul Louineau, Gérard Moine

Fondation Énergies pour le Monde team
Valentin Benoît, Cyril Durieu, Alice Coureau, Vincent Jacques Le Seigneur, Isaure Marchand, Marie-Estelle Grison, Jérémy Ankri, Raphaël Sappey, Tanguy Poupart-Lafarge, Julie Trognon, Emilie Souchaud, Mehrin Ashraf

Translation
Shula Tennenhaus

President
Jean-Louis Borloo

Founding President of Fondation Énergies pour le Monde
Alain Liébard

Fondation Énergies pour le Monde particularly wishes to thank its financial partners – ADEME, IFDD and Synergie Solaire – for without their support the book would not have been published. It also thanks all the partners and donors, who have made it possible for it to continue its mission and develop its expertise to serve access to inclusive and sustainable electricity.

Partners

ADEME

Almost 20 years after the publication of an initial opus that stressed the interest of Decentralized Rural Electrification, presented as “a chance for mankind and the planet”, we felt it was important to support Fondation Energies pour le Monde in its effort to gauge the progress made in this area, especially through technological and social innovations.

Access to energy is still a crucial challenge for human development, economic growth and environmental and climate protection. Its inclusion in the United Nations Sustainable Development Goals adopted in 2015 reflects this.

About a billion human beings across the globe have no access to electricity. Because their access is based on generators that run on expensive and polluting fossil energies, several hundred millions have unsatisfactory access to electricity. This particularly applies to Sub-Saharan Africa. For despite encouraging progress, this region has the world’s lowest electrification rate, and the International Energy Agency forecasts indicate that in 2030 about 600 of the 674 million inhabitants without access to electricity on our planet will be in Sub-Saharan Africa, more particularly in its rural areas.

While it is unrealistic to imagine extending the centralized grids to all rural populations, their electrification can be greatly facilitated by using decentralized renewable solutions. Thanks to digital developments and falling renewable energy costs, a paradigm shift is now feasible for off-grid access to energy. Disruptive, more flexible models are emerging, that associate the electrification of villages with the development of income generating activities for the populations. According to the World Bank, 210 000 mini-grids would enable 490 million people to be electrified by 2030, particularly in Sub-Saharan Africa, for an investment of 220 billion dollars.

Nonetheless, many challenges, mainly equipment reliability, maintenance, and solvency, need to be met to ensure that off-grid solutions are effectively rolled out. It is also vital to bolster local skills and involve the communities so that the most suitable solutions can be jointly defined, including their governance aspects. Women are among those in the front line, both as actors and beneficiaries of rural electrification, combatting deforestation and climate change. They are highly committed, be they local councillors, teachers, promotors of environmentally-friendly farming techniques or innovative entrepreneurial solutions.

Improving access to funding is another pressing challenge, in a context where it comes as a paradox that there are few mechanisms available to back these types of projects that cost less than extending centralized grids or building higher capacity renewable energy power plants. Other challenges need to be met to adapt many countries’ public policies to these new models. Innovative business plan* and financing method solutions must also be deployed, by bringing together the private actors, the NGOs and the national and local public authorities.

On the strength of more than thirty years’ experience in the area of access to energy in Africa, ADEME launched an initial call for projects to support the development of innovative solutions, as its contribution to meeting these challenges in 2017, and selected 9 projects. Given the success of this call for projects, ADEME joined forces with the AFD to put out a second call for projects in 2019. Incidentally, actions are being carried out with the Syndicate for Renewable Energy of France (SER) and all the French access to energy actors to spur on their collective action.

This guide, starting from a round-up complemented with many case studies, describes the progress made in recent years, sets out future prospects and proffers recommendations enhanced by feedback from many actors. We sincerely hope that it will be useful reference to guide the momentum set in motion, as well as the coordinated rallying of the various actors to allow DRE to reach a new milestone towards the expected change of scale needed to achieve the universal access to energy goals set for 2030.

Dominique Campana
Director of International Affairs, Agence de l’Environnement et de la Maîtrise de l’Énergie

ELECTRIFYING RURAL AFRICA: AN ECONOMIC CHALLENGE, A HUMAN NECESSITY

IFDD

The decentralized rural electrification (DRE) challenge has been on hold for the last few decades while the developing countries' rural populations have witnessed a string of programmes and projects undertaken with unequal economic, social and technological, sustainability levels in time and space.

Since the first edition of the DRE book, the public sector actors have worked on changing the regulatory environments in an attempt to bridge the growing gap between the rural regions and the urban centres. The private sector and the technical and financial partners have also contributed to proposing innovative solutions to support this struggle for access that affects hundreds of millions of rural dwellers.

The IFDD, which at the time was the IEPF, had provided its support for the first edition of the DRE book in 2000, that was already produced under the supervision of Fondation Énergies pour le Monde (FONDEM). The Institute is glad to continue this partnership to strengthen the capacities of all types of actors involved in improving the access to electricity reality for all French-speakers living in rural areas.

It is the very purpose of reissuing this technical guide, which after providing a very comprehensive report illustrated with many DRE field experiences over the last decades in Africa, presents the desired or ongoing changes needed for sustainable development. I applaud the work of FONDEM and all the partners who have contributed to it and encourage the book's readers to take its recommendations to heart. I hope that the next decade will witness the rollout of decentralized, desirable and sustainable rural electrification models wherever they are needed.

Jean-Pierre Ndoutoum
Director, Institut de la Francophonie pour le développement durable (IFDD)

Synergie Solaire

Access to renewable energies is the common thread that links economic growth, social equity and sustainable development. The Synergie Solaire endowment fund was created on the basis of this belief to mobilize renewable energy firms around solidarity-oriented access to energy projects, implemented by French, then European NGOs.

The NGOs have recognized decentralized rural electrification expertise, especially in the area of social engineering*, which is a key success factor that the entrepreneurial world tends to overlook. Matters have taken a turn for the better in the last 10 years. This experience and expertise, that of Fondem in particular, is now making increasing numbers of economic actors aware, and new partnerships are emerging thanks to it. They associate two key factors, financial engineering and social engineering to create increasingly ingenious models. It is heartening that decentralized rural electrification (off-grid) is now considered as the indispensable adjunct to centralized (grid-connected) national electricity grid extension programmes. The two go together to give the African territories coherent and more efficient access and enable the most remote populations to enjoy this expansion.

The publication project arose in the context of the DRE stakeholders coming together, the desire to understand and acknowledge each party's place to move forward more effectively in common projects, regardless of whether they are states, rural electrification agencies, companies, international development agencies, NGOs, banks, impact funds, foundations or even young local start-ups.

We have been very honoured to join Fondem, ADEME and the Institut de la Francophonie pour le Développement Durable and back the production of this work which promotes synergy between actors. We have to build an ecosystem of actors and coordinate our actions at all levels, for we are convinced that this is the only way to take on the huge challenge of Access to energy with hope of making a real impact.

Hélène Demaegt
President of the Synergie Solaire endowment fund

Executive Summary

Inclusive and environmentally-friendly rural transformation is the order of the day for Sub-Saharan Africa, whose population will double by 2050. The world-challenging energy issue is crucial for the region's future, for there can be no development without sustainable electricity infrastructures to serve education, health and the employment of rural, essentially farming communities who will have to keep the cities fed. It constitutes a human imperative.

Yet, the electricity divide gives cause for concern in many Sub-Saharan countries that paradoxically have rich sources of renewable energy. As their national policies prioritize urban electrification, the rural populations naturally turn to readily-available market solutions, that tend to be mediocre in quality, to cover their essential electricity needs. The experience built up over 50 years and recent technological progress made in the solar power* and digital fields could enable the required sustainable electrical infrastructures to be deployed on a wide scale.

The question of economic model remains wide open, especially for those territories shunned by private operators because of profitability pressures that are at cross purposes with the goal of universal access. Yet, it could be technically possible to cover a significant part of the needs and achieve the aim of rural, if not universal then at least inclusive electrification by a judicious combination of collective (primarily mini-grid) and individual electrification solutions.

To achieve this, analyses and experiences must be shared to harness the resources of the developing and industrialized countries in a more coordinated and effective way. The authors posit approaches for consideration by each actor involved to restart the debate on the direction and means of action.

The Sub-Saharan region's continuing energy divide maintains the prevalence of informal rural electrification

The international community is rallying to promote access to energy in its most versatile form of usage – electricity – which goes hand-in-hand with human development. Despite this impetus, more than **600 million people still live without electricity in Sub-Saharan Africa (i.e. more than 70% of the region's population), essentially in rural areas**. However, the combination of economic and demographic growth will fuel the demand for electricity. Thus, the region needs to face the twofold, social and environmental challenge of keeping up with the electricity demand along a low-carbon growth path.

The Sub-Saharan countries are particularly well endowed with renewable sources (water, sun, wind and biomass), all of which can be harnessed in certain conditions. Solar energy, by far the most plentiful of these, raises much hope. Photovoltaic technology, which is currently the easiest to roll out in the rural environment for small and medium systems, is becoming widespread despite the limitations of electricity storage* to meet night-time demand.

So, the problem is not the availability of the energy resource. The low rural electrification rates of Sub-Saharan countries are primarily due to the lack of grids to feed them. The national utilities, backed by institutional donors, have made a priority of electrifying urban and peri-urban zones. Although these are more profitable, the utilities have been unable to generate the investment needed to finance grid extension to the rural areas. Furthermore, even when a favourable national strategy is in place, the effective implementation of off-grid electrification projects through local or private initiative runs into several political and institutional barriers (primarily the dearth of territorial institution resources and conflicts of competence between national agencies) but above all, economic barriers (rural areas are unattractive to investors).

At the same time, the need for electricity is stoked by the massive spread of mobile telephony. The populations, weary of waiting for a hypothetical grid connection, are as expected turning towards the ever-increasing range of alternative available solutions. The market sector, taking advantage of the swift democratization of photovoltaic production equipment and high-performance receivers (primarily LED), provides a growing array of electrical services that basically cater for domestic needs. Clearly, this fragmented, often poor quality supply, with no guarantee of inclusive, long-lasting service, is not the right answer. Incidentally, the exponential spread of individual solar systems that some claim to be a major advance in access to electricity, is mainly based on portable lamps, which are light years away from covering all the rural communities' social and productive needs.

The acceleration of rural electrification based on decentralized solutions, that draw on innovations as well as past experience

Decentralized solutions make sense for electrifying the rural environment as an adjunct to the grid, whose extension cannot be rolled out fast enough, for it is too costly for the operators. The hinterlands of France and the USA gained access to electricity, precisely through local impetus (via communal concessions granted to private firms or rural electricity cooperatives).

For 50 years, Sub-Saharan soil has seen many off-grid access to electricity projects, also known as "decentralized rural electrification" (DRE) projects, undertaken by humanist pioneers to serve human development. It should cover the widest possible spectrum of electricity uses, where respect for the territory, understanding of the populations' needs and the quest for equity must prevail when undertaking projects. In Sub-Saharan Africa, DRE (especially hydropower-based) was already being tested before its countries gained independence. It then spread in the 1970s with international cooperation backing, often in wind or solar energy collective electrification infrastructure projects (schools, health centres, pumps...) led by pioneering NGOs. Since the mid-80s, it has gone through an extension phase, characterized by stronger private sector involvement that has recently picked up speed.

The DRE sector has been going through a promising, yet risk-laden transformation for a decade or so.
The dawning that there is an environmental emergency is positive for projects that promote renewable energies and energy efficiency. A real technological paradigm shift, founded on the digital revolution has occurred with the falling cost of photovoltaic, low-consumption receivers and progress in storage, that jointly make for faster rural electrification through solar energy. The private sector is exploiting the opening up of a loosely regulated broad market and betting that improved chances of operational viability will proliferate innovative distribution schemes to populations so far denied grid access. These solutions are backed by international aid because of the social benefits they promise, yet they are based on commercial rationale that is often far removed from the historical DRE goal of sustainable service and community empowerment.

Thus, the barrier to spreading decentralized solutions is not technical but financial.
Bringing electricity to a rural or urban territory is extremely capital-intensive for the operation must cover its operating and maintenance costs including equipment renewal. These operations are doubly penalized because of the low contributions rural users are in a position to make. Firstly, they are unappealing to investors (their operational constraints are almost as harsh as in urban areas with much longer ROI time). Secondly, they are highly dependent on international funding, including grants and aid, in a context where the state coffers have insufficient fiscal resources, which fall far short of needs despite the increase in funding initiatives.

Some types of project such as rural mini-grids suffer particularly from this sort of shortfall. Nonetheless, they are penalized by their complex institutional cooperation rationale, the cost of actions to reinforce local capacities and the business plan uncertainties (without reference data, it is hard to be precise about the change in demand of the service over several years), despite being recognized as being the preferred decentralized solution for achieving universal access. On this basis, decentralized cooperation looks like a promising alternative to finance and implement socially ambitious DRE projects structured at territory scale, because this cooperation is founded on the sustainable relationship between two territorial institutions.

Cooperation between private and public donors, the first avenue for resolving this complex, mixed financing equation, is no doubt set to expand. Strengthening of the grant or preferential rate loan mechanism should nevertheless be directed in preference to the most inclusive projects to serve universal access to electricity.

Over and above the changes and uncertainties, cross-cutting feedback from the DRE actors has pinpointed several stable methodological elements for successful projects, that all concur on the same observation... the human factor is decisive. The arrival of electricity brings no social and economic benefits without the community's approval of the project and local control of the electrical systems. An ecosystem of actors must emerge to make the service operate sustainably across the territory. So, the success of a project firstly depends on the quality of stakeholder orchestration, which may be more or less complex depending on the type of electrification scheme, and this calls for specific project management know-how. When institutional cooperation rationale is central to the construction of the technical solution, as applies to a mini-grid, the constraints stemming from the difference in how the various actors (future users, public authorities, funding partners, equipment suppliers, etc.) grasp the issues and their sometimes conflicting interests, should not be underestimated.

Access to electricity projects are not merely technological in nature, they need a sociological approach founded on attentiveness out on the ground and cooperation, combined with budgets to fund all the awareness-raising activities, guidance and mediation required before, after and during the infrastructure commissioning. Primarily it must ensure that the decentralized solution usage conditions that differ from those of the urban grid are properly grasped (limited capacity, restricted daily quantity and/or times, use of batteries, etc.), as well as its pricing (higher per kWh rate, choice of service level, no subsidized rate) and payment methods (prepayment).

In addition, the sector is still having to deal with persistent equipment quality issues, due to the absence of standards and competent regulator, not to mention installation servicing capacity. From its very conception, the project must forestall the equipment dilapidation and the issue of end-of-life management. Although quality is being driven upwards by recent subscription offers (operators have a strong interest in limiting equipment maintenance costs), proper ownership of the service by the users is the best guarantee of sustainability.

Whichever scheme is rolled out, the electricity service calls for investments by the operators and contributions by users to have access to a sustainable service. The right pricing level and suitable payment methods are two factors that are kernel to a viable operation.

Rural Sub-Saharan Africa has become a proving ground for decentralized solutions from portable lamps to mini-grids

The off-grid access to electricity sector is as pioneering and fast moving as it is fragmented and disorganized. But, the range of current schemes which are all based on a long institutional process or almost instant commercial exchange, have one point in common – photovoltaic technology, whose simplicity and accessibility for any use wields an advantage.

The electrification of publics amenities (schools, health centres, places of worship and cultural buildings) is the historic access to electricity project. The developers of these projects have tended to be swayed by the obvious social utility and technical simplicity of the operations and have often underestimated the constraints arising from running the installed systems. Apart from those carried out by national programmes, few of these amenities are still up and running. In any event, the community must pay for routine servicing and component renewals. Another historical application of PV, solar pumping, is a useful solution (access to drinking water, crop irrigation, cattle watering), economical (no fuel or batteries) and mature enough to have the skill and spare parts available, which explains the remarkable longevity of some solar pumping infrastructures. Another example of community-wide application, solar public lighting is developing through recent technological progress (LED, PV, storage). Apart from the fact that it improves safety along main roads, it expands the range of social activities and offers the poorer inhabitants free use of a high-quality light source.

ELECTRIFYING RURAL AFRICA: AN ECONOMIC CHALLENGE, A HUMAN NECESSITY

Small individual systems intended for domestic use (SHS) have become widespread in the past few years. Users traditionally purchase them from a local reseller for cash and Pay-As-You-Go (PAYG) operators have been making them increasingly available on a prepaid standing charge basis since the middle of this decade. These systems have several limitations despite the fact that they have come to symbolize the democratization of decentralized energy. They are unsuitable for most productive uses as the power rating offered is low and the amount of energy per day restricted. Furthermore, although PAYG is backed by aid and free of any regulatory pressure as to service quality or pricing equity, its economics are turning out to be more fragile than forecast, which has forced its advocates to redirect their efforts to peri-urban areas.

Neither the spontaneous acquisition of a SHS, only affordable to the better-off, nor the generalization of PAYG will be enough to electrify the rural Africa inclusively. Hence the importance of initiatives that broaden access to these systems, such as Decentralized Service companies, managed by private operators along similar lines to public service delegation. Another avenue is to associate a private operator with a microfinance institution to enable small firms to acquire a quality PV installation on credit. In any case, the support of a development financier is required, to cover the technical assistance and/or subsidize part of the equipment.

A few innovative schemes are trying to resolve the conundrum of all the uses across a territory, in addition to these individual or collective electrification initiatives. The generic “energy kiosk” concept, with its sizeable electricity production in the centre of the locality, offers its inhabitants a range of services (telephone or portable lamp charging, multimedia, refrigeration, etc.). The kiosk tends to remain the private operator’s property who entrusts it to a local manager selected for his/her commercial and entrepreneurial profile and solid local presence. A few pioneering French NGOs are testing several energy platform concepts.

The nano-grid is an intermediate solution currently at experimental stage, that organizes pooled electricity production in a dwelling to which 3-5 other households are connected, essentially for domestic use. The concept is based on the economies of scale and the device’s ability to be upscaled (interconnection of nano-grids than can take over from each other, connection to the grid), to bring electricity to the whole territory gradually, in concertation with the local authorities and in line with any planned grid extensions.

Only mini-grids can supply electricity simultaneously to all the members of a rural community, by covering the range of their domestic, productive and social needs. This model, which is found right across Sub-Saharan Africa is being transformed. While the technological shift taken since RES and the digital revolution were harnessed supports the economic model (prepayment, more accurate consumption monitoring), it weakens local ownership. Furthermore, the private sector now develops most projects applying the fast-track rationale demanded by the financiers and populations. Meanwhile, the original model, founded on the collaborative mechanism spearheaded by the NGOs, whose lead times are often disheartening, is fading away. These operations, that often bypass national planning, naturally target dynamic rural centres and users likely to pay a price high enough to cover the profitability expected by the investors.

The many RES rural mini-grid projects are full of practical lessons. Most, if not all of them, reflect the variety of possible approaches and highlight the limitations of standardized tools. They also demonstrate how difficult it is to reconcile economic viability with social value.

Prior contextual analysis is decisive: real approval by the future customers, the electricity demand, growth potential, local ownership capacities, incomes and willingness to pay for the electricity service... In this field, nothing can replace experience, knowledge of local socioeconomic factors and the analysis of neighbouring projects. There is no magic formula for defining a mini-grid’s catchment area. It is a one-off exercise of diplomacy, calling for tact when treating often differing interests. The arrival of a mini-grid in a locality calls for close consultation between all the stakeholders (formal and informal authorities, associative and community bodies) that incurs extra costs but strengthens the sustainability of the economic model.

System design is also based on arbitrages that define the economic model. The system’s global architecture also depends on the approach. A proven first step, encourages the use of local skills and bolstering the capacities of local actors. The second, the technologically innovative step, is geared to “containerized” solutions, assembled by the manufacturer and turnkey-delivered to the project developers to be remotely monitored.

While digital solutions make payment for electricity services easier, they do not guarantee it. Price and service, the two key aspects of pricing, the central element of the economic model, must be suitable and understood by all. They differ considerably from the price and service of urban grids, so it is vital that a minimum of energy management and rational usage culture is passed on to the users.

The operator is the pledge of service quality (consumption control, equipment servicing), upholding the rules and collecting essential information to satisfy customers, planning an extension or capacity enhancement. As the vital link, its profile must thus be very versatile... technical capacity, trustworthiness, investment and management ability, social entrepreneurial spirit and sensitivity as a service public delegate.

Apart from these observations, it seems that the rural access to electricity boom is unlikely to be achieved merely by adding better devised and managed projects. It is also dependent on actions that go beyond the scope of “good practices” and “project” scale. It calls for sectoral changes stemming from real political resolve to guarantee system sustainability.

Achieving access to electricity for all calls for an alliance with better-coordinated actors, more suitable methods and resources

The lack of political resolve and proliferation of decision-making levels, fiscality’s failings and the dependency on international aid, the shortfalls of legal and standardization frameworks and national planning, the lack of coordination between international donors and understanding between the financial and non-financial sectors... the sector’s many weaknesses are not technical in origin, but stem from all levels of governance, organization, regulatory supervision and funding of actions. These complex issues persist despite the digital revolution, increasing private actor involvement and the spread of the latest electrification solutions. The appraisal made here logically leads us to raise the question of possible actions that will take the sector forward, and to make recommendations for each actor concerned, to (re) launch the debate.

These recommendations are directed towards the development of collective electrification solutions (primarily the mini-grid) which, combined with individual solutions, seem crucial to achieve universal access to electricity and should thus be at the centre of strategies. Incidentally, they are centred around four focal points to ensure the sustainability of the systems with respect for the recipient populations: make rural access to electricity an inter-ministerial issue for better strategic coordination, strengthen decentralization and deconcentration for more efficient local implementation, supervise the action of private actors to guarantee quality and professionalism, and lastly respect the principle of equity between users across a territory.

Find all the developments and recommendations that are freely downloadable on the book's webpage:
http://www.fondem.ong/electrifierlafriquerurale/

The turmoil sweeping the access to electricity sector brings both opportunities and risks. The path is a narrow one between the human imperative and meeting the economic challenge of serving inclusive rural transformation. It involves the notion of territory, on which all the stakeholders' analyses and actions must be centred. This issue of rural electrification, that we attempt to analyse on the basis of the seasoned experience of sector practitioners in the field, could serve as a blueprint. The issue of electrification is the same as that of all the distribution networks of essential services for the development of all territories. It raises the fundamental question of "commons", and the protection they must be afforded to guarantee that access, even to the most vulnerable.

ELECTRIFYING RURAL AFRICA: AN ECONOMIC CHALLENGE, A HUMAN NECESSITY

Contents

All terms whose first occurrence is followed by an asterisk (*) are included in the glossary, p. 420.

The whole of this book and many additional documents (case studies, interviews and articles) are freely available for consultation on the Fondation Énergies pour le Monde website: ***http://www.fondem.org/electrifier-lafrique-rurale/***

List of acronyms

AC
alternating current

ACP
Africa, Caribbean, Pacific

ADEME
Agence de l'environnement et de la maîtrise de l'énergie

ADER
Agence pour le développement de l'électrification rurale

AFD
Agence française de développement (French development agency)

AfDB
African Development Bank

AFME
Agence française de la maîtrise de l'énergie

AGER
Agence guinéenne d'électrification rurale

ARE
Alliance for Rural Electrification

AREI
Africa Renewable Energy Initiative

ASER
Agence sénégalaise d'électrification rurale

CAPEX
capital expenditure

CIRAD
Centre de coopération internationale en recherche agronomique pour le développement (French agricultural research organization working for development)

CNRS
Centre national de la recherche scientifique (France)

COP
Conference of parties

COPERES
Conseil patronal des énergies renouvelables du Sénégal

CSR
Corporate social responsibility

DC
direct current

DEG
Deutsche Investitions- und Entwicklungsgesellschaft

DFID
Department for International Development

DRC
Democratic Republic of Congo

DRE
decentralized rural electrification

DSC
decentralized service companies

EC
European Commission

ECDPM
European Centre for Development Policy Management

EIB
European Investment Bank

ELECTRIFI
Electrification Financing Initiative (European Union)

ESMAP
Energy Sector Management Assistance Program

EU
European Union

EUEI
European Union Energy Initiative

FAO
Food and Agriculture Organization of the United Nations

FCFA
CFA franc

FFEM
Fonds français pour l'environnement mondial

GIZ
Gesellschaft für Internationale Zusammenarbeit (German Corporation for International Cooperation GmbH)

GOGLA
Global Off-Grid Lighting Association

GSM
Global System for Mobile Communication

GSMA
GSM Association

GW
gigawatt

IEA
International Energy Agency

IED
Innovation énergie développement

IFDD
Institut de la francophonie pour le développement durable (Institute of the French-speaking world for Sustainable Development)

IFRI
Institut français des relations internationales

INES
Institut national de l'énergie solaire

IPCC
Intergovernmental Panel on Climate Change

IRENA
International Renewable Energy Agency

ISA
International Solar Alliance

KfW
Kreditanstalt für Wiederaufbau (German Development Bank)

kVa
kilovolt-ampere

kW
kilowatt

kWp
kilowatt-peak

LDC
least developed countries

LED
Light-Emitting Diode

LV
low voltage

MFI
microfinance institution

MFP
multifunction platform

MV
medium voltage

NGO
non-governmental organization

NiMH
Nickel-Metal Hydride

NOAA
National Oceanic and Atmospheric Agency

NRECA
National Rural Electric Cooperative Association (USA)

OCEF
Off-Grid Clean Energy Facility

OECD
Organization for Economic Co-operation and Development

OPEX
operational expenditure

PAYG
Pay-As-You-Go

PV
photovoltaic

RECP
Renewable Energy Cooperation Program

RES
renewable energies

RTE
Réseau de transport d'électricité (French transmission system operator)

SDG
sustainable development goals

SE4ALL
Sustainable Energy for All

SENELEC
Société nationale d'électricité du Sénégal

SHS
solar home system

SME
small and medium enterprises

STS
standard transfer specification

TWh
terawatt-hour

UNDP
United Nations Development Program

UNECA
United Nations Economic Commission for Africa

UNO
United Nations Organization

UNICEF
United Nations International Children's Emergency Fund

UNIDO
United Nations Industrial Development Organization

USAID
United States Agency for International Development

USD
US dollar

WB
World Bank

Wp
Watt-peak

Introduction

In 2016, *Le Monde* ran the headline "The world's future is at stake in Africa". All eyes are set on the continent, and in particular on the vast Sub-Saharan region, which is 36 times bigger than France and home to some 50 countries, 1 billion inhabitants in 2017 which will rise to 2 billion in 2050.

Onlookers mingle hope and misgivings as they take in its contrasting panorama of vigorous entrepreneurial spirit, droves of connected millennials, new prospects for goods and services that are poles apart from the sluggish global economy. They also see its unusual demographics, its fiscally-strapped states whose many zones are riven by political or religious tensions.

It is regarded as the most symbolic and visible expression of ongoing transformation. The fast and somewhat disorderly growth of its metropolises attract a lot of media coverage.

Yet, the future of Sub-Saharan Africa will probably be played out elsewhere, in its rural areas, where "the majority of the poor and famine-stricken populations are concentrated". The need for inclusive, environmentally-friendly rural transformation, is the order of the day for a whole raft of reasons that are highlighted in many reports (FAO, IFAD, UNECA). They can be summed up as follows: its very young population that will double in less than fifty years, most of its new workers will be rural, will have to be fed and employed.
How can the rural populations be provided with the means for their development, other than by methodically tackling the inequalities that fuel their forced exodus? How can this transformation occur while rural territories remain cut off, deprived of basic infrastructures and services? How can the food challenge be met while accelerated climate change is leading to great uncertainties about the quantity and quality of agricultural production?

The energy issue, the planet's 21st-century challenge, is crucial for the region's future, in that it focusses on part of the solution... no sustainable rural development without environmentally-friendly rural energy infrastructures.

The energy divide is a fact. It is manifold, to the point that one could talk of several energy divides, not just one – between the industrialized and developing countries, between the emerging and least developed countries of the South, between the rural and urban areas, between the social classes of a single rural community... The first part of this book summarizes the topic by giving a broad outline of this divide, its origin and the resulting energy usage habits.

The struggle to reduce the energy divide started about fifty years ago by bringing electricity to the populations not served by the national operators, based on decentralized and renewable energy solutions. In recent years, new momentum has been injected into it by the upturn in solar technology and the digital revolution. However, in an environment where electrification project profitability is generally uncertain, if not impossible, achieving really inclusive rural electrification is fraught with obstacles. The second part of the book tells of this struggle and the lessons of the last five decades' experience.

The third part, devised as a technical handbook to be read by the uninitiated, aims to give the keys to understanding the photovoltaic systems scattered over the Sub-Saharan region. It draws a detailed panorama of today's solutions, with their strengths and weaknesses and sketches tomorrow's solutions.

These three accounts reveal many unresolved issues that affect a broad range of actors, sector fault lines that form the grounds for most of the delay that has accumulated by access to electricity in Sub-Saharan Africa. Best project management practices alone will not be enough to reduce them. Root-and branch work in cooperation and coordination is needed to devise, finance and sustain the change of scale. The fourth and last part of the book identifies these essential actions, so many recommendations directly addressed at the actors who can and must turn things around.

This book reflects the observations and analyses of decentralized rural electrification practitioners using renewable energies. While it does not claim to represent all points of view, it does present a realistic vision of the current state of play, based on their long field experience.

It deliberately focusses on the rural electrification of the French-speaking countries of Sub-Saharan Africa, a subject that has had little coverage from capitalization literature. It concentrates on the use of solar photovoltaic technology, which, at the time of writing, is the most appropriate for the rural Sub-Saharan context. Lastly, it centres attention on mini-grids, which stand out as the only electrification scheme able to cater for all the uses needed for the sustainable development of rural communities.

It has been produced with the support of the Agence de l'environnement et de la maîtrise de l'énergie (ADEME), a pioneering actor in the renewable energy field and access to electricity, as well as the Institut de la francophonie pour le développement durable (IFDD), which has dispensed training and information on the main themes, and Synergie solaire, an endowment fund that has enabled many access to electricity projects to come to fruition in French-speaking Africa.

[Part 1 - Context]

The Sub-Saharan region's continuing energy divide maintains the prevalence of informal rural electrification.

Info

Feedback from the field

Definition

Key Dates

Key figures

Introduction

The international community has set itself the global goal of achieving universal access to clean, affordable and modern energy by 2030. In real terms, this goal has two main focal points – the electrification of off-grid territories based on renewable energy sources and spreading clean, efficient cooking solutions.

In 2015, the rural world of Sub-Saharan Africa, accounted for...

62% of the population
25% of GDP (agricultural production)

Sources: Sara Mercandalli and Bruno Losch, "Rural Africa in motion – Dynamics and drivers of Migration South of the Sahara" (FAO and CIRAD, 2018).
FIDA, "Rural Development Report 2016 - Chapter 3: Structural and rural transformation in Africa" (Rome, 2016), 133.

It has to be said that in Sub-Saharan Africa, the energy divide is closing very slowly and that its rural areas are still predominantly under-electrified despite the substantial potential of renewable energy in the region (1.1).
Rural electrification tends to be overlooked by national policies biased towards the electrification of urban centres for both economic and social reasons and so its share of resolve and resources is left seriously wanting (1.2.).

The upshot is that electrification remains largely informal. The rural populace has no choice but to resort to its own devices to procure off-grid electricity for its needs by combining the many solutions available on the market (1.3.).

« Energy lies at the heart of two fundamental aspects of Africa's future – firstly, economic and social development and secondly, climate change. »

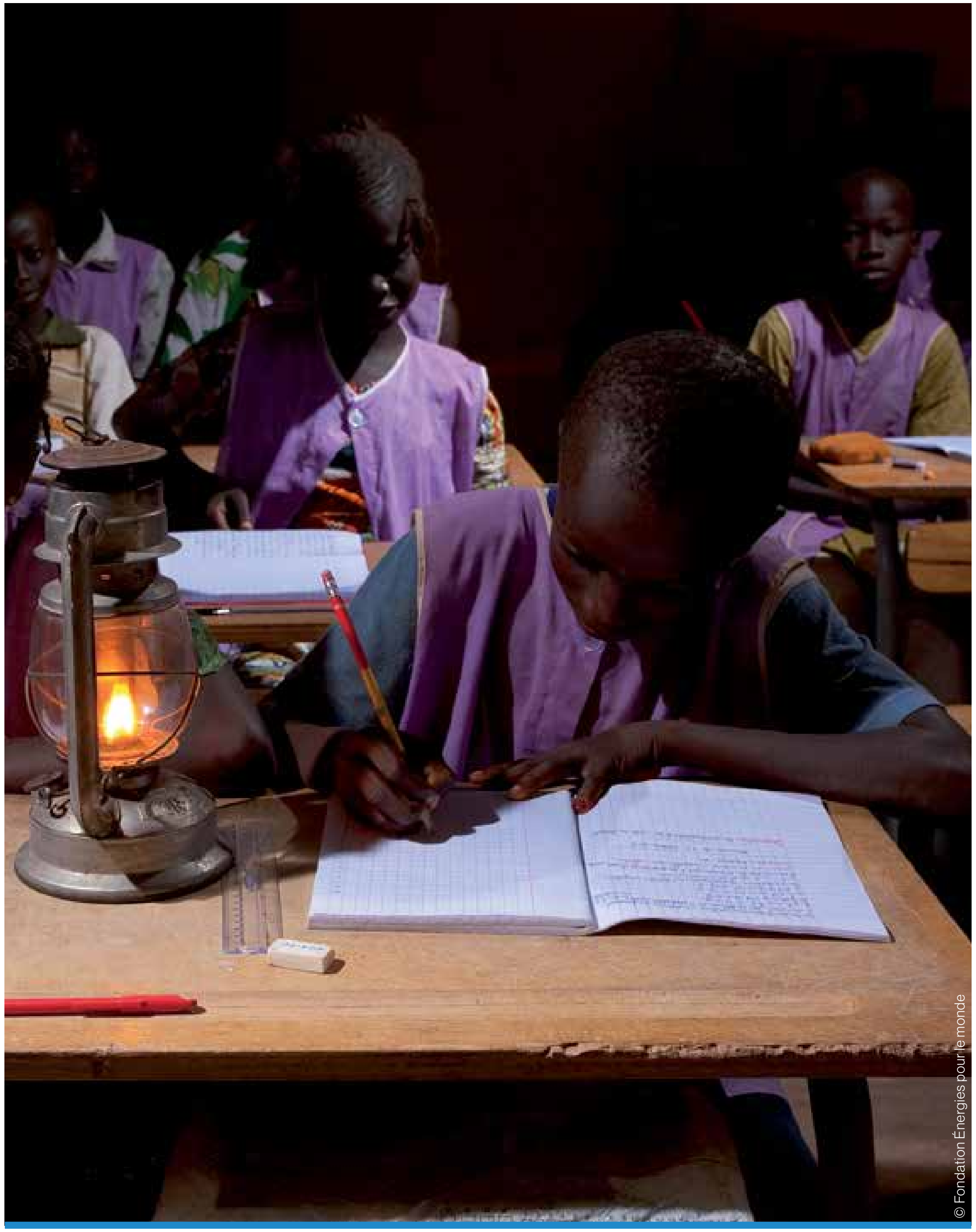
Marta Musso et Roberto Cantoni, "Energy in Africa: facts and figures – Introduction", *Afrique Contemporaine* 1-2, n° 261-262 (2017): 9.

ELECTRIFYING RURAL AFRICA: AN ECONOMIC CHALLENGE, A HUMAN NECESSITY

1.1.
Despite the abundance of renewable energy sources, the energy divide still gives cause for concern

The international community has rallied round to promote energy at its most versatile in terms of uses... electricity. But in Sub-Saharan Africa the energy divide remains deep. The prospects for demographic and economic growth amplify the challenge of electrifying rural areas (1.1.1.).

Yet the Sub Saharan subcontinent has significant renewable energy sources, led by solar energy, the most widespread and easiest source to harness (1.1.2.).



© Fondation Énergies pour le monde

Kerosene lamp.

1.1.1. Access to electricity is far from universal despite positive international momentum

Access to energy, and in particular renewably-sourced electricity, is a key factor in human development and a major issue in combatting climate change, it is buoyed by positive political momentum. Yet despite this impetus, reality challenges the objectives set out on the African continent. In the Sub-Saharan region in particular, the current pace of rural electrification can in no way cover the increasing needs.

Electrification must focus on the ambitious goals of universality and sustainability

Access to environmentally-friendly electricity should be given to all. This collective, global ambition was initiated in the 90s by a few institutions, such as ADEME followed by the European Union, and started to take shape in the wake of the 2002 Johannesburg Earth Summit.

This proactive political approach is based on a two-fold observation

First observation: reducing the energy divide is a precondition to combatting poverty. Electricity is a "basic service"[1] and access to it is a limited, necessary prerequisite for improving learning and working conditions and healthcare (cf. diagram below), and for developing economic activities.
Second observation: reduction in the energy divide cannot be achieved without considering environmental impacts and must be inseparable from combatting the effects of climate change. Therefore, preference should be given to access to electricity via renewable energies.

This proactive approach sets ambitious aims for universal access to environmentally-friendly electricity

International mobilization has primarily materialized under the auspices of the United Nations.

Human development

The real wealth of a country is made up of all the humans living there. When we address the notion of "human development", it may be defined as the process that aims to maximize the opportunities offered to men and women to improve their living conditions and allow them to experience well-being: opportunities to have access to income and employment, education and healthcare and a safe environment, opportunities to participate fully in the decisions of the community and enjoy human, economic and political freedoms.

Source: Larousse; UNDP

1. UNDP, "Human development report 1990" (New York : UNDP, 1990), 10.
United Nations Organization, "Report of the World Summit on Sustainable Development" (New York, 2002).

Access to energy

Access to energy is the physical availability of modern services, including access to affordable electricity and improved appliances such as ovens, to meet fundamental human needs.

Source: "Sustainable Energy for All database, derived from SE4ALL Global Tracking Framework", World Bank Group, IEA and ESMAP, https://donnees.banquemondiale.org/indicateur/.

"Electricity alone is not sufficient to spur economic growth, but it is certainly necessary. Access to electricity is particularly crucial to human development, as certain basic activities — such as lighting, refrigeration, running household appliances, and operating equipment — cannot easily be carried out by other forms of energy".

Enrique Crousillat, Richard Hamilton and Pedro Antmann, "Addressing the Electricity Access Gap" (Washington, D.C: World Bank Group, 2010).

Access to energy and human development are linked.

Main international initiatives taken to promote access for all to environmentally-friendly energy

2001

G8 Summit at Genoa: member countries undertook to negotiate a quantified reduction in greenhouse gas emissions under the *Climate Convention*, to provide funding for the Global Environment Facility and to develop renewable energies.

2002

Johannesburg Earth Summit: in the final report, point 9 was devoted to access to energy as an auxiliary human development aim: "access to energy facilitates the eradication of poverty, as a means of generating other important services"[1].

1. United Nations Organization, "Report of the World Summit on Sustainable Development" (New York, 2002), 12.

2004

Creation of the **EU Energy Initiative Partnership Dialogue Facility** (EUEI PDF), to co-finance projects that aim to increase access to modern and sustainable energy services for impoverished populations of the countries of Africa, the Caribbean and the Pacific, in particular in the rural and peri-urban areas.
Website: *http://www.euei-pdf.org/fr*

2007

Launch of **Lighting Africa**, a World Bank and IFC programme to promote development of the off-grid clean lighting solutions market in 10 Sub-Saharan countries (aim: to give access to lighting to 250 million people by the 2030 timeline).
Website: *https://www.lightingafrica.org*

2011

Launch of the **Sustainable Energy for All** programme (see inset below).
Website: *https://www.seforall.org*

2012

The **Power Africa** programme led by the US Agency for International Development (USAID), in partnership with the African Development Bank and the World Bank was launched. It offers technical assistance and funding to develop sustainable projects through American firms.
Website: https://www.usaid.gov/powerafrica

2015

Sustainable Development Goals adopted by United Nations Assembly (see inset below).
Website: *https://www.un.org/sustainabledevelopment/fr*

2015

Decision of the 21st Conference of the Parts to the United Nations Framework Convention on Climate Change 1992 (COP 21) to adopt the **Paris Agreement** and recognize the need to promote universal access to sustainable energy in developing countries, in particular in Africa, by strengthening the deployment of renewable energies. While this reference to sustainable energy is not mentioned in the Agreement text, the latter provides for mechanisms to mitigate, adapt, finance, build capacities and transfer technologies whose implementation should foster the development of sustainable energy.

2015

Launch of the **Africa Renewable Energy** Initiative, AREI, which brings together the 54 countries of the African continent. It is led by the African Union and aims to "accelerate and increase large-scale deployment of Africa's enormous renewable energy potential. It aims to increase installed capacity to at least 10 gigawatts (GW) by 2020 and to at least 300 GW by 2030. This Initiative promoted by the African Heads of State and Government was ratified by COP 21."[2]
Website: *www.arei.org*

2. Africa Renewable Energy Initiative, "Africa Renewable Energy Initiative, Summary" (2016).

2015

Creation of the **International Solar Alliance** (ISA) during COP 21. The treaty was signed by 58 countries and ratified by 26 of them. It plans to form a coalition of countries that enjoy plentiful sunshine situated in the intertropical area, to foster a change of scale in the roll-out of solar energy, by slashing costs. The creation of financial instruments aiming to mobilize one billion USD of investment in solar energy by 2030 should ensure that these aims are implemented.
Website: *http://isolaralliance.org*

Firstly in 2011, when a global platform was launched to foster universal access to electricity and promote clean and efficient cooking: *Sustainable Energy for All* (SE4ALL).

Following the lead of this initiative, the Sustainable Development Goals, (SDG), adopted in September 2015, make access to energy a fully-fledged goal and include the three targets formulated in the SE4ALL programme.
Sustainable Development Goal (SDG) No.7 provides for ensuring *access for all to reliable, sustainable and modern energy, at an affordable cost*. The "sustainability" criterion listed resonates directly with SDG No.13, devoted to combatting climate change: **the achievement of the universal access to energy goal must be combined with transition to a carbon-free economy.**

Sustainable Energy for All (SE4ALL)

The SE4All programme has set three goals to achieve by 2030 to transform the world's energy system positively:

1. Ensure universal access to energy and particularly to electricity;
2. Double energy efficiency, to reduce overall energy consumption;
3. Double the renewable energy share in the global energy mix, and thus increase it to 30%.

Source: "Sustainable Energy for All: SE4ALL", *https://www.seforall.org/.*

The lack of electricity exacerbates existing inequalities

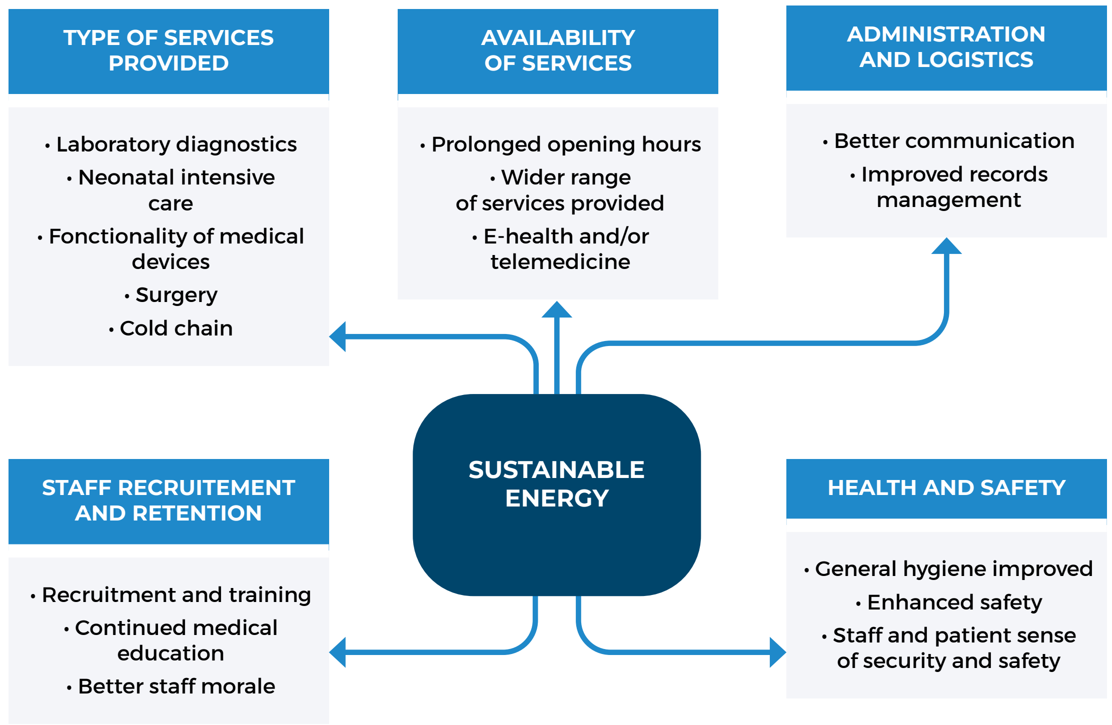
Poverty-stricken households spend a greater part of their incomes on lighting, which they cannot sidestep, yet only have access to the more expensive substitution resources. In Africa, **138 million poor households (people living on less than 2.50 USD (€ 2.23) per day) spend 20 times more than high-income households connected to the grid.**

In Burkina Faso, a survey assessed monthly lighting expenditure at 3 100 FCFA (€ 4.7) of up to **10% of a household's budget.**

Sources: Africa Progress Panel, "Africa Progress Report 2015" (Genève, 2015), and Lighting Africa, "Lighting Africa Market Trends Report 2012" (Nairobi, 2013).

1. Exchange rate (May 2019): € 1€ = $ 1.1186.

The beneficial impact of electrification by renewable energies on health



Source: IRENA, "Off grid renewable energy solutions to expand electricity access: An opportunity not to be missed" (Abu Dhabi, 2019).

SDG No.7 comes with two targets for implementation by the 2030 timeline:

- **enhance international cooperation** to facilitate access to clean energy research and technology, including renewable energy, energy efficiency and advanced and cleaner fossil-fuel technology, and promote investment in energy infrastructure and clean energy technology
- **expand infrastructure and upgrade technology** for supplying modern and sustainable energy services for all in developing countries, (in particular the least developed countries, small island developing states, and land-locked developing countries)

The SDGs also devote the essential auxiliary role of access to energy to achieving other human development goals (health, education, gender* equality, etc.), endorsing electrification as a "basic service" for populations.

These initiatives encourage mobilization and action in a meaningful way

The majority of international organizations' instruments (resolutions, declarations, recommendations, positions, white papers, principles) can be described as soft law and are in no way legally binding. Nonetheless they may encourage political commitments and lead to the promulgation of new standards of international or national law.

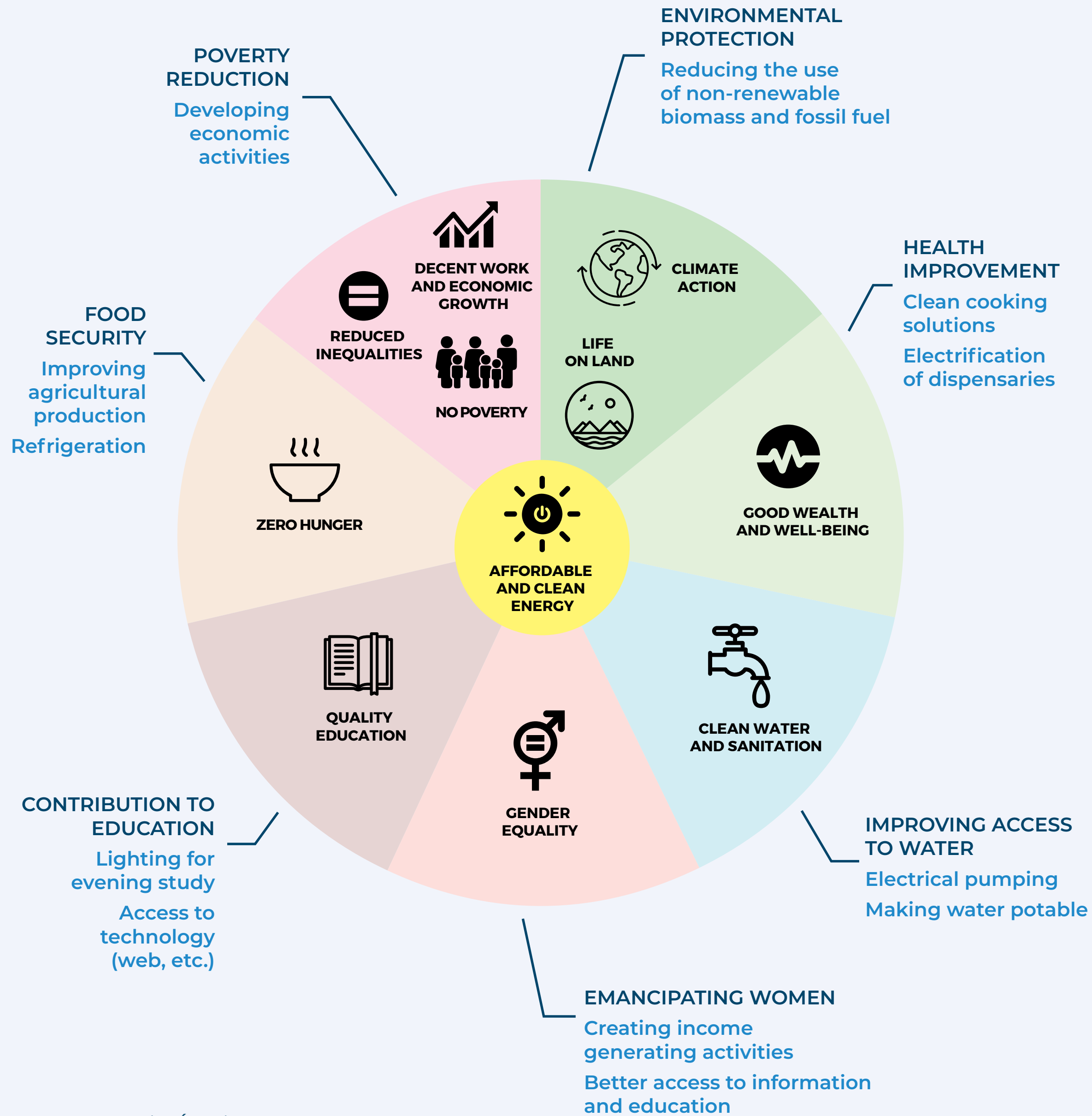
Hence, the diagnosis on the energy divide and the formulation of the goal of universal access to electricity via renewable energies have raised many players' awareness and accelerated the implementation of policies and programmes that promote access to environmentally-friendly electricity.

Universal access to "reliable, sustainable and modern energy, at an affordable cost" is an ancillary goal of many other human development goals.

"Be it for jobs, security, climate change, food production or increasing incomes, access to energy for all is essential. Working towards this goal is especially important as it interlinks with other Sustainable Development Goals."

Source: Sophie Farigoul, "Sustainable Development Goals – Reliable, sustainable and modern energy for all", UNO, *https://www.un.org/sustainabledevelopment/fr/energy/.*

The main links between Access to energy and Human Development



Source: Fondation Énergies pour le Monde.

Financial players have been spurred on to take up the gauntlet... which is essential, because electrification requires substructures and thus is capital-intensive (cf. chapter 2.3.2). For example, between 2012 and 2017, the French Development Agency, Agence Française de Développement (AFD) increased its annual allocations for the energy sector from € 921 m to 2 339 m[1]. Funding for renewable energies and energy efficiency secured 60% of this allocation compared to 8%, or € 940 m, for access to energy.

As is often the case, the international community has set itself very ambitious common goals to achieve that by the 2030 timeline

Current projections suggest that it will be impossible to achieve 100% universal access, for even at a constant electrification pace, more than 670 million people will still have no access to electricity in 2030. Massive investment will be needed to reverse the trend. Current investments will have to be increased five-fold to achieve universal access, and they will have to be increased two- or three-fold to achieve the renewable energy goals[2].

According to International Energy Agency projections, annual investments of about 32 billion dollars will be required through to 2030 in order to guarantee access to electricity for all.

The International Energy Agency's Energy Access Outlook published in 2017, came up with different scenarios for access to energy in Sub-Saharan Africa.
In the New Policy Scenario (NPS), which aims to achieve 60% electricity access in Sub-Saharan Africa by 2030, cumulative investment for providing electricity access in Sub-Saharan Africa is estimated to be 84 billion USD (€ 75 Bn) over the 2017-2030 period, averaging 6 billion USD (€ 5.36 Bn) per annum. To achieve universal access to electricity in Sub-Saharan Africa by 2030, the Energy for All Case scenario shows that the additional cumulative investment required amounts to $370 billion between 2017 and 2030 relative to the New Policies Scenario. These 454 billion USD (€ 406 Bn) of combined investments, namely 32 billion USD (€ 28.6 Bn) per annum until 2030, equate to 1.7 times today's total investments in the energy sector. These investments will be primarily funnelled into accelerating the development of mini-grids and individual systems.
At global scale, annual investment of $52 billion (€ 46.5 Bn) per annum would be required to provide electricity for all by 2030.

Source: IEA, "Energy Access Outlo 2017, From Poverty to Prosperity" (Paris, 2017).

We need to remember that all the world's regions do not start on a level playing field. For while the trajectory of certain regions (South Asia for instance) seem to converge favourably towards the 2030 goals, what lies ahead of the African continent is of greater concern.

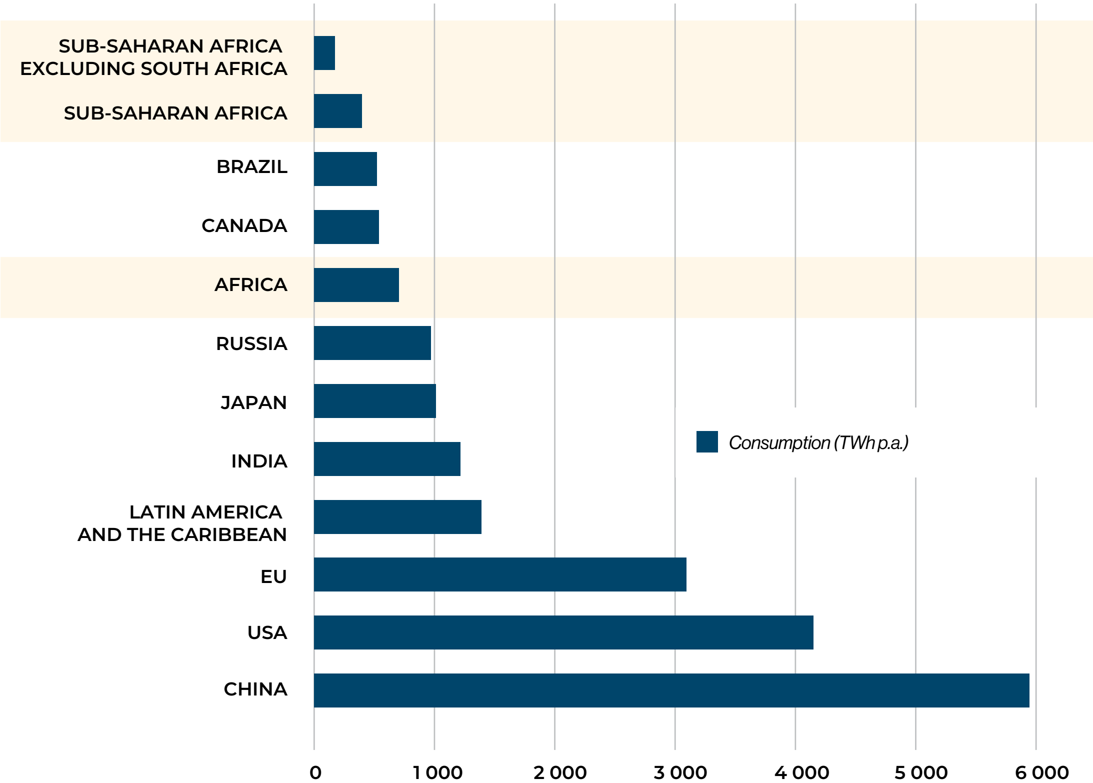
The reality of access to electricity for all on the African continent is a long way off

Sixty percent of people living in Sub-Saharan Africa (590 million[1]) still have no access to an electricity service. Moreover, where services do exist, they are not necessarily reliable.
In 2012, the World Bank described the failings in the existing installations (through servicing shortcomings or undersizing) and, particularly limited access to electricity as an 'energy crisis' for 25 of Africa's 54 countries.
The AFD reckons that making up for the lack of access to a reliable electricity service costs African households and businesses 5 billion dollars annually[2].

1. French development agency, "Speed up the energy transition in Africa" (Paris, 2016).
2. W orld Bank Group, "State of Electricity Access Report" (Washington, D.C, 2017).

Forum SE4All, september 2017.

Comparison of annual electricity consumption in Africa and the world

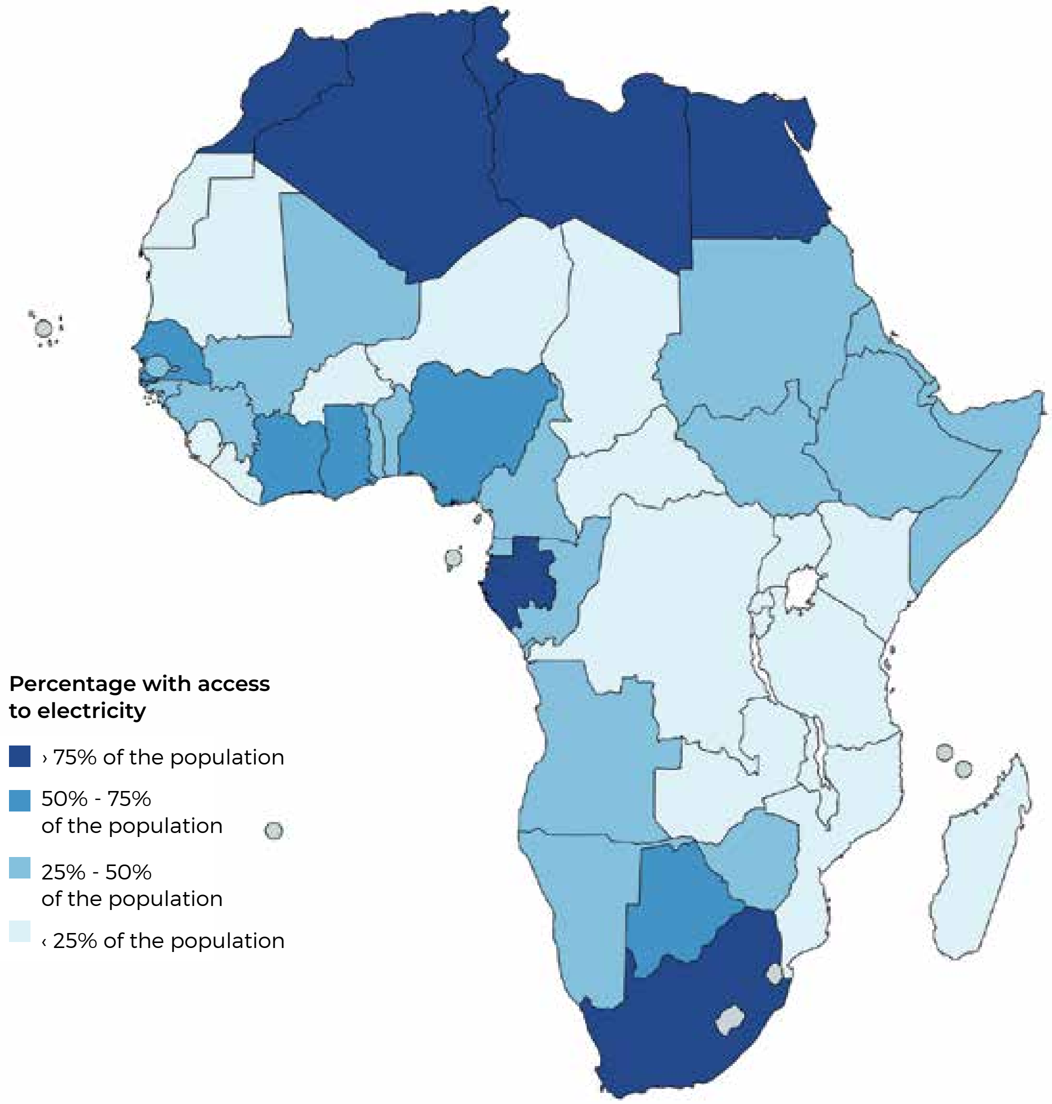


Source: Diagram produced from the World Bank Group's database (https://donnees.banquemondiale.org/indicateur/) and from the IEA's report "Key World Energy Statistics 2018".

Sub-Saharan Africa has the most acute access to electricity divide

This region concentrates 57% of the world's population that is devoid of access to electricity. In 2017, two out of every three inhabitants still had no access to an electricity service. The continent's figures hide its patchwork reality as there are great disparities between countries and subregions, as there are between rural and urban areas. The energy divide between rural and urban areas is particularly marked. In 2016, the rural electrification rate was below 20% in almost two-thirds of the region's countries (excluding South Africa), and below 10% in 17 of those countries. Only five countries had an electrification rate in excess of 50% (while in North Africa the electrification rate is in excess of 90%).

Sharp disparities in electrification rates between subregions are observed



Source: AIE "World Energy Outlook" (Paris, 2015).

Yet, more than 60% of the region's population is rural. The region also uses little electricity compared to the rest of the world. According to the World Bank, from 2010-2014, average annual per capita consumption in Sub-Saharan Africa equated to only 4% of the per capita consumption of the United States, 15% of China and 21% of Brazil.
Furthermore, the regional trend is worrying, as the number of people living without access to electricity increased between 2000 and 2014. Strong demographic growth, especially in rural areas was not matched by commensurate electrification efforts.
The region[1] suffers from critically undersized installed production facilities and inadequate distribution infrastructures for its needs. They pale in comparison with those of a country such as France. The maximum electricity generating capacity in Sub-Saharan Africa is 122 GW for more than 1 billion inhabitants[2], while that of France is 130 GW for 67 million inhabitants.

Sub-SaharanAfrica

Sub-Saharan Africa covers 22 million km² south of the Sahara. In 2017, it had 1.06 billion inhabitants in 51 states*. It includes 33 of the 47 Least Developed Countries (LDCs).

*Angola, Benin, Botswana, Burkina Faso, Burundi, Cape Verde, Cameroon, Central African Republic, Chad, Comoros, Congo, Côte d'Ivoire, Democratic Republic of the Congo, Djibouti, Equatorial Guinea, Eritrea, Ethiopia, Gabon, Gambia, Ghana, Guinea, Guinea-Bissau, Kenya, Lesotho, Liberia, Madagascar, Malawi, Mali, Mauritania, Mauritius, Mayotte, Mozambique, Namibia, Niger, Nigeria, Reunion, Rwanda, Sao Tome & Principe, Senegal, Seychelles, Sierra Leone, Somalia, South Africa, Sudan, Swaziland, Tanzania, Togo, Uganda, Zambia, Zimbabwe.

Source : UN.

Access to electricity (% of the population) according to the World Bank

Access to electricity is the percentage of the population that has access to electricity. The electrification data was obtained from industry, national surveys and international sources.

Source: "Sustainable Energy for All database, derived from SE4ALL Global Tracking Framework", World Bank Group, IEA and ESMAP, *https://donnees.banquemondiale.org/indicateur/.*

Yet, through the combination effect of economic and demographic growth, demand for electricity in Sub-Saharan Africa will remain high

Current projections forecast 3-4% average economic growth from 2019 to 2020[3]. That will result in rising electricity demand for productive uses (agriculture, craft trades, commerce, industry) and so call for massive new infrastructures to meet it.

1. Excluding South Africa.
2. International Energy Agency, "World Energy Outlo " (Paris, 2015), 78.
3. African Development Bank, "African Economic Outlo , 2019" (Abidjan, 2019), and World Bank Group, "Global Economic Prospects" (Washington, D.C, 2019).

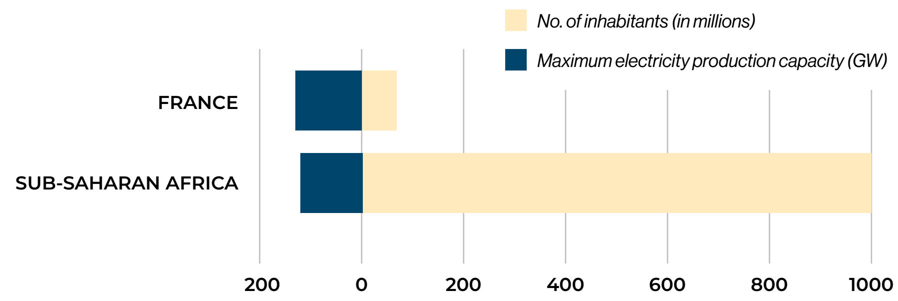
Sharp disparities are observed between the urban context (left) and the rural context (right)

Electricity access rate

- › 80% of the population
- 60% - 80% of the population
- 40% - 60% of the population
- 20% - 40% of the population
- ‹ 20% of the population

Source: Sia Partners analysis from IEA, "World Energy Outlook " (Paris, 2015).

Sub-Saharan Africa has similar production capacity for 14 times more inhabitants



Source: Diagram produced from the World Bank Group's database (*https://donnees.banquemondiale.org/indicateur/*) and from the IEA's report "Key World Energy Statistics 2018".

Not forgetting that as the demographic pace will remain strong, Africa's population will have doubled by the 2050 timeline, and exceed 2.4 billion inhabitants including 2.2 billion living south of the Sahara[1]. Furthermore, the rural population will continue to grow in numbers and most new workers will be living in the rural areas (cf. inset). Their needs will not be covered by the current electrification rate.

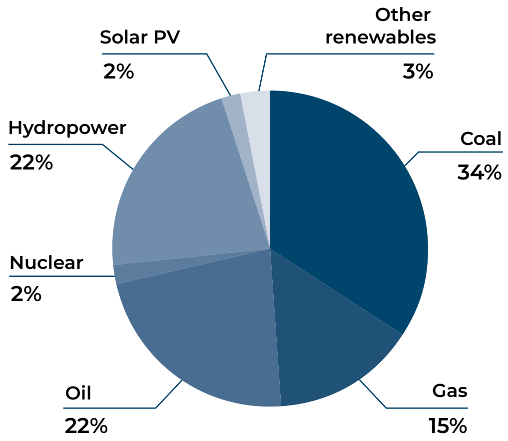
Whence a dual social and environmental challenge... to keep up the electricity demand following a low-carbon growth trajectory

Even if today, the African continent's environmental footprint is the smallest in the world[2], continued high demographic growth automatically raises the question of electricity production methods. In 2016, fossil fuel was the main electricity production source in Africa (80% of all electricity production[3]), while non-hydraulic renewable energies only accounted for 2.5% of production[4].

Still, the impacts of climate change can already be seen on the continent (cf. inset): rarefaction of water resources, disrupted rain cycles, higher temperatures... Because of "its geographic location and its scarce institutional intervention resources for political and economic reasons"[5], the Sub-Saharan region is and will remain one of the areas most affected by climate change according to the IPCC[6].

So, the question is whether renewable energies, which Sub-Saharan Africa has in abundance, will really be able to play the fundamental role expected of them to increase access to electricity while mitigating the effects of climate change.

Production capacity in Sub-Saharan Africa per energy type in 2016 (total = 122 GW)



Source: Sia Partners analysis from IEA, "World Energy Outlook" (Paris, 2015).

1. François Héran, "Europe and the spectre of sub-Saharan migration", Population and Societies, n° 558 (2018).
2. "Open Data Platform", Global Footprint Network, *http://data.footprintnetwork.org/#/.*
3. International Energy Agency, "Key World Energy Statistics 2016" (Paris, 2016).
4. International Energy Agency, "Key World Energy Statistics 2016" (Paris, 2016).
5. Marta Musso and Roberto Cantoni, "Energy in Africa: facts and figures – Introduction", *Afrique Contemporaine* 1-2, n° 261-262 (2017): 10.
6. Intergovernmental Panel on Climate Change, "IPCC Special Report - Global Warming of 1.5 °C" (2018).

Rural population – a unique demographic dynamic and unprecedented growth

Sub-Saharan Africa is the last region in the world to have embarked on its demographic transition, slower than expected. While in southern Africa and some of the West African coastal countries, the number of children per woman has fallen by at least three, most of the other regions display lower and uncertain drops in birth rate. As a result, the estimated population of Sub-Saharan Africa in 2050 has been revised upwards by 208 million, and the region should have 2.2 billion inhabitants by that date.

Sub-Saharan Africa is also unique for the continuity of its rural population figure. In 2015, the average proportion of rural dwellers was still put at 62%. While the world has gradually swung towards towns and continues its course of rapid urbanization, the region remains essentially rural because of the relatively recent urbanization process. It will only reach the rural to urban tipping point at the end of the 2030s. The urban population has increased since the 1960s, but this growth has stabilized at around 3.5-4% per annum because the transformation of most of Sub-Saharan Africa's economies is structurally weak.

It is reckoned that in 2050, there will be 980 million people living in rural Sub Saharan Africa, i.e. one third of the world's rural population. This population will increase by 63%, namely another 380 million rural dwellers, which implies a sharp rise in rural population densities. Thus, the greatest challenge for Sub-Saharan Africa is to generate sufficient jobs to absorb its burgeoning workforce. On the basis of current population distribution and migratory trends to the cities, some 60% of the new workers (i.e. about 220 million people) will most probably live in rural areas.

Source: Sara Mercandalli and Bruno Losch, "Rural Africa in motion – Dynamics and drivers of Migration South of the Sahara" (FAO and CIRAD, 2018).

The impacts of climate change on Sub-Saharan Africa

Sub-Saharan Africa, which accounts for 14% of the world's population is the region that has made the lowest input to climate warming. Despite an increase in its CO2 emissions in previous years, they remain very low (3.6% of global emissions) compared to those of Europe or the United States. Africa's main contribution to climate change relates to the faster pace of deforestation on the continent over the past decade.

However, the IPCC singles out Sub-Saharan Africa as the most vulnerable zone to climate change. The continent is undergoing myriad environmental changes while 75% of its surface is in the tropical zone. Desertification and drought affect some zones, while rising sea levels, flooding risks and coastal erosion phenomena affect others. Climate projections suggest that extreme heat episodes should not let up, but on the contrary will become more frequent.

Because of the high dependency on agriculture, high poverty level and increased vulnerability caused by the limited capacity to adapt, the repercussions of these many changes will (and are already are) affecting human ways of life and the natural ecosystems. More than elsewhere, agricultural production systems, on which much of the population depends, will be particularly disrupted by changes to the rainy seasons and greater temperature rises.

The IPCC considers that as well as climate-related harvest shortfalls, livestock losses and water shortages, 250 million Africans could experience food insecurity, which is the primary cause of rural exodus.

Sources:
- IEA, "World Energy Outlook" (Paris, 2017).
- IEA, "Key World Energy Statistics 2017" (Paris, 2017).
- Christopher B. Field and al., "Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part A: Global and Sectoral Aspects. Summary for Policymakers" (Cambridge and New York: GIEC, 2014), 1-32.
- Laurence Caramel, "Africa must take its share of responsibility in combatting climate change", major interview with Arona Diedhiou, *Le Monde* (online), 12th of December 2018, *https://www.lemonde.fr/planete/article/2018/12/12/l-afrique-doit-prendre-sa-part-de-responsabilite-dans-la-lutte-contre-le-changement-climatique_5396144_3244.html.*

Rural electrification by renewable energies and combatting climate change

Despite any empirical proof of the impact of access to electricity on populations' resilience to climate change, indirect links are nonetheless noted. A study (Scott et al.,2017) illustrates the positive benefits of electricity on adaptation, foresight and absorption capacities, that are needed for resilience to climate change.

Rural electrification by renewable energies seems a shrewd way to reduce dependence on fossil resources, whose constantly rising costs sap rural households' means. It also persuades local communities to own their sources of electricity and contribute to their management.

It also facilitates communication and access to information and improves the dissemination of alerts in the event of serious climate events, and so enable even isolated populations, to protect themselves and prepare better for the consequences.

Renewable decentralized systems may also make up for the shortcomings of centralized infrastructures until the latter are restored. The risks of outages or extended outages are limited in small-scale, decentralized projects, where local structures, in charge of the operation can respond faster. The traditional transmission and distribution grids are vulnerable to extreme meteorological phenomena, whose frequency is likely to increase. As fallout from that, their disruption may close other essential infrastructures such as transport and health services.

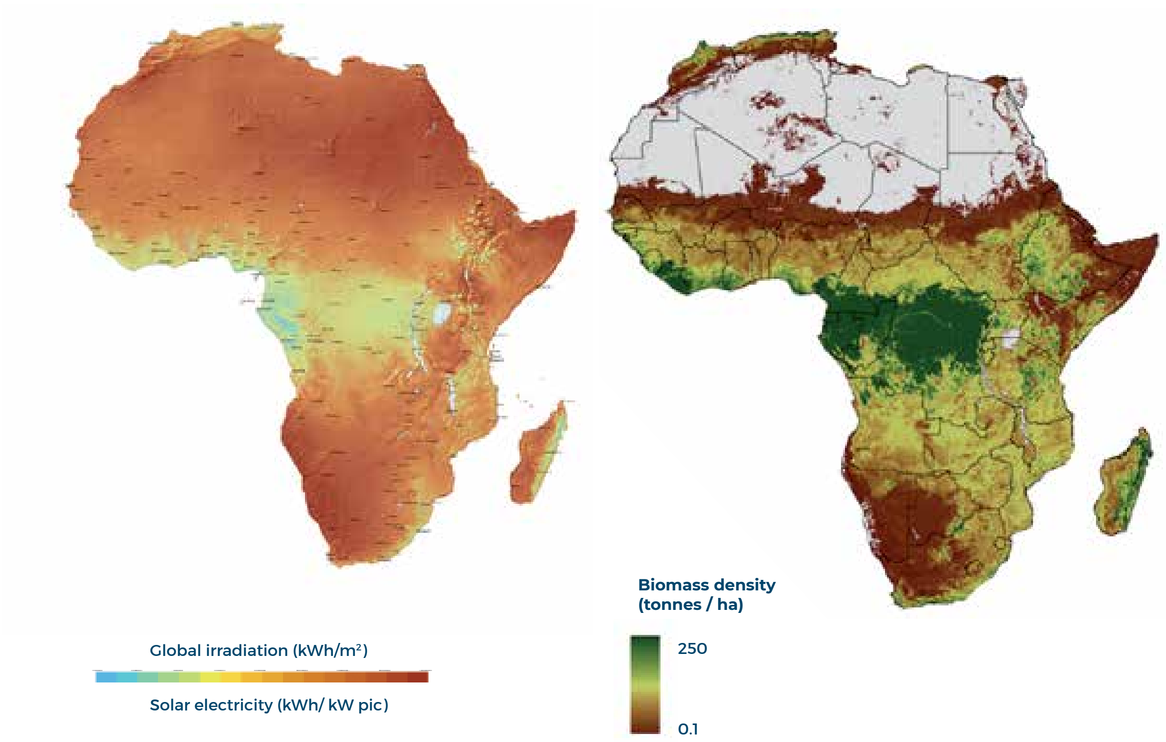
Lastly, ancillary applications of solar energy such as solar pumping, make it easier to access water resources and increase crop yields, thereby strengthening food security.

Sources:
- IEA, "World Energy Outlo " (Paris, 2017), 80.
- Andrew Scott and al., "How solar household systems contribute to resilience" (ODI, 2017).
- Valérie Masson-Delmotte and al., "Global Warming of 1.5°C. An IPCC Special Report on the impacts of global warming of 1.5°C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change, sustainable development, and efforts to eradicate poverty. Summary for Policymakers" (Geneva: GIEC, 2018), 32.
- IEA, "Key World Energy Statistics 2016" (Paris, 2016).

1.1.2.
Yet, the region has major electrification potential from renewable energy sources

Access to electricity in the rural environment is experiencing revived interest and activity thanks to the fresh possibilities offered by using renewable energy sources. All the territories are endowed with sources that enable electricity to be produced in the same place as it will be used, which precludes paying for its distribution. However, most of these countries that suffer from low rural electrification rates are located between the tropics, mainly in the Sub Saharan area which is generously endowed with renewable resources.

Map of africa's res – solar and biomass potentials



Sources: Alan Belward and al., "Renewable Energies in Africa - Current Knowledge" (Luxembourg: Joint Research Centre (European Commission), 2011).

While there is a broad range of renewable energies that can be harnessed, solar energy is by far the most abundant source

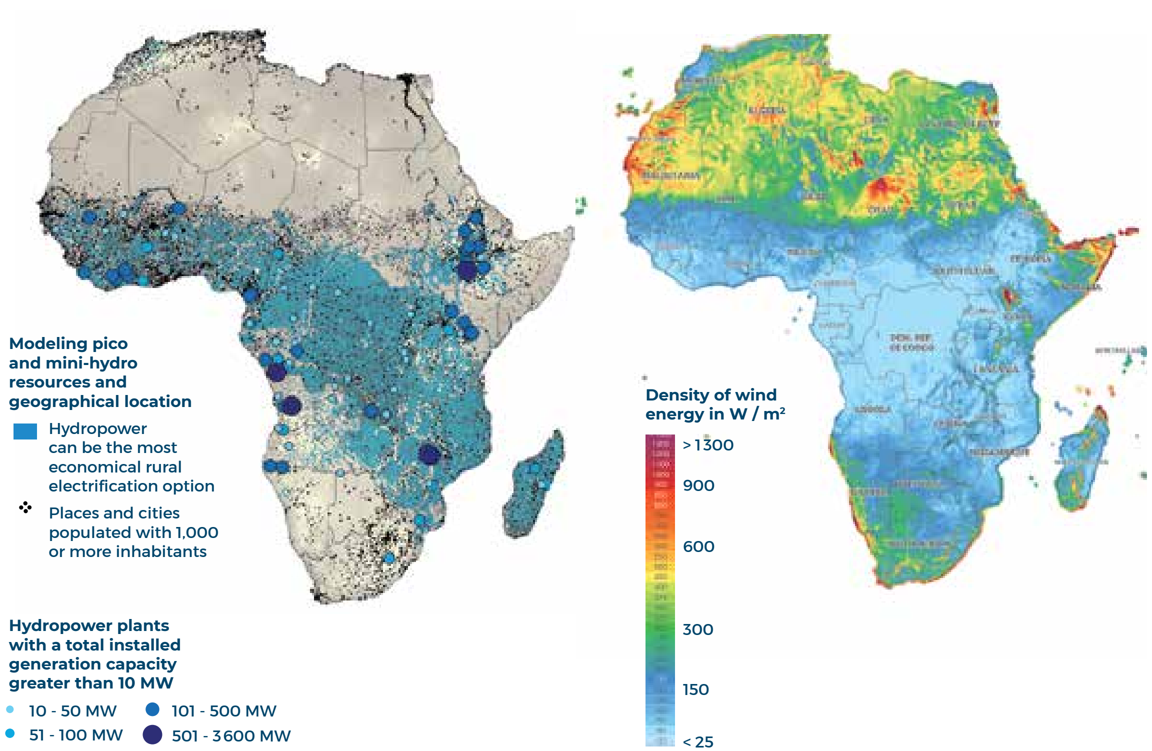
Solar energy is plentiful in tropical zones. Biomass is found everywhere, particularly in Central Africa. The mountain ranges of West Africa and the watercourses of Central Africa are brimming with hydraulic sources. Wind energy can be harnessed along tropical coastlines.

Great hope springs from the diversity of sources and the very high potential of the solar source. For all that and regardless of the source, real life experience and feedback remind us that the associated constraints should not be underestimated when it comes to using them for off-grid electrification of isolated sites with low electricity consumption prospects.

Solar energy

The solar resource was long spurned as a possible source for producing electricity. For instance, the International Energy Agency only started factoring in solar in 2012. Given the global potential

Map of africa's res – hydro and wind energy potentials

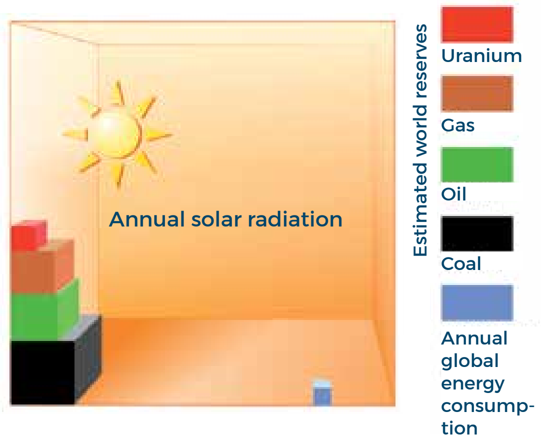


Sources: Alan Belward and al., "Renewable Energies in Africa - Current Knowledge" (Luxembourg: Joint Research Centre (European Commission), 2011).

of this source (23 000 TWh p.a.), its inclusion has shaken up the rankings between the various sources (cf. diagram).
The solar source for all of Africa is fully identified thanks to measurements primarily supplied by civil aviation and corroborated by NASA data. These measurements have been taken over a long time and are reliable. The relatively constant sunlight ratios over the year (about 6 kWh/m²/day in the tropical zone and 4 kWh/m²/day in the Equatorial zone[1]) mean that solar photovoltaic systems[2] can be used efficiently.
Once it is used exclusively, solar power's daily intermittence (or the existence of wintering periods[3]) – its Achilles heel – means there is no option but to couple it with an electricity storage system and/or hybridize it (couple it with controllable production sources).
See chapter 3.1. for detail on how solar photovoltaic technology works.

Batteries can store energy.

The solar resource far exceeds global energy needs



Source: Solarpraxis Engineering, *https://www.solarpraxis.com/english/.*

Wind energy

We have less knowledge of this resource, as measuring the wind potential of a site is a complex matter. It is rarely constant throughout the year and is influenced by its direct environment (local microclimate).
Furthermore, wind potential measurement campaigns have to be conducted for at least a whole year, then the results must be correlated with those of the nearest stations. It is particularly important to obtain this data over several years in the case of off-grid electrification.
Knowledge of wind speed distribution is a key element, because delivered electrical capacity is proportional to the cube of wind speed. Long windless periods are experienced, which imposes hybridization of electricity production systems. However, the prospect of violent winds, tornadoes or cyclones penalizes potentials sites, because of the risks of damage if the wind turbines are not made safe in time.
A decade or so ago, wind energy was an economically competitive option in areas where the wind resource was constant and strong. Now that photovoltaic costs have fallen so much, wind energy is often passed over because of its low capacities. Additionally, the wear on moving parts leads to severe operating constraints in rural contexts.

1. Compared with average horizontal solar radiation in France: 1100-1700 kWh/m² p.a. (Source: Solargis), i.e. 3-4.6 kWh/m2/day, but very variable from one day to the next.
2. There are other inappropriate applications such as concentrated solar power.
3. Primarily in the rainy season, that may result in a significant fall in sunshine, for example in coastal countries like Guinea and Sierra Leone.

The wind turbines of Ambondro (Madagascar)

Since November 2010, two 6-kW wind turbines, linked to a local electricity distribution grid have been supplying the locality of Ambondro in the deep south of Madagascar. Less than a year after commissioning, a loose bolt damaged the hub rotor of one of the wind turbines.
The manufacturer replaced the parts as they were still under guarantee and they were reinstalled by installer who had a base nearby. Correct tightening avoided a recurrence of this incident. Whatever happens, moving parts on innovative equipment are sources of failure and breakdown in service.
In this particular case, the negative impact of the breakdown was limited by wind turbine redundancy.

Source: Fondation Énergies pour le Monde, RESOUTH project.

Biomass

Biomass is found all over Sub-Saharan Africa. The resource in its dry and wet forms is suitable for use in energy, food and industrial applications. Despite its great potential, reliance on biomass has been unsatisfactory so far.

There are two types of constraint that penalize biomass. Firstly, the technical constraints of small installations with variable load regimes, and secondly, feedstock supply constraints (sufficient and constant quality and quantity)

Biomass

The dictionary definition of biomass is general and incomplete: "mass of living animal or plant matter, from the Earth's surface". Biomass also includes all biodegradable organic matter produced by living creatures. It encompasses the constituents of human and animal nutrition, materials (wood, hide, paper, fibreboard, rope), textiles (cotton, linen, silk), chemical compounds (resins, cosmetics, medication), natural fertilizers (manure, compost) and organic waste, in addition to all biosourced fuels (firewood, charcoal, biofuels, biogas and industrial biofuels).

Source: Christian de Gromard and Roland Louvel, "From biomass to bioeconomy, an energy strategy for Africa?", *Afrique Contemporaine* 1-2, n° 261-262 (2017).

As the current state of technologies stands, these constraints prevent biomass from supplying reliable and lasting electricity, regardless of which technique is used (gasification plant, jatropha oil-fired engine, steam turbine, etc.).

While the potential exists, more research is needed to harness the resource. Other extraneous factors such as demographic factors and climate change may upset the balance required of the local ecosystem.

Hydraulic energy

Outside the Sahel, Africa has vast hydraulic energy resources only 3% of whose 1 750 TWh p.a. potential is harnessed[1].

While this energy appears to be the ideal resource for the electrification of localities near watercourses, awareness of the potential tends in rural contexts is poor, even though investment and running costs may be promising if the sums add up. Furthermore, conducting detailed feasibility studies is essential, regardless of the intended capacity, technology and configuration. The region's rainfall, the river's hydrology must be analysed[2], as well as the site's geology and geometric stresses. As for sites with waterfalls, many details need to be carefully analysed, yet local contexts do not always offer the right conditions for collecting accurate data. Knowledge is mainly required of the available capacity, the length of the low-flow period (when the watercourse is at its lowest level), the distance to the consumption points and the civil engineering costs.

1. United Nations Industrial Development Organization 2009, and Food and Agriculture Organization of the United Nations 2011.
2. However, the results of the hydrological study are less critical if the exploited capacity will be less than the available capacity, i.e. when only part of the flow is used.

Gasification plant (Cambodia)

The village of Sambour in Kampong Thom province, Cambodia, has ample biomass resources.
A gasification plant installer is well-established in Cambodia.
This combination of factors gave rise to the project to install a plant in the village.
While the generating set worked well at full capacity on the gas released by the pyrolysis of the dried biomass, it rapidly started faltering because the cylinders clogged at low motor speeds. As the motor block had to be disassembled too frequently, the electricity supply kept cutting out and increased the operating costs, which eventually put paid to the innovative technical option. The gasification plant was replaced by a petrol-driven generating set.

Source: Fondation Énergies pour le Monde, Mékong II Solidarity Energy project.

© Fondation Énergies pour le monde

The Sambour gasification plant

Hydraulic data is relatively easy to obtain on sites close to fast-flowing level watercourses, the. However, greater attention needs to be paid to data on bed material load, drops in level and anchoring.

We can now widen the range of suitable sites using new types of water current turbines, that exploit the water's speed in the same way as wind turbines exploit wind speed.

When a suitable, exploitable resource is available all year round, hydropower offers potential that can compete with PV economically and in terms of the amount and quality of the electricity services it can provide.

The other renewable energies

The stable and constant nature of geothermal energy, which is particularly prevalent along the Rift Valley, is an interesting source, but its investment and technical requirements make it more suited to contributing to centralized electricity production (national grid), alongside conventional power plants, rather than to electrifying isolated rural areas. Lastly, even if these resources may seem significant along Africa's coastlines, the use of marine renewable energies is not currently on the cards.

Antetezambato hydropower plant (Madagascar)

The Antetezambato hydropower plant in the centre of Madagascar has been supplying electricity to the 180 domestic and business customers through a network that covers a 2-km radius since 2002.

The plant supplied by the Belgian company JLA, with its modest civil works, delivers 42 kW of capacity on a narrow watercourse at the bottom of a waterfall with a small impoundment. During the low-flow periods, lasting no more than 3 weeks, the customers have agreed to revert to their old lighting habits, without any problems.

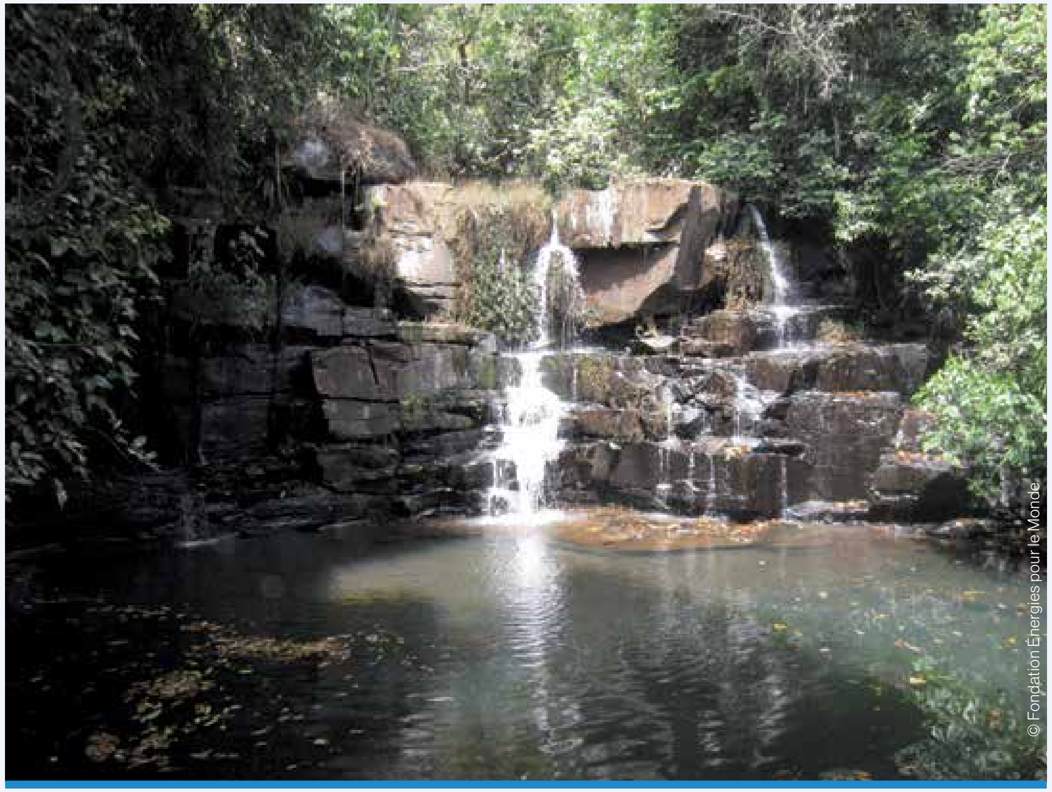
For 17 years now, the operator, a former teacher, along with a small team, has been operating the plant and the grid uninterruptedly, save for maintenance stoppages. Forward planning is required for changing just one component… the European-made belt.

The Antetezambato micro-hydropower plant

Hydraulic sources at Kouramangui (Guinea)

The locality of Kouramangui is in the heart of Fouta Djalon, in the Middle Guinea region known as the water reservoir of West Africa. Studies of the hydraulic resource conducted to secure international funding indicated that there was an exploitable waterfall two kilometres from the village centre. The data was consistent and preliminary work confirmed the site's relevance.

Thus, a hybrid solar/hydro project to electrify the locality was proposed. While the environment seemed to be perfect for a smooth operation, much to the stakeholders' astonishment, the conclusions of the detailed preliminary work refuted this. The hydraulic option had to be abandoned because the waterfall site is constricted and would have necessitated major civil engineering works. In the end, solar/thermal generating set hybridization was chosen. This proves the importance of paying meticulous attention to preliminary site studies.



Hydraulic source at Kouramangui

Private Sector Participation in Micro Hydro Power Supply for Rural Development (PSP Hydro)

Prior to 2006, the Rwandan government's policy was to finance micro-hydro power plant (MHPP) projects from public funds. The regulatory and legal framework for private investment had not been prepared on a broader scale. Furthermore, it was conceded that the government and financial backers would sign turnkey contracts and entrust the ownership of the facilities to public or community cooperatives under the terms of these projects. These mini-grids managed by the cooperatives soon floundered as a result of this policy, the lack of technical skill and inability to apply electricity tariffs that would reflect the costs.

At the time, there were no Rwandan micro-hydro firms or experts. PSP Hydro, that aimed to support the development of private Rwandan firms and micro-hydro power plant projects, solved these problems. It used workshops, feedback on the various business plan development stages, technical and commercial advice, and co-funding limited by subsidies to train the private sector. It helped the national institutions to draw up a propitious policy and regulatory framework. As a result of the project work, there are now more than twenty enterprises in business capable of constructing and operating micro-hydro power plants, including 9 local firms specializing in small power plants. The ten or more power plants supported by PSP Hydro are connected to the national grid and offer better reliability than those run by the national utility. Most if not all the output can be sold to the grid, so enhancing the power plants' viability. Incidentally, this result was achieved with only 3.4 million euros of financial backers' money, who garnered about 2.8 million euros of private funding from local and international sources.

Works for the construction of a hydroelectric power station as part of the PSP hydro project in Rwanda.

PSP Hydro owes its success to the combination of financial aid and policy reform. While a project can support the launching of activities, a prerequisite is a political environment conducive to ensuring that its long-term impact is tangible.

Sources: Summary produced on the basis of the MARGE website *http://www.marge.eu/PSP-Hydro-in-Rwanda*

Find the whole case study on the book's website in French: *http://www.fondem.ong/electrifier-lafrique-rurale/*

Rhyvière I et II

Madagascar is one of the least electrified countries on the African continent with a 17% electricity access rate nationwide. Dire poverty affects 77% of its population, in particular in the rural environment where the electricity access rate is only 11%.

This is the background to the 2007-2015 Rhyvière I project (Village Hydroelectric Grids, Energy and Respect for the Environment), financed by the Agence de Développement de l'Électrification Rurale (ADER) and the European Union through the Energy Facility. Gret led the project in partnership with Energy Assistance. It aimed to meet the micro hydropower development challenges for rural electrification in Madagascar by providing electricity to 2500 families in 5 rural communities with high agricultural potential, by installing rural hydro power plants in conjunction with the local and national public and private bodies.

On the strength of the experience gained during Rhyvière I, the Rhyvière II project (2014-2019), conducted in partnership with the CITE, Enea Consulting and the IRD, succeeded in achieving a change of scale. Larger hydropower plants were installed, and the general intervention methods were revised, to give the last 3 of its 4 areas a bigger role:

- energy: construct and perpetuate hydropower plants and decentralized solutions, as well as the electricity service in this unprofitable sector
- environment: protect the river basins and water resource from environmental damage (e.g.: deforestation) that would alter its quality and quantity, thereby impairing power plant operation
- socio-economic: educate the population and small businesses about the economic opportunities opened up by electricity, thus fostering economic development around the sites
- governance: involve the local authorities in the rural electrification contracting scheme, encourage user associations to form, ensure that the installed electricity service is of benefit to the entire population.

The Rhyviere I project was conducted in Madagascar by Gret from 2008 to 2015.

Lastly, the follow-up evaluation and capitalization activities have provided references for the national rural electrification policy, identified recommendations for future projects (more regular updates of the business plan, improving delegate follow-up and securing their funding, building standard requirements) and have revealed the weaknesses of all taking part.

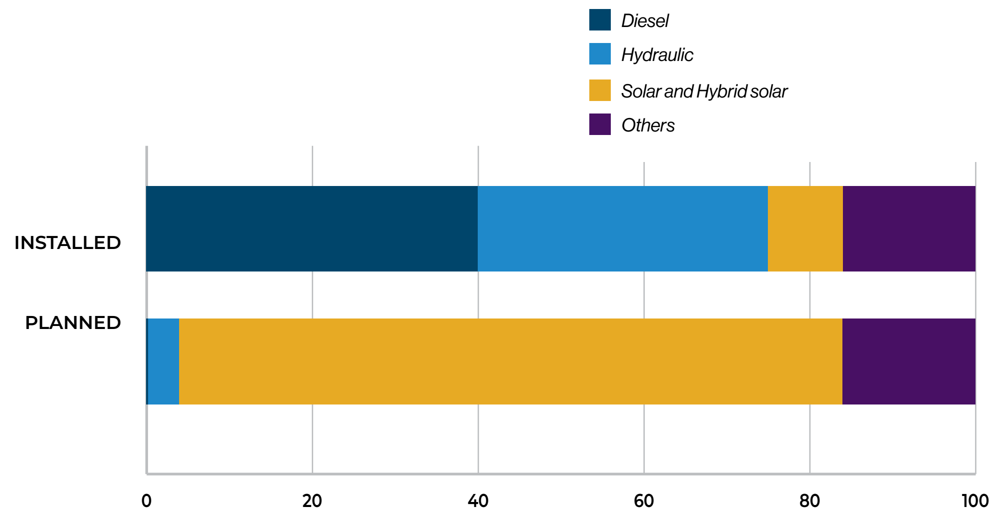
Source : Summary produced on the basis of the GRET website: *https://www.gret.org/publication/le-project-rhyviere-i-a-madagascar/*

Find the whole case study on the book's website in French: *http://www.fondem.ong/electrifier-lafrique-rurale/*

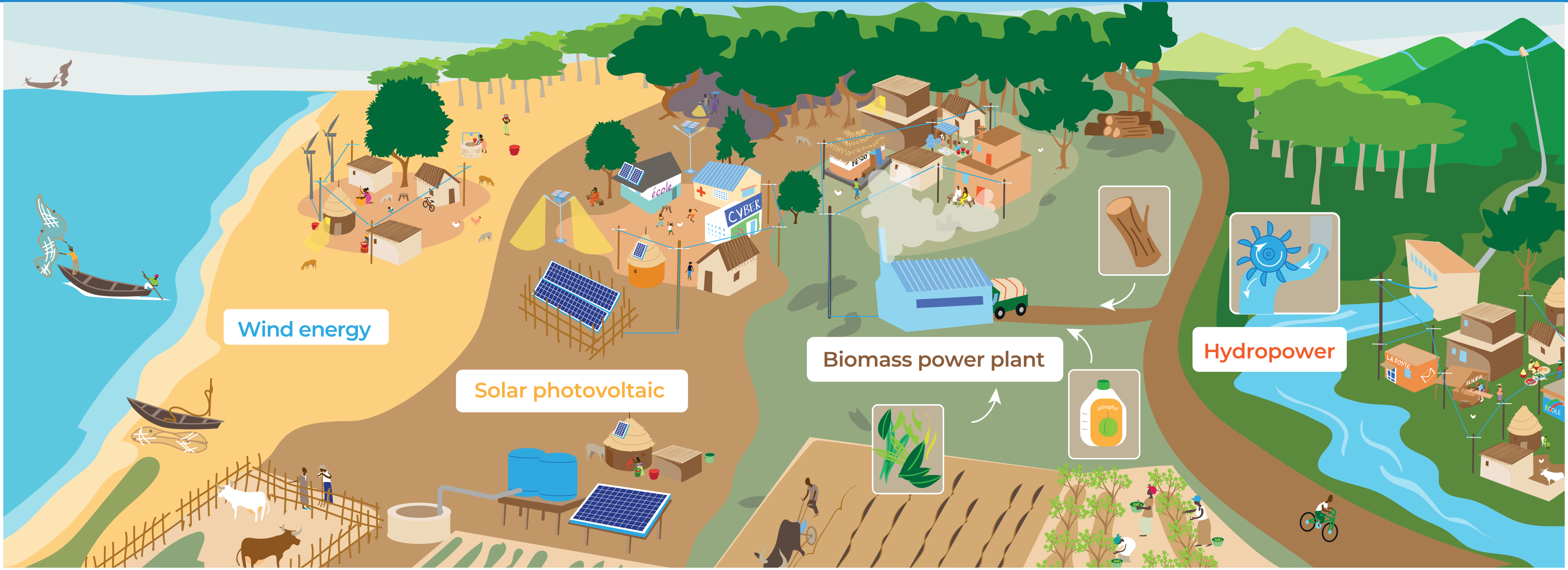
Certain conditions apply to exploiting these renewable energy sources for rural electrification

The following table summarises the strengths and limitations of the four renewable energy sources available on Sub-Saharan soil and their operating conditions for use in off-grid rural electrification. It shows that solar energy presents simplicity and permanent availability that, coupled with its affordability, makes it the most easily applicable renewable energy source for implementing off-grid electricity systems. The other renewable energy sectors lend themselves to deployment on a massive scale for on-grid solutions only.

Mini-grids under development are mainly solar or hybrid solar installations



Source: James Knuckles, "State of the minigrid market globally, 5th minigrid Action Learning Event and Summit" (Washington, D.C: World Bank Group, 2019).



Review of energy sources suitable for off-grid rural electrification

Source	Operating conditions	Strengths	Limitations
Solar energy	Site clear of any relief or vegetation that could mask the sun's rays	Accurately-charted source	Daily intermittence Seasonal variations that may be significant (wintering)
Wind energy	Regular wind spread over a period of at least 6 months per annum No obstacles in the vicinity	No day-night intermittence	Requires measurement campaigns over at least one year Frequent seasonal intermittence
Hydropower	Short distance between the waterfall and the locality (depending on installed capacity) Shortest possible low-water period	No day-night intermittence	Requires measurement campaigns over at least one year Seasonal intermittence related to rainfall
Biomass	Development constrained by the immaturity of the technologies	No daily intermittence Local feedstock transformed Creation of new activities for collecting and conditioning the resource	Unknowns – quantity and quality variations in the resource

1.2. Formal electrification is first and foremost urban and centralized

The Sub-Saharan countries' low rural electrification rates basically stem from the fact that their rural populations have no access to the power grid. Why?
Firstly, the Sub-Saharan countries' utility companies have made a priority of electrifying urban and peri-urban zones that they consider to be the most profitable, yet they do not generate enough investment capacity to fund grid extension to rural areas (1.2.1.).
Secondly, although rural electrification strategies are often formulated and an organisation is defined to roll them out, they have difficulty getting off the ground for lack of resolve and wherewithal (1.2.2.).


© Fondation Énergies pour le Monde

An electrified periurban zone in Burkina Faso.

ELECTRIFYING RURAL AFRICA: AN ECONOMIC CHALLENGE, A HUMAN NECESSITY

1.2.1. By default, institutions give priority to urban and peri-urban zones

In the countries of Sub-Saharan Africa, formal electrification is mostly based on public operators and so-called "centralized" electrification, rolled out around a national grid. As these utility companies suffer chronic difficulties managing and servicing their grids that concentrate on densely populated zones, they cannot participate meaningfully in rural electrification.

The electrification of the Sub-Saharan countries is historically based on the national utilities

Electrification of African countries was founded on operators and public financing once the countries gained their independence and was modelled on the European electricity sectors of the 60s-70s (with electrification rates of almost 100%). National companies took over the management of the public electricity service (production, transport and distribution).
Following a wave of privatisations encouraged by the international institutions, primarily the World Bank, in the 90s, many companies were renationalised. The public powers are still the majority stakeholders.
Today, electricity production (not distribution) is gradually leaving the public domain. Private operators inject electricity into the public grid and sell the electricity they generate through "PPAs" (Power Purchase Agreements) signed with the national utility.

The national utilities give exclusive rather than "just" priority to the grid

Given the immensity of the task and in keeping with the rational management of public funds, the governments of Africa's countries with the support of the funding bodies, have given priority to centralised electrification firstly the major cities, then the smaller cities by grid extensions and interconnection.

The economic argument backs the priority given to the grid

The experience acquired by many countries illustrates the point. Centralised electrification is a rational choice. The highest density of potential consumers in the urban environment and needs stemming from economic activities make for economies of scale (cf. chapter 2.1.2). Thus, the priority given to urban zones and grid extension is logical.
Incidentally, this priority has been backed by funding partners, as illustrated by the funding allocated to rural electrification by the Agence Française de Développement (AFD) (cf. chapter 2.3.2).

1. Christian de Gromard, "Structuration des investissements et outils de financement de l'accès à l'énergie" (Conference, 22nd of May 2018).

Examples of national utilities

Country	Company name	Main functions	Date created	Public capital (%)
Benin	Société Béninoise d'Energie Electrique (SBEE)	Production, transport & distribution	1975	100%
Ghana	Volta River Authority (VRA)	Production	1961	100%
	Electricity Company of Ghana Ltd (ECG)	Supply & distribution in Southern Ghana	1967	100%
	Northern Electricity Distribution Company (NEDCo), subsidiary of VRA	Supply & distribution in Northern Ghana	1987	100%
Kenya	Kenya Electricity Generating Company (KenGen)	Production	1998	70%
	Kenya Power (KP)	Transport & distribution	1983	50.1%
Senegal	Société Nationale d'Électricité du Sénégal (Senelec)	Production, transport, distribution	1998	90.58%
Madagascar	Jiro sy Rano Malagasy (Jirama)	Production, transport & distribution	1975	100%
Mali	Énergie du Mali (EDM SA)	Production, transport & distribution	1960	66%
Rwanda	Rwanda Energy Group (REG) and its subsidiaries: Energy Utility Corporation Ltd & Energy Development Corporation Ltd	Production, transport & distribution	2014	100%
Tanzania	Tanzania Electricity Supply Company (TANESCO)	Production, transmission & distribution	2002	100%

In actual fact, the limitation of serviced areas more particularly reflects the deterioration in the national utilities' finances and technical status.

These companies are penalized by the low electricity consumption of their users, who are about forty times fewer than the European average (cf. diagram), and also by the high cost of procuring fossil fuel for thermal power plants.

Furthermore, they suffer abnormally high technical losses due to often aging production installations and transmission networks. These losses amount to more than 15% of output in many countries of Sub-Saharan Africa, compared to 5-7% in Europe, North America or China.

Outages and rolling blackouts are frequent. Between 2010 and 2017, the World Bank's measurements report more than 8 outages per month lasting an average of almost 6 hours[1].

They also suffer commercial losses due to difficulties in recovering outstanding amounts from users and from many illegal connections.

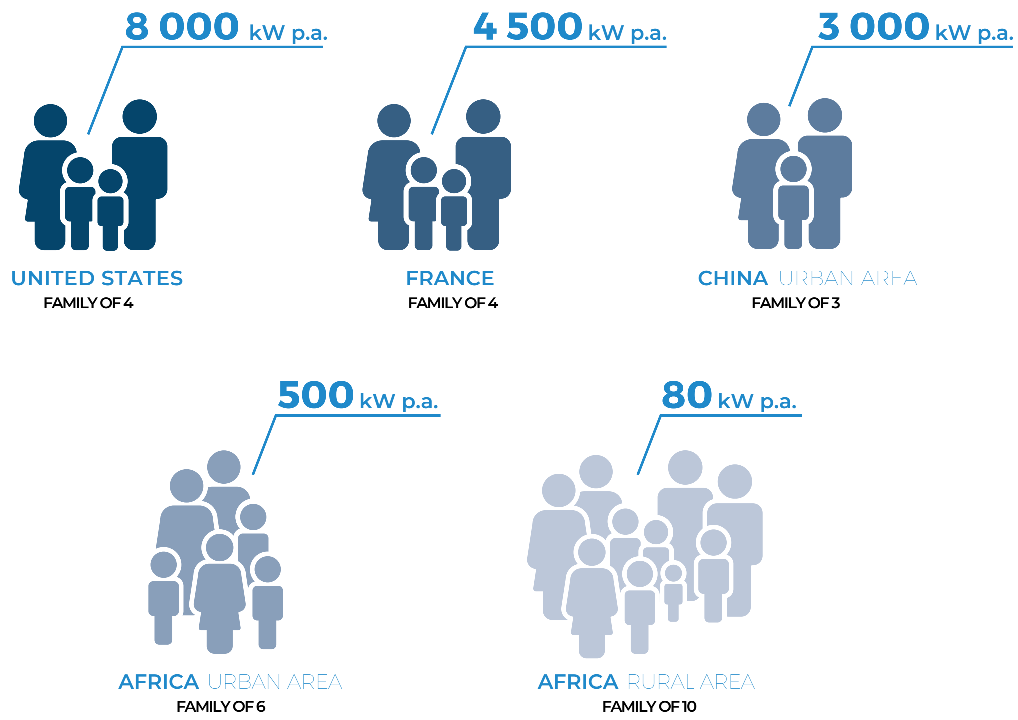
This is compounded by governance methods that tend to be often unsuitable, inadequate management and technical innovation methods and regulated subsidised rates that are very much lower than the real costs, all of which prevent them from being profitable or investing. This inability to invest obviously affects service quality. Most of the national utilities are "drip-fed" by their governments and funders to cover their operating losses.

1. Source: "Infrastructures", World Bank Group, 2019, *https://www.enterprisesurveys.org/data/exploretopics/infrastructure*. Quoted by Rebecca Martin, "Afrique subsaharienne : des matières premières, des hommes… mais pas d'électricité", *The Conversation*, 2018, *https://theconversation.com/afrique-subsaharienne-des-matieres-premieres-des-hommes-mais-pas-delectricite-107478*.

Lighting is an important part of rural electricity consumption.

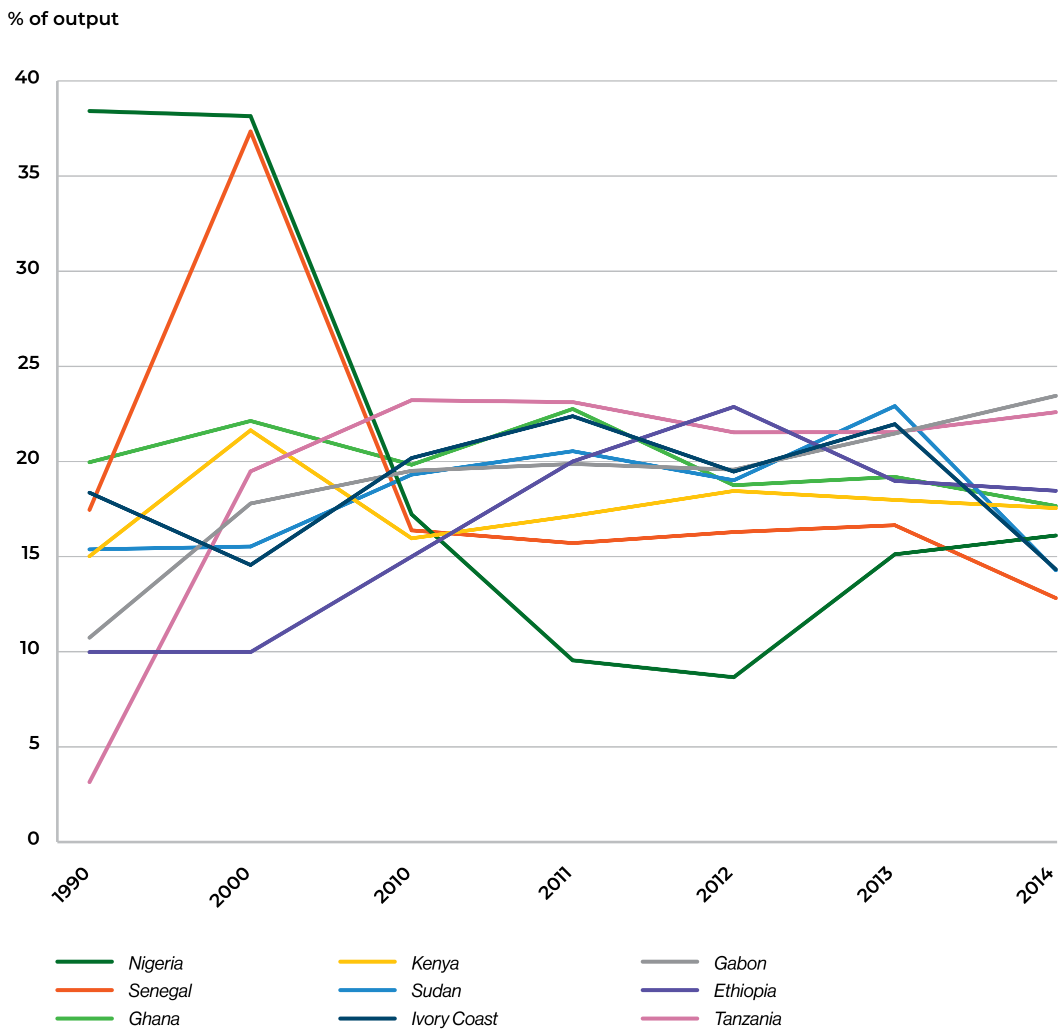
Order of magnitude of average electricity consumption in the world

Excludes substitution energy needs (heating, cooking, hot water production)



Source: Fondation Énergies pour le Monde.

T&d losses are still heavy in sub-saharan africa



Source: IEA, 2018, "Energy Statistics and Balances of non-OECD countries", and "Statistics of OECD members' energy and UN's energy statistical yearbo ", *https://www.iea.org/statistics/?country=WORLD&year=2016&category=Energy%20supply&indicator=TPESbySource&mode=chart&dataTable=BALANCES.*

As the national utilities have not succeeded in completing urban electrification, they do not have the means to electrify the rural environment

In rural areas, population densities and electricity consumption levels are too low compared to the investment sums required to extend the power grid. The national utilities settle for distributing electricity to the capitals and major cities, hence the faster progress made in urban electrification rates and the continuing very low rural electrification rates (less than 20%) in most of the Sub-Saharan countries (cf. graph).

On balance, public investments in the electricity sector have largely contributed to the countries' indebtedness but have made a low-key impact on the population, predominantly the urban population.

Rates unrelated to the reality of costs

In many countries, manufacturers pay high prices in an aim to avoid raising electricity prices for householders. Furthermore, the high-consumption households, like businesses, "subsidise" the lower consumption of low-income consumers via the introduction of minimum rates (RISE, 2014). As a result, most countries' costs cannot be covered because of their current pricing structures. As the analysis of the electricity pricing data for 27 countries between 2004 and 2008[1] indicates, less than a third of the sample countries apply high enough prices to cover all the service costs. This analysis also reveals that the cost recovery thresholds fell during the observation period. A recent World Bank study of 39 countries of Sub-Saharan Africa[2], concludes that the public utilities of only two countries – Uganda and the Seychelles – fully covered their operational expenditure and their capital expenditure. Cost recovery is particularly difficult in countries whose production costs are high because of their dependency on expensive oil-based energy sources (heavy fuel oil and diesel).

Source: World Bank Group, "Africa's Pulse: An Analysis of Issues Shaping Africa's Economic Future" (Washington, D.C, 2018).

1. Joern Huenteler, and al., "Cost Recovery and Financial Viability of the Power Sector in Developing Countries" (World Bank Group, 2017).
2. Trimble, and al., (2016).

Comparison of the urban and rural area situation for 1 km of lign

URBAN AREA

1 km OF LIGN

500 USERS

1 000 KWh PER DAY

RURAL AREA

1 km OF LIGN

50 USERS

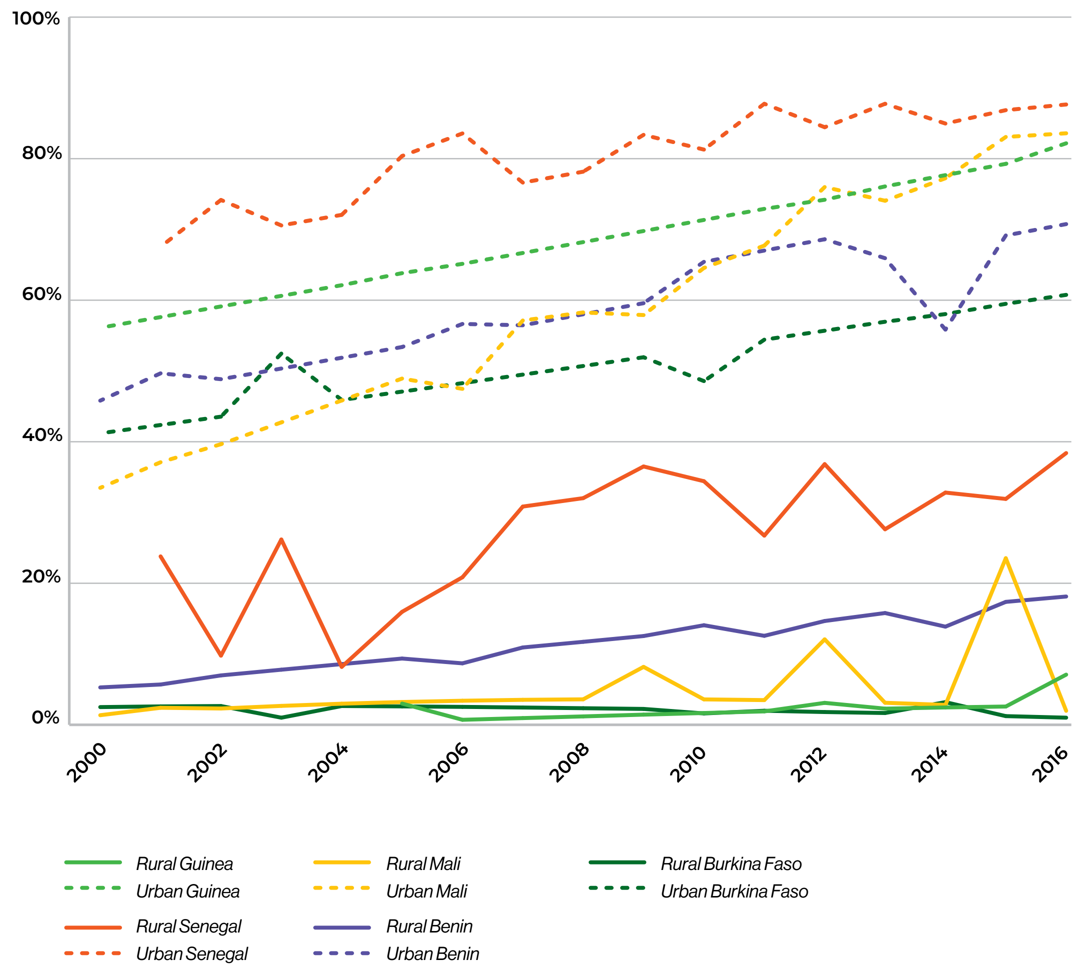
10 KWh PER DAY

Source: Fondation Énergies pour le Monde.

Admittedly, the situation is improving with the establishment of interregional connections in West and Central Africa. But increased consumption in the urban environment, stemming from the vitality of urban demography (see inset) and the increase in specific uses of electricity (air-conditioning, computers, etc.), will no doubt prevent any massive grid extensions from being made to the rural environment.

Africa by night – only the major urban areas are lit up

Apart from Senegal, the rural electrification rate is rising very slowly in Western Africa



Sources: "Sustainable Energy for All database, derived from SE4ALL Global Tracking Framework", World Bank Group, IEA and ESMAP, *https://donnees.banquemondiale.org/indicateur/.*

1.2.2.
Although rural electrification is held up as a goal, it suffers from lack of funding and resolve

Politicians have not forgotten about rural electrification, but the initiatives to narrow the divide between the urban and rural areas are undermined by weaknesses. The experiments prompted by the institutional funders are disjointed, while national strategies struggle to be effectively implemented.

International cooperation has above all encouraged experimentation which has had limited effects

In the countries of Sub-Saharan Africa, the major public investment flows for centralized electrification ran out of steam in the 80s, not because of the amount of funds required to compensate for the financial precarity of the national utilities but because of the constraints imposed by implementing structural adjustments to release them from debt. Waves of reforms and privatisations led to the gradual dismantling of the various legal and contractual monopolies (cf. diagram). Depending on the individual country level, the private sector's role ranges from contractual service provider to public electrification companies (supply, civil engineering, technical assistance, etc.) to that of electrification operator paid by the users. These operators work under private public asset management contracts (leasing), or electrification infrastructure and service development contracts over a defined territory (concession), or via the privatisation of public companies (disposed of to local, or more often than not, foreign enterprises). Since then and despite the many re-nationalisation ventures in the 2000s, the African states have revised their view of the national interest. The electricity sector, like others abandoned by institutional funders, who sought higher efficiency (return on capital employed) along with new institutional frameworks (better guarantees), has gradually opened up to private players.

By diversifying their fields of action, the institutional partnerships and funders have made rural electrification their priority issue

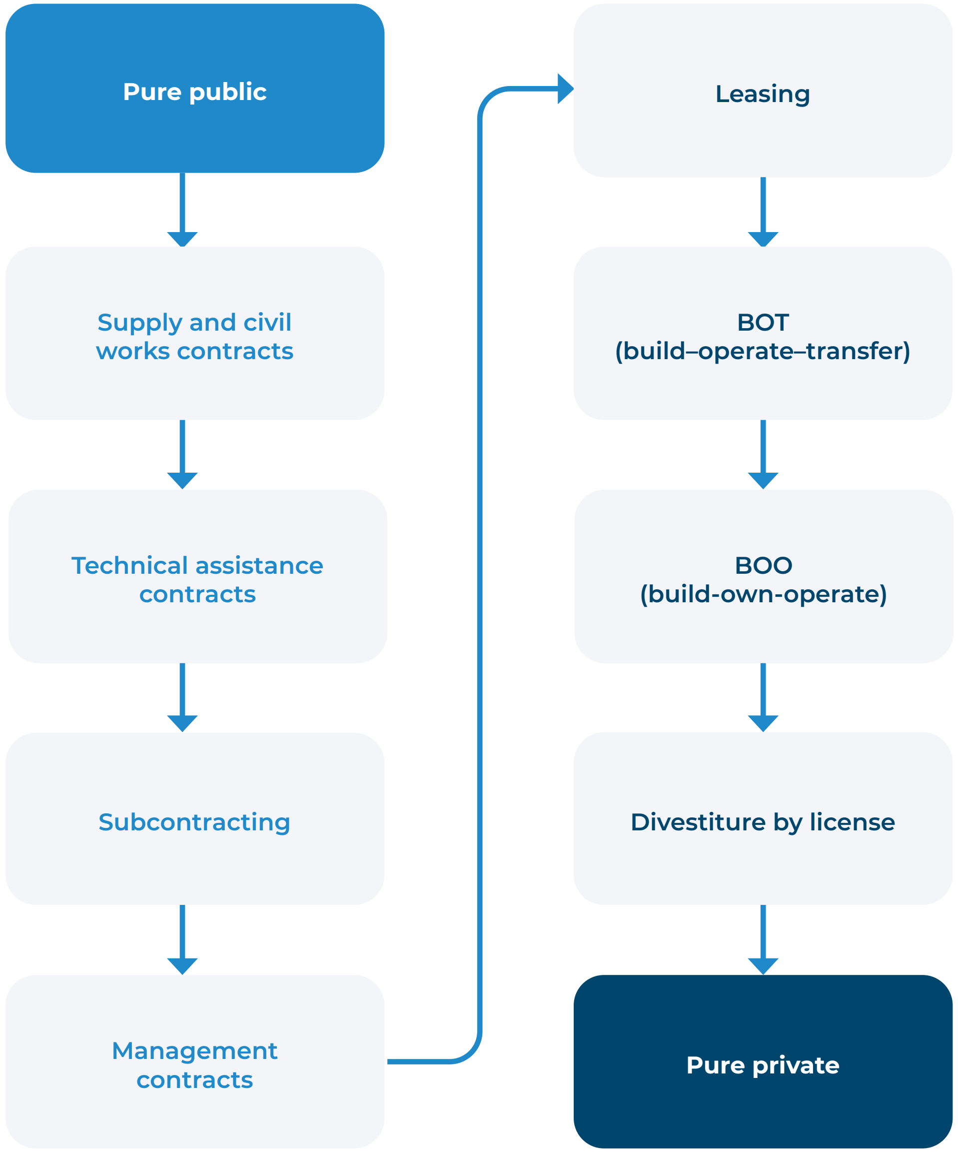
"Access to electricity in the rural environment", the main aim of international cooperation, as a basic fixture in the fight against poverty, attracts increased international community attention. The financial institutions have been encouraged to become involved in this sector, primarily in the wake of the Johannesburg Sustainable Development Earth Summit of 2002. An example of this is the initiative taken during the Summit by the European Union[1] to set up the ACP-EU Energy Facility for energy. The first of its three components effectively aims to improve energy services in rural areas.

A profusion of one-off, scattered initiatives has emerged with differing organisational arrangements, techniques and prices

Funders have backed a wide range of electrification solutions (detailed in part 3), and in particular individual electrification, inspired by a liberal approach* to electrification (cf. chapter 2.4.1), i.e. centred on the direct supply of goods or service

1. European Union Energy Initiative.

The various ways in which the private sector works on electrification projects



Source: Richard Hosier, Morgan Bazilian, Tatia Lemondzhava, Kabir Malik, Mitsunori Motohashi, and David Vilar de Ferrenbach, "Rural electrification concessions in Africa: what does experience tell us?" (Washington, D.C: World Bank Group, 2017), 3.

The main European Union instruments for access to energy in Africa

Financial instruments	• Africa Investment Facility (AFiF) (2015-2017) • EU-Africa Infrastructure Trust Fund • Electrification Financing Initiative (ElectriFI) • ACP-EU Energy Facility (2005-2017) – including the 'pool mechanism" • Regional investment platforms for Africa of the External Investment Plan (EIP), that contains a specific envelope for renewable energies (2017-...). **European Investment Bank (EIB):** • Africa Sustainable Energy facility mechanism (ASEF) • Africa Energy Guarantee Facility (AEGF) • Global Energy Efficiency and Renewable Energy Fund (GEEREF) • Micro finance equity and investment impact fund **EIB instruments associated with the European Development Finance Institutions (EDFI):** • Interact Climate Change Facility • European Financing Partners (EFP) • Eu-EDFI support mechanism for private sector development • Investment fund for micro finance and impact investing **European Bank for Reconstruction and Development (EBRD)**
Technical assistance	• Technical Assistance Facility for sustainable energy for all (SE4ALL) • Africa-EU Renewable Energy Cooperation Programme (RECP)
Political dialogue	• Africa-EU Energy Partnership (AEEP) • Africa Renewable Energy Initiative (AREI) • EU Energy Initiative Partnership Dialogue Facility (EUEI PDF) (2004-2018) • Contribution to national, regional and global indicative programmes (€ 2.7 Bn in the Sub-Saharan renewable energy sector) • Agreements with the mayors of Sub-Saharan Africa to strengthen the role of local authorities • 22 common declarations for closer energy cooperation

Table adapted from the ECDPM document by Sebastian Grosse-Puppendahl, San Bilal and Karim Karaki, "EU's Financial Instruments for Access to Energy. Support in remote and poor areas in Africa" (Maastricht: European Centre for Development Policy Management, 2017).

by private operators to consumers (cf. chapters 3.2.1 and 3.2.2.).

Thus, within a single country and sometimes even within a single region, unrelated solutions have been rolled out with variable sales and pricing rationales behind them... the supply of equipment or services, subsidized or otherwise, accessible via micro-credit institutions or offered for sale by start-ups...

The problem is created not so much by the existence of a wide range of solutions as the lack of global vision.

The limitations of political resolve and resources mobilized for rural electrification are highlighted by uncoordinated experiments

The proliferation of projects, although very rich and dynamic, has been conducted outside the structured and coordinated framework that would have resulted in a constructive evaluation for the future. Most of these many, often short-lived experiments have been conducted in a rural space almost devoid of any seasoned operational players (apart from a few NGOs) or regulation, without prior methodological or organizational reflection, and what is worse, without any concern for territorial coherence.

It has to be said that most of the countries have been unable or unwilling to set up a strong enough institutional body to impose game rules on all those taking part (consumers, investors, operators, territorial communities and development officers).

The public authorities of the recipient countries find it hard to maintain a firm policy when they are faced with the increase in external aid for a sector that has had little backing so far.

Putting national rural electrification strategies and planning into operation is a hard task

Nowadays, the vast majority of Sub-Saharan countries have set up an institutional framework for their electricity sectors.

Funders, such as the World Bank, have encouraged the states to build a framework with the dual perspective of liberalizing the electricity sector and eradicating poverty:

- by creating two types of organizations independent from the national utility – an electricity sector regulation commission (that defines the frameworks and limitations of public and private player involvement in detail), and a dedicated rural electrification agency to organize it.
- by adopting national rural electrification strategies.

However, national rural electrification policies, that are often defined as a one-stop answer to the international community's expectations, are riddled with structural weaknesses that hinder effective implementation.

Many countries have adopted rural electrification strategies with the support, if not under pressure, from international funders

National rural electrification strategies and their formulated master plans tend to be influenced by the centralist vision of the ministries for energy's technical departments and international cooperation experts, who are the national utilities' natural travelling companions.

In practice, effective implementation of these strategies runs up against compound difficulties of three kinds even in the presence of proactive off-grid electrification strategies through local or private initiatives.

The first difficulty is political in nature

The political powers still focus on urban electrification, primarily to consolidate it. They would lay themselves open to popular discontent that could give rise to serious public disturbances if they fail to improve electricity distribution in towns, in the event of repeated breakdowns or power outages. Additionally, the central public authorities are only interested in rural electrification during the run-up to elections, given the weakness of the local communities (the decentralisation process is often incomplete).

The second difficulty is institutional in nature

Institutional patterns are often inappropriate, disjointed or redundant.

A few national rural electrification agencies have come about opportunistically. Their creation, under the auspices of institutional partnerships, has been viewed as a condition for releasing funding, rather than as a necessity. Yet, these agencies often compete, or come into conflicts of responsibility, with the ministries and decentralized services responsible for energy, which then feel cheated of one of their main assignments.

Demonstrations against stripping in the city of Tanout, in Niger in 2018.

Overconcentration of power at central level is the first obstacle to rural electrification

The highly Jacobin concept of power in French-speaking Africa and the historical operators' legacy of exclusive authority in energy policy management is a major impediment to promoting decentralized production of the kind that could spur institutions, communities, users and operators at territory level into adopting empowerment.

The overconcentration of power along with its associated institutional culture are the first major obstacle to rural electrification founded on developing the capacity to stimulate real decentralized production. In the context of our countries, it is the only means of accelerating the energy divide's resorption process.

Abdou Fall, Former Minister of State, President of the Renewable Energy Business Council of Senegal (COPERES)

At times, the complexity and confusion are compounded by the creation of other organizations: rural electrification funds, renewable energy agencies or rural energy service agencies that handle both electrification and domestic fuels.

Incidentally, these new agencies are also challenged by the difficulty of hiring qualified staff and the lack of continuing vocational training and technical assistance programmes geared to rural electrification.

Lastly, the territorial decentralisation rationale, which is also supported by the international funders, cuts both ways. While it seems essential to meet the needs for proximity, it complicates the institutional and decision-making framework by multiplying the number of spaces and players.

The third difficulty is economic in nature

Even when political resolve and international finance are in place, few investors and private operators are ready to participate in rolling out inclusive rural electrification projects, with the rationale of covering all the needs of a territory down to the "last mile".

These players are put off by the unattractiveness of this type of involvement, characterised by harsh conditions due to the remoteness and restricted access to sites, local personnel lacking in skills, the lack of guidance and risk coverage for investments that generate low sales and internal profitability rate, etc.

The main French NGOs that have pioneered access to electricity

A few NGOs in France have developed expertise in access to energy services. Each of them has consolidated its working methods as funds have been allocated by donor agencies.

GRET (the Group for Research and Technology Exchanges) created in 1976 has been working in the energy sector for over twenty years, initially through projects to improve transmission to households and solar dryers, nowadays by implementing electrification programmes using hydraulic, solar and wind energies. GRET's positioning has changed significantly on institutional issues, at the same time as it has been involved in these technical aspects, by mobilizing public and private players to support sustaining access to energy for populations.

GERES (Group for the Environment, Renewable Energy and Solidarity), created in 1976, has developed expertise in access to energy, energy efficiency, clean and renewable energies, and the management of natural resources and waste. It proposes energy solutions that are both economic and social development drivers and as an alternative to existing systems that damage the environment.

Électriciens sans frontières, created in 1986 on the initiative of EDF employees, is dedicated to combatting the inequalities of access to electricity and water around the world. The NGO has the support of more than 1 000 volunteers and partnerships with local players. It provides emergency and post-emergency response to help the disaster-stricken populations of humanitarian crises. It also leads development projects to make available clean, safe and inexpensive energy in isolated rural areas to help eradicate poverty, improve education, health conditions, economic development and food security.

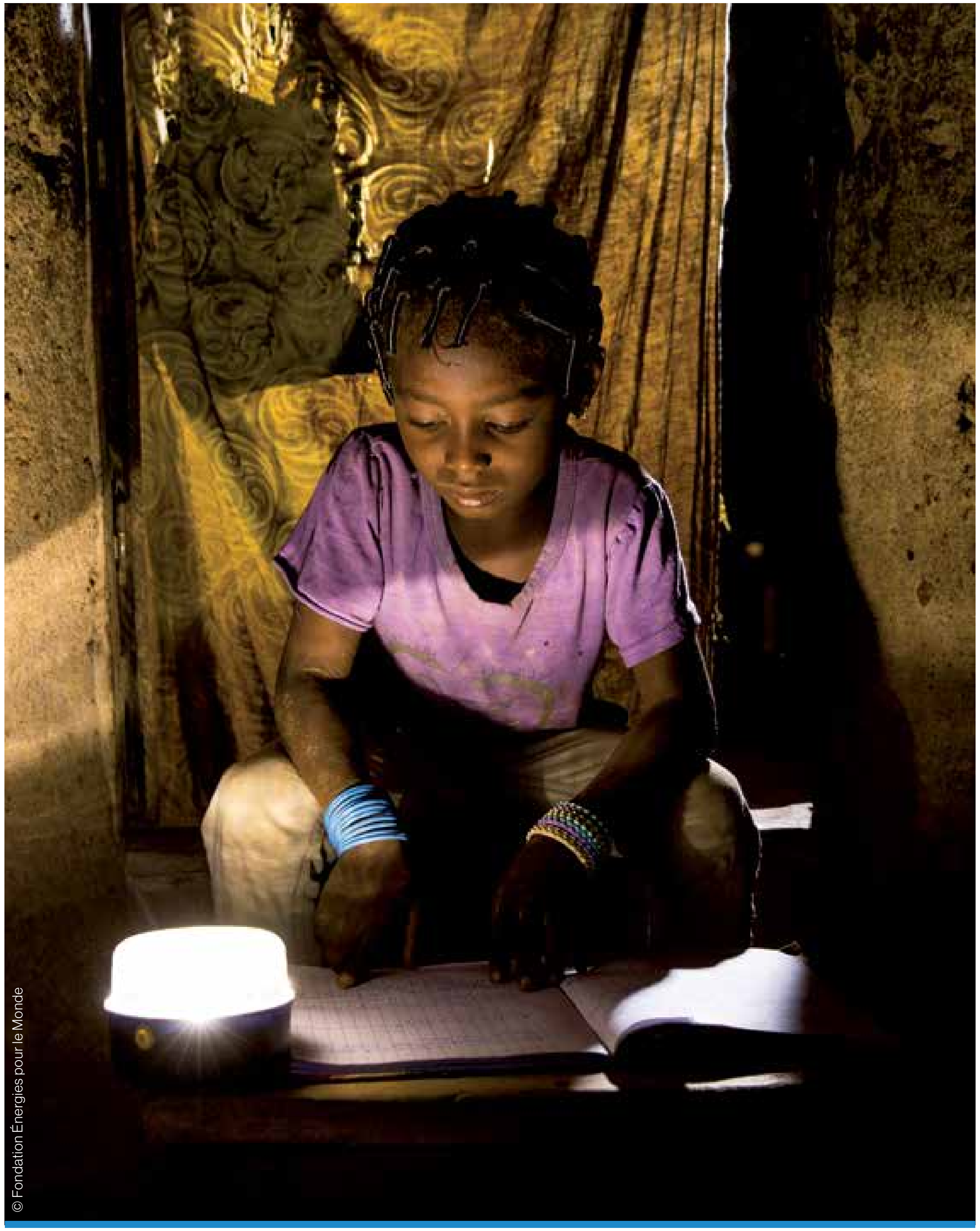
Fondation Énergies pour le Monde (Fondem), created in 1990, promotes and develops access to electricity through renewable energies to improve living conditions and the incomes of rural populations. It has developed special expertise in mini-grids and guidance on productive uses of electricity. It focusses most of its action where needs are greatest, in Sub-Saharan Africa, in close conjunction with its local partners (local populations and associations, communities, institutions, and so on).

Urban grid.

On balance, formal electrification in Sub-Saharan Africa is first and foremost urban.
Admittedly, NGOs specializing in access to renewably-sourced electricity work in cooperation with the institutional and traditional powers to install facilities to supply a territory and its business catchment area, but these are isolated and marginal operations. The numbers and resources of these NGOs are too meagre to rise to the immense challenge of rural electrification, especially for the most inaccessible areas and most vulnerable populations.
So, while projects sometimes give access to electricity, more often than not the rural populations of Sub-Saharan Africa far-removed from any reliable and sustainable service, have no choice but to resort to their own devices to obtain electricity to meet their needs.

1.3. As a result, rural electrification, remains largely informal

Today, for the Sub-Saharan rural populations, access to quality electricity, distributed by the grid and accessible to all, is more of a concept than a reality. In the meantime, their expectations are changing rapidly through the influence of the technologies and policies developed in the North.
Rural populations therefore resort to a whole raft of alternative solutions that are available on the market to cover their electricity needs, and in particular their domestic needs, which are more often than not removed from any formal electrification initiative.



Reading in the light of a lamp from a solar kit, Burkina Faso, 2016.

1.3.1. Rural electrification supply and demand are subverted by many innovations

Rural populations' expectations are changing rapidly through several breakthroughs from industrialized countries, bringing them new technological solutions, which increase their electricity needs:

- **the mass roll-out of mobile telephony and a host of derived applications creates demand.** They facilitate information, exchanges and transactions, and have been adopted very quickly all over the world, including by the poorest countries. The socio-economic fabric of Africa, including that of rural areas is being is radically reshaped by the use of digital communication;
- **LED (*Light-Emitting Diode*) technology offers a new response to the need for lighting:** with its quality light, very low power consumption and long service life, LED has become widespread all over the world and has made for unquestionable economic and environmental gains;
- **The low-carbon energy policies of the Northern countries are leading to the technical and economic adoption of renewably-sourced systems.** The technical solutions for producing "off-grid" or "decentralized" electricity, which until recently were complex and expensive and even associated with simple receivers, can now be reinvented (cf. chapter 2.3). RES systems now lead the newly-installed electricity production capacity figures every year. In 2018, about 100 MW of renewable capacity was installed in Africa. Solar energy accounted for 88% of the systems[1].

Populations and economic players are naturally forced to look for alternative solutions to the national grid when it does not reach them. Hence, the rural demand for electricity is growing under the influence of new uses, particularly that of telephony. **Accordingly, electricity is now certainly present in many forms, even where it is out of the power grid's reach.**

Different types of LED bulbs.

1. IRENA, " Renewable Capacity Statistics 2019" (Abu Dhabi: IRENA, 2019).

1.3.2. In this tumultuous environment, electricity's entrance to rural dwellings tends to be informal and piecemeal

Domestic lighting, charging telephones, supplying electricity for productive activities... off-grid rural populations spontaneously get their electricity supplies in various forms and qualities for their individual or collective needs.

Lighting is a fundamental need that will not wait for the power grid to arrive

Lighting is a timeless and universal need, that the "miracle" of electricity has gradually taken on. For millennia, "artificial" light was based on a combustive reaction... candles, oil or kerosene lamp and/or the traditional hearth, that are still widely used for lighting in remote rural areas.

Now there is a rapid shift to modern lighting sources, that offer benefits to health, education, the rural economy, the environment, and reduce the population's dependency on oil imports for their activities.

LED technology has been adopted with open arms and brought many positive impacts

In the space of a few years, LED lighting has made its way into Sub-Saharan households on a massive scale. Its spread has been nurtured by the above developments but also motivated by the repeated failures of the electricity services in urban and peri-urban areas. LED technology offers undeniable advantages to domestic or collective applications.

Inside the home, reducing the use of traditional fuels (kerosene, oil, candles or wood) improves air quality[1] , domestic living standards, and also provides more powerful[2] and uniform light for night-time activities.

Incidentally, as their cost keeps falling, this modern lighting equipment is becoming increasingly affordable, and enables households to make substantial savings on their energy expenditure[3].

In almost all african markets you can find:

Portable LED lamps (designed for indoor and outdoor use) powered by dry cell batteries, photovoltaic sensors with integrated battery, rechargeable using an external direct current source (battery, photovoltaic sensor).

Fixed LED lighting points (for indoor use) powered by photovoltaic kits or stationary batteries, with LED bulbs on a conventional base to be powered by the traditional domestic network.

1. Every year, the secondary effects of fumes discharged by kerosene solutions cause more deaths than malaria and HIV put together – ODI "Accelerating access to electricity in Africa with off-grid solar, the impact of solar household solutions", 2016.
2. LED technology offers the feature of emitting light that is impervious to voltage variations as opposed to traditional bulbs which are more stressful to the eyes.
3. According to M-KOPA, in 2107 its 500 000 customers saved more than 60 million hours of kerosene lighting every month, which equates to more than 300 million dollars over four years – Séverine Leboucher, "Le pay-as-you-go sur les terres du microcrédit", *Revue Banque*, n°811 (2017).

These savings can then be channelled into other household use items or used to develop income-generating activities.
On a collective scale, rolling out LED technology standalone streetlamps on streets or agricultural plots boosts the safety of property and individuals in certain remote areas, by dissuading theft. But above all, it paves the way for night-time social and economic activities in regions where daylight fails at around 6 p.m. all year round.

But the spread of LED lighting has an environmental downside

The success of certain items has had an adverse effect. In just a few years, consumption of disposable batteries used in LED-powered torches and standalone lamps has mechanically surged.
In the already fragile biological ecosystems, where soil conservation is another major environmental challenge to be met, tens of thousands of spent batteries of highly variable quality are dumped every day far away from any recycling stream.

Individuals resort to a mixed bag of solutions to satisfy their various domestic and economic needs

The advent of digital and wireless telecommunications networks is a major event in Sub-Saharan Africa. Mobile telephony has grown faster in this region than anywhere else in the world in the last few years (cf. graph).
With the help of lower costs[1], according to the GSM Association (GSMA), almost 500 million people, i.e. one in two inhabitants had a mobile telephone subscription in 2018.

1. According to the GSM Association, the cost of a smartphone fell by 56% between 2012 and 2017 in the 27 countries surveyed. GSM Association, "The Mobile Economy: Sub-Saharan Africa 2018" (London, 2018). The GSM Association is an association that represents almost 800 operators and cell phone manufacturers across 220 countries worldwide.

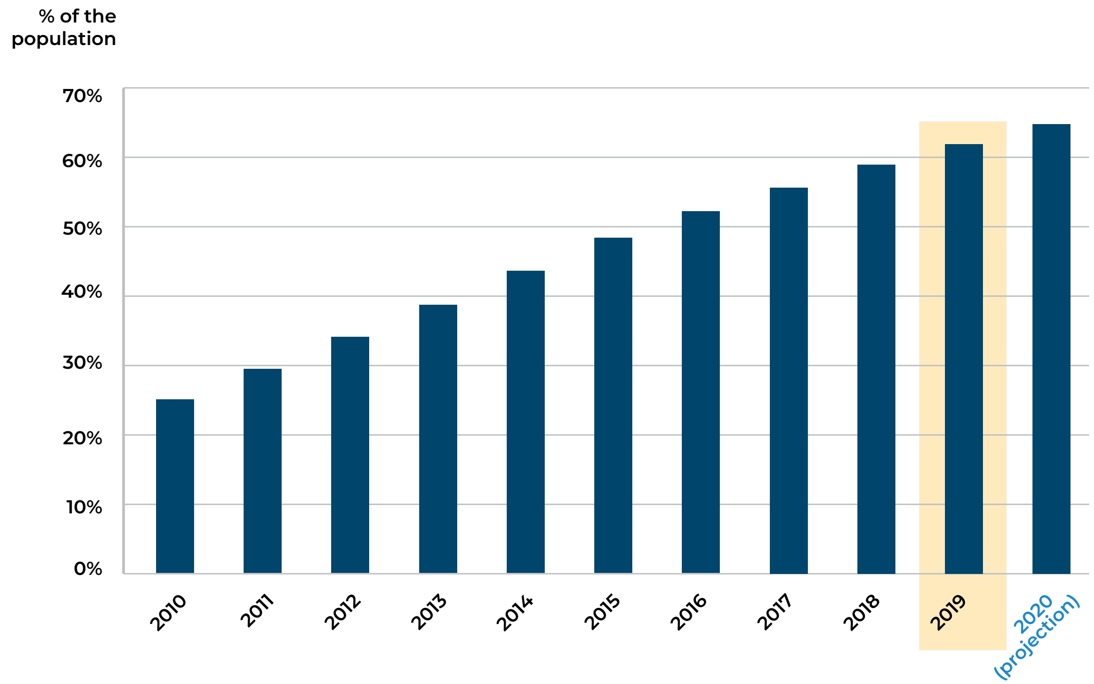
The polluting and toxic impact of burning kerosene

"Kerosene-burning devices can impair lung function and increase cancer risks as well as incidence of infectious illnesses and asthma. There is extensive evidence that indoor air pollution is strongly linked to human health problems, especially among children, and that the presence of kerosene pollutants in the environment also impairs human health. In addition, kerosene lamps have a major impact on the environment. These devices are held responsible for an estimated 7 percent of annual global black carbon emissions".

Maximo Torero, "The Impact of Rural Electrification: Challenges and Ways Forward", *Revue d'économie du développement* 23, n° 3 (2015).

Jettisoned batteries pollute the soil in Sub-Saharan Africa

In sub-saharan africa the number of cell phone subscribers has more than doubled in less than a decade



Source: GSMA, "The Mobile Economy: Sub-Saharan Africa 2018" (London, 2018), and "The Mobile Economy: Sub-Saharan Africa 2019". (London, 2019).

Cell phone charging has become the main driver of the electrification process ahead of lighting and is a buoyant market for individual electrical solutions. Additionally, with the arrival of Mobile Money, the telephone is a tool used for making financial transactions for many Sub-Saharan users (cf. inset).

Various telephone charging market mechanisms have naturally fallen into place

Some portable or battery-operated solar lamps offer a dedicated charging socket for one or more cell phones, in the same way as most of the individual solar systems installed in well-off households or some shops.
Cell phone charging centres are cobbled together in electrified collective buildings (dispensaries, religious centres, schools, village halls), in houses or traders equipped with solar systems or generator sets.

Mobile Money: definition and figures

Mobile Money, or *Mobile Banking*, designates the financial transactions (payment, withdrawal, money transfer) performed using a telephone. These mobile solutions have primarily taken off fast in developing countries to facilitate access to financial services by populations without bank accounts. More than a third of adults are active mobile money users in 13 African countries.

In Sub-Saharan Africa over 2017, we identified:
135 live *Mobile Money* services;
122 million active user accounts;
1.2 billion financial transactions made by *Mobile Money*...

... For a value of 19.9 billion dollars.

Source: GSMA, "The Mobile Economy: Sub-Saharan Africa 2018" (London, 2018), and "State of the industry report 2018" (London, 2019).

Individual solar systems for domestic uses compete with battery charging stations

We have to bring up the subject of car batteries to appreciate this "informal" electricity whose presence is very real. They are used by certain well-off rural households located not so far away from electrified urban centres.
An average quality car battery offers a minimal electricity service with a few days' range. Several times a month, users go to the neighbouring generator set, or more frequently the nearest electrified locality to "buy" a top-up.

Villagers carry their batteries on foot to get them recharged.

In the new technological environment, battery use has tended to decline in favour of acquiring individual solar systems, which technically amounts to charging a battery as well, but by using a roof-mounted source of electricity (cf. chapter 3.2).
Likewise, given the plethora of individual photovoltaic solutions, the "community kiosks" for charging thermal- or renewable-powered batteries, that were long-supported by institutional funders, are being phased out.
However, these individual solar electrification solutions are restricted to a few basic services that can be described as "intangible" (lighting, telephone, radio and maybe television). They cannot cover all the daily uses for an entire territory. They can do nothing to meet the electrification needs of businesses (cf. chapter 3.2).

Entrepreneurs resort to using generator sets for productive activities... a robust but costly solution

Mechanical energy, agricultural processing, pumping and tooling, are much more energy-intensive and call for capacities and energy that individual photovoltaic kits can hardly match.
When users are deprived of the national grid but also far removed from any collective rural electrification initiative such as a mini-grid, they resort to using generator sets for their productive uses despite the fact that the latter's' costs and operating conditions weigh heavily on their business profits and thus on their family incomes.
Hence, the installation of a mini-grid makes perfect sense for productive use (cf. chapter 3.5).

Feedback from the field

Ambondro is a secondary locality in the south of Madagascar that has been electrified by an associatively-managed mini-grid and a hybrid wind/solar power plant since 2010. On the weekly market day which draws thousands of people from the surrounding hamlets, you can see hastily put together cell phone charging points. We reckon that as many as 500 cell phones are charged every Friday... the power plant's production and storage equipment takes the toll!

Source: Fondation Énergies pour le Monde.

The locals recharge their cell phones on Ambondro's market day

Un soudeur malgache utilisant un groupe électrogène

Recharging a battery… an uphill battle.

Before electricity made its way by solar mini-grid to Ifotaka, a rural community in southern Madagascar in 2015, many families cycled 90 km every week to the nearest town during the day to recharge their batteries, where they were invoiced about € 5, and it must be borne in mind that 90% of the Malagasy population lives on less than 2 dollars (€ 1.77) a day. To add injury to insult, the batteries only offered a few months' service life as they were badly charged and had no protection from deep discharge.

Source: Fondation Énergies pour le Monde.

The difference between capacity and energy

Capacity measured in Watts (W) is an instant notion – it is what is produced or used at any given moment. 1 Watt = 1 Joule per second.

Energy measured in Joules (J) or Watthours (Wh) refers to a duration. It is what has been produced or used for an hour, a day, or a year. Energy is therefore a capacity multiplied by time (1 Watthour = 1 Watt × 1 hour).

Is Kouramangui electrified?

Snapshot of the electricity situation at Kouramangui, a dynamic, unelectrified secondary locality in Middle Guinea.

At Kouramangui, the social hierarchy of individual electricity and the uncoordinated combination of solutions are patently clear:
80% of the poorest households have small portable solar lamps, with some 20 different models detected in the village.
90% of the "permanent" dwellings have their own individual solar systems that all differ technically from one system to the next.
Roadside tradesmen use their dilapidated generator sets on market days. For want of specialist maintenance and equipment replacement resources and skills, the solar systems supplied to the village hall and the school by a World Bank programme broke down after 2 years' use. The dispensary has a well-designed photovoltaic system through the office of UNICEF, that forbids telephone charging and is kept in perfect running order by extremely enthusiastic staff.
A French NGO approached by the Kouramangui diaspora association, is going about electrifying its youth centre using a photovoltaic system.
Lastly, following a "gift"[1] from the Chinese government, the locality had 60 solar lampposts installed on the main arterial road. After 18 months in operation, 25% of them are already out of order. Poor equipment quality and the lack of any organized management are to blame.

A shopkeeper in Kouramangui, Guinea using a generator set

This snapshot of the electricity situation at Kouramangui could be that of thousands of slightly or moderately landlocked rural localities of West Africa.

So, how should we answer the question of whether Kouramangui is electrified?

1. Equipment supplied and installed pro bono as part of a sales policy rather than a long-term development programme.

[Part 1]
Conclusion

As we observe these new energy habits, it is hard to be conclusive about the effective electrification of a rural African locality. The frontiers between "electrified" and "unelectrified" territory have been blurred. A vast sales market selling wildly different electricity services has been spawned by the combination of two factors – the rapid popularization of photovoltaic production equipment and high-performance receivers, on the one hand, and the growing demand from rural areas, tired of waiting to be connected to the grid, on the other hand.

The new individual electrification players, whose operations often elude any regulatory or organized territorial planning mechanism, are de facto part of the so-called "off-grid" or "decentralized" rural electrification landscape.
The following chapters will attempt to outline this renewed, complex and moving landscape, primarily by answering the following questions: How can we define decentralized rural electrification (DRE)? How has it developed and what stage of maturity has it reached today? Which developments are unsettling traditional patterns? What are the opportunities and risks that underlie these developments to achieve the goal of universal access to electricity in rural areas? Despite these upheavals, which non-variables need to be factored in to undertake a successful access to electricity project in the rural Sub-Saharan context?

Info

Feedback from the field

Definition

Key Dates

Key figures

[Part 2 - Comprehensive review]

The acceleration of rural electrification can be based on decentralized solutions that draw on innovations as well as past experience

Introduction

Sub-Saharan Africa, which suffers from a seemingly intractable energy divide without the injection of dramatically increased resources, is lavishly endowed with renewable energy sources, especially solar energy. It has been the testing ground for many off-grid access-to-electricity projects all banded together under the "decentralized rural electrification" (DRE) umbrella term.

What does this term mean? What does it encompass? Which values and aims does it uphold? It is by analysing this term, which nowadays tends to be replaced by that of "off-grid access to electricity", that we can gauge the complexity of the subject matter. This second section starts by clarifying the notion of "decentralized rural electrification" (DRE) and its raison d'être, spotlighting its major role for achieving quality rural electrification in the Sub-Saharan region (2.1.) now and then.

What are DRE's building blocks? What sorts of projects have been carried out in the developing countries? Decentralized solutions, spawned in Europe through the resolve of the local communities, started germinating on the African continent in the 1970s (2.2.)

"There is clearly no miracle… decentralized electricity is an inescapable but very demanding path".

Pierre Jacquemot et Marie-Noëlle Reboulet, "Technological options and organizational models for rural electrification in Africa", *Afrique Contemporaine* 1-2, n° 261-262 (2017): 155.

Where is DRE going? Today it is still trying to find the middle ground between economic viability and social equity as it is crisscrossed by many technology breakthroughs and resulting new business models (2.3).

Which "markers" can help us find our way around this changing environment? On the basis of the DRE pioneers' five decades of experience (2.4), we can identify many operational invariants and draw the outlines of effective practice of implementing renewable access to electricity projects in the rural environment.

2.1.
The definition and aims of decentralized rural electrification cover a number of territorial, economic and human aspects

Contrary to what the use of an acronym might imply, “DRE” is not a cold, purely technical and strictly defined notion. If we analyse this term, it raises more questions than it answers. Yet, it is built on a firm base of principles derived from the pioneering, experimental and humanist spirit of the first projects – respect for the territory, understanding the populations’ needs and the search for equity (2.1.1.).

The word ‘decentralized’, which is inextricable from this term, links the fate of rural electrification with that of the national grid and explains how it inevitably complements the latter (2.1.2.)

A DRE projet in Madagascar

2.1.1. What do we mean by "Decentralized rural electrification"?

There is no unanimous or official definition of this term, which is essentially used by its practitioners. As it happens, it is gradually being replaced by "off-grid access to electricity", under the influence of English-language speakers, which reflects another way of looking at the subject, by distinguishing *grid connected* from *off-grid*. DRE is a way of accessing electricity – there can be no universal access to electricity in the rural environment without using decentralized electrification solutions.
The following paragraphs analyse each of the three words that make up the term "decentralized rural electrification" one-by-one, to render their various underlying aspects and concepts.

When can you claim that at territory is electrified?

It is commonly accepted that electrifying means giving an area sustainable access to electricity for various domestic, and also collective or economic uses (cf. table).
'Electrification' thus firstly designates the process used to equip a zone with lasting electricity accessible to all the human activities it accommodates. Whatever happens, this definition is assimilated with the idea of *universal* access to electricity.
In this instance, the term "DRE" comes with the twofold aim of electricity service being sustainable and useful:

- **access to the service is permanent, not occasional;**
- **the service covers all current and future needs,** by supporting the changes in uses over time.

To date, this dual criterion is still the target rather than the status quo. More complex questions hide behind this apparent simplicity. Sometimes as we have already seen, it is hard to be categorical about whether or not a territory is electrified. The plethora of solutions and profusion of corresponding service levels (cf. chapter 1.3) foil any attempt to make a simple and single definition of electrification in rural areas.

Can we claim that a territory is "electrified" if all the uses are covered in part, or totally but unreliably covered?

If we reckon that electrification has not be attained when the service does not meet all the needs of a given territory, then few, if any solutions are eligible for inclusion in the scope of DRE. The restricted volume of energy of an individual solar system (cf. chapter 3.2.), for example, immediately disqualifies it, in contrast to a mini-grid that can enable any kind of apparatus to be connected (cf. chapter 3.5). The same applies to the national grid, which, with its many power outages, does not necessarily fulfil the service quality criterion.
Thus, DRE's practical scope cannot rule out solutions that offer partial needs coverage, despite its aim to cover all uses.

Uses of electricity

Domestic uses Households	Lighting, telephony, audio-visual, refrigeration, freezing, ventilation, air-conditioning and many other household uses.
Collective uses Public or private service sector	Drawing water, public lighting, lighting public buildings (schools, health centres, administrative buildings, places of worship, etc.), telephony, internet, photocopying, printing, medical equipment and apparatus, etc.
Economic uses Industrial and trade sector	Lighting, signage and product storage for shops, sawing, welding, milling, sewing, drying, machine-tool work, etc.

Can we claim that a territory is "electrified" if some of its inhabitants do not have access to electricity services?

Does partial electrification of an area serving only the inhabitants who can afford to pay for the service, leaving out the more vulnerable households, enter the scope of what we call "DRE"? This question of service accessibility leads to another one... namely does DRE include a social aspect?
DRE, which was originally driven by sustainable development pioneers, is not just an economic "sector" or a "market" ... it is first and foremost a movement whose view is that electrifying does not merely bringing an energy solution to a given area and that electrification cannot be reduced to a process. DRE harks back to a specific conception of human development, which cannot merely cover the technical side of providing a territory with an electricity service.

Most of the projects conducted under the DRE banner, in the developing countries like those of the North before them[1], aim for regional development and seek to improve its inhabitants' living conditions. In other words, **DRE is less concerned with electrifying a territory than a human community – if we electrify, the reason is to provide an essential service.** It is this vital attention provided to individuals, their activities and their collective organizations that has formed the historical basis for DRE, in the North and in the South alike and explains why the *use* of electricity occupies centre stage in its practitioners' minds.
The approach, based on the conviction that there is a "universal right to electricity", is sometimes reinforced by the use of renewable energies. Renewable energy, that Nature offers impartially to all, naturally assumes the status of "commons". One whose enjoyment can and must be guaranteed to all without discrimination.

Nonetheless from the outset, energy's unavoidable conversion into electricity moves it into another universe. This is because, much like purifying water, energy conversion into electricity involves a process and equipment (production,

1. See chapter 2.2. for the history of French and American ERD

"Sustainably electrifying a territory, means establishing a multi-purpose commercial electricity service over time for multiple users scattered over a more or less regulated space".

Christian de Gromard, energy Specialist, Agence Française de Développement

transport, distribution, storage, regulation, and so on) that come with a cost. That said, we can consider that electricity then loses its "commons" quality to become a "service".
From then on, other questions arise. Is this "service" necessarily "commercial"? If that is true, should it be excluded from the arena of profitability to safeguard its essential nature as a service, accessible to all? The French interventionist school and the liberal Anglo-Saxon tradition offer different lines of argument.
This book does not set out to discuss the nature of the commons, a commercial electricity service, or the legitimacy of entrusting access to this essential service to a private operator. What we see in practice nowadays, is that the services offered to rural communities are in both interventionist and liberal hands (cf. chapter 2.4.2), and that neither should be excluded when reporting on the reality of DRE (cf. Part 3).
This book intends to encompass **any electricity service that covers, albeit partially, the uses in the territory in question** without denying universality of service as the essential end to which DRE is directed.

So, what exactly does "electrification rate" mean?

Given the spread and variety of electrification solutions found in the rural areas of developing countries, it is hard to make a categorical distinction between those that are and are not "electrified". Caution must be taken when considering the "electrification rate" figures and indicators, although a few countries like India, have attempted to define what an "electrified" territory is by applying normative criteria. This rate often makes no distinction between the different levels of service offered by the available electricity production and distribution systems in the territory in question (cf. inset).
Incidentally, access to limited services, such as lamps or individual solar systems is sometimes called "pre-electrification", which illustrates the fact that a service that only offers partial coverage of the uses is nothing more than imperfect electrification.

Access to electricity rates in the rural environment – a variable rate...

"Protocols differ in defining access, but in some cases, the existence of one grid-connected household in a village is sufficient to establish that the whole village is electrified. In other cases, access is identified by the existence of physical connections, even if no electricity is actually flowing".

Source: World Bank Group, "Africa's Pulse: An Analysis of Issues Shaping Africa's Economic Future" (Washington, D.C, 2018).

Urban electrification rate... the same lack of reliability

Although it refers to urban (as opposed to rural) electrification, the following example, proffered by a researcher working for the French Institute for International Relations (IFRI) illustrates how the quantitative and qualitative assessment of an electricity service is a tall order, even in an area where statistics are theoretically easier to compile (national capital city) than in an out-of-the-way territory.

"The electrification rate as currently calculated (by the number of grid interconnections), only gives an incomplete vision of the situation. No allowance is made for maintenance problems, coupled with illegal connections, poor management of demand or fuel shortages. Thus, the UN revealed that in the city of Kinshasa, whose electrification rate is calculated at 90% using standard methods, the situation on the ground is much murkier. Some 62% of the population has electricity available less than 8 hours a day and 85% of the city only has access to very low voltage".

Source: Gabrielle Desarnaud, "L'électrification rurale en Afrique : comment déployer des solutions décentralisées ?" (Paris: IFRI, 2017).


© Remy Delacloche

The many power cuts disturb daily life and force the populations to light their homes by candle or kerosene lamp

"Electrification processes are deployed over time and are part of the specific rural electrification system histories by state and zone of application. A territory's electrification level and its progress are indicated by its electrification rate (number of electrified villages to total number of villages in the area considered) and its connection rate (number of homes and other electrified users to the total number of potential users identified in the area concerned)".

Christian de Gromard, energy Specialist, Agence Française de Développement

Where does "rural" electrification start and stop?

If electrification is defined as a process of providing a service (electricity) in a given space, then rural electrification equates to this process applied to a *certain category* of territory. Yet, in the end, a space said to be "rural" has fairly hazy borders.

How do we recognize a "rural" space?

In each country, the land use planning authorities and territorial communities have their own definition of what is "rural". Generally, a "rural area" is considered to be *any space that is not an urban conurbation and its peri-urban area.* Sometimes the distinction is founded on a quantitative criterion... the number of inhabitants in a locality. In France, for example, urban areas with less than 2 000 inhabitants are considered to be rural.

Thus, there is no commonly accepted definition of a "rural area", first defined by default, with reference to the urban area... for which there is no single definition either (cf. inset).

In Sub-Saharan Africa, these areas nonetheless match a certain landscape: a dispersed habitat (hamlets and villages) or small clusters where subsistence activities, are mainly centred on seasonal agriculture, animal husbandry and forest management. Exchanges fluctuating in line with the volumes and market prices, stem from the sale of farming products on markets to intermediate wholesalers or to food-processing industries. The incomes of these populations tend to be unstable and low.

These qualitative characteristics (dispersed habitat, predominantly primary activities, seasonality, instability and low incomes...) are adopted to define DRE, as the term will be used throughout this book.

Why make the distinction between rural and urban electrification?

The rural environment is characterized by the low density of potential users, whose electricity demand is limited because of their poor financial resources and who are geographically scattered. Electrifying a rural space in Sub-Saharan Africa calls for heavier investments without being able to achieve the same economies of scale as when constructing an urban power grid. This partly explains the lack of service in the Sub-Saharan rural environment and the price differential between urban and rural electricity (cf. chapter 2.1.2).

As a result, DRE implies designing relatively extended rural electrification perimeters, with appropriate planning, that combine high potential localities with low density population spaces. This territorial mix is one of the essential aspects to be considered so as to ensure the financial viability of a rural mini-grid project (see chapter 3.5 for this

Examples of criteria used to distinguish urban from rural for some Sub-Saharan countries

Rural areas, often defined as the absence of urban areas, are *de facto* a residual category. The definitions used by the statistics institutes vary from one country to the next, some of which only take one criterion into consideration (45% of countries), while others (53%), use several criteria to define urban areas to reflect the different geographical and socioeconomic realities.

Benin: an urban area is defined as:

- Any main town of at least 10 000 inhabitants with at least one of the following infrastructure facilities: post and telecommunications office, tax office, water supply system, electricity supply system, health centre, college.
- Any district that has at least four of the above facilities and at least 10 000 inhabitants. (INSAE, 2011)

Ghana: rural areas include all communities with fewer than 5 000 individuals. (Ghana Statistical Service)

Nigeria: rural areas are deemed to be any community with fewer than 20 000 inhabitants, whose activities are primarily farming.

Source: ILO, "Rural-urban labour statistics" (Geneva, 2018).

The lack of an internationally agreed definition of rural areas.

Although rural areas were historically the matrix of economic and social development and have always been at the centre of the development debate, they do not have a clear-cut definition: what is rural is what is not urban. According to the UN Statistics Division, the rural population can be identified as a residual number after subtracting urban population from the total population.

However, an additional difficulty is that cities do not have any standardised definition. The definition of urban areas varies broadly between countries. The main criterion is the size of population, with a threshold above which a conglomeration becomes urban. Other criteria are used, such as the percentage of households engaged in agriculture, administrative boundaries or service provision, and a mixed approach is sometimes adopted.

Source: Sara Mercandalli and Bruno Losch, "Rural Africa in motion – Dynamics and drivers of Migration South of the Sahara" (FAO and CIRAD, 2018).

solution). Designers are also called on to look for investment and operating subsidy mechanisms because **the idea that users will bear the whole financial burden of an installation cannot be countenanced.**
While individual electricity service distribution by the commercial sector (lamps, domestic kits) does not suffer from exactly the same constraints, it cannot get around the need to optimize and mutualize costs. Bias is rarely slanted in favour of the most hemmed-in areas and these solutions are restricted to just part of the population (cf. chapter 3.2.)

What do we understand by "decentralized" electrification?

Rural electrification by gradually extending of a centralized grid, in a star-shaped constellation around one or more interdependent production centres managed by a single structure (such as the national utility), is not economically viable (cf. chapter 2.1.2). Achieving the electrification for all goals in 2030 thus requires us to call on alternative technical solutions, said to be "decentralized", namely, in contrast to the organization of the national grid, **calling on their own local "short supply chain" electricity production facilities to meet the electricity demand.**
There are many decentralized options (cf. Part 3) – small power plants (by generator set or renewable energy) supplying a local distribution mini-grid, standalone photovoltaic systems, portable devices, and so on. When combined over a single electrification perimeter, they can satisfy various electricity requirements and bring service to almost all the members of a rural community.

DRE is not diametrically opposed to centralized solutions

National and local grids are not based on fundamentally different techniques (cf. inset), but their equipment sizing, and economic assumptions differ, so resulting in very different pricing rationales (cf. chapter 3.5.1.).
These two approaches are complementary when the electrification of a national territory comes under consideration (cf. chapter 2.1.2).
Incidentally, decentralized systems are not the preserve of rural areas. Lamps and individual solar systems are distributed to make up for faltering national grids and to urban and peri-urban households that cannot afford to hook up to the grid.
The English term *off-grid* puts the emphasis on this "off-grid" aspect rather than referring to the type of territory to be electrified.

At first glance, the decentralized nature of the solution can be taken as a difference in method

Decentralized solutions, released from the consistency constraints of a single grid, have specific features. They are potentially "made to measure" for a territory or a given category of users and involve a wider variety of players.
The basis for rolling out a collective electrification scheme (cf. chapter 3.4.) is thus a methodological triad that also echoes the two founding values of DRE – centrality of use and the universality of service goal:
• **an on-demand approach** – implies knowledge of the needs of the future users that will determine the characteristics of the electricity service[1] and the design of production infrastructures.

1. The generally accepted assumption is that the RES potential exceeds demand.

A decentralized electrification system is based on the same fundamentals as a centralized system

Every electrification system be it centralized or decentralized, comprises four sub-assemblies:

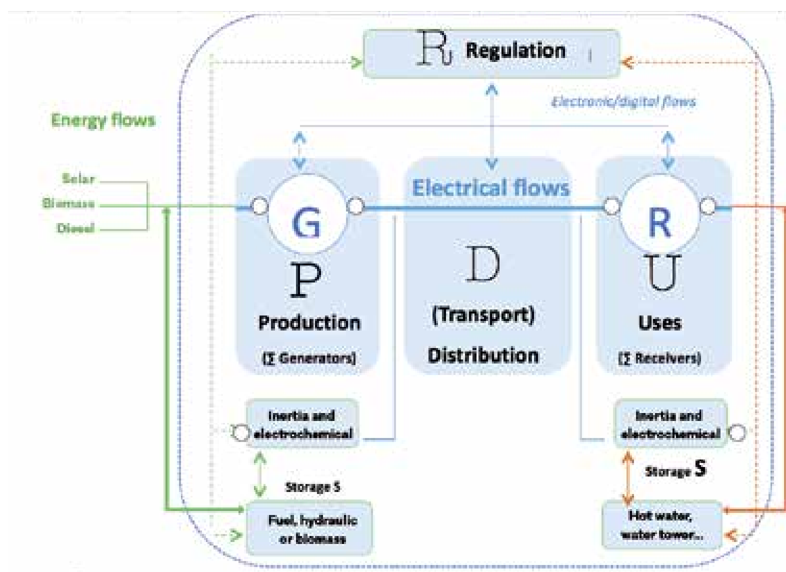
1 PRODUCTION
that includes one or more generators that convert one or more different sources of energy (oil, gas, hydraulic, solar, etc.) into electricity

2 THE USE
of electricity is made by receivers (telephone, television, lamps, computers, engines, pumps, radiators, ovens, etc.)

3 THE TRANSPORT AND DISTRIBUTION EQUIPMENT
that links the generators and electrical receivers across the space

4 STORAGE DEVICES
are required to harmonize electricity production and usage in time

5 THE REGULATION SYSTEM
covers all the appliances that support the management, control, interruption or re-establishment of energy and electrical flows



○ electrical flow or energy cuts/(re) establishment/ measurement/ metering/modulation

Source: Christian de Gromard, Energy Specialist, French development agency.

- **the effective participation of all the stakeholders in the electrification process.** Service sustainability depends on the civil society and its institutions' capacity (national or regional institutions, administrative authorities, elected representatives, local populations, associational and economic fabric) to absorb and make the most of electricity's arrival.
- **operation by a contractually regulated pre-existing or purpose-created, local electricity operator,** that must become proficient in all the relevant business areas (technical, management, commercial, and so on; cf. chapter 3.5).

A fourth pillar can be added to this methodological vision… **the implementation of environmentally-friendly solutions** by using locally available energy sources, provided the equipment allows for this. The use of renewable energies, primarily solar energy, provides the most relevant answer to short supply chain electricity production logic.

Decentralization of the electricity service and political decentralization are not unconnected

Wherever grid extension tends to start from a top-down vision, DRE takes a *bottom-up* approach. Hence, it should follow that the implementation of decentralized solutions encourages national authorities to decentralize the technical services responsible for rural electrification and transfer strong skills in this area to the territorial communities.
As it stands, decentralization is still flawed. The fact that projects are borne by local stakeholders equipped with suitable resources results in:

- **more effective deployment of this DRE-specific method,** by giving better guarantees of awareness of the demand, collective ownership and enhanced local operator skills (cf. the recommendations made in chapter 4.1);
- **boosting job creation**, by integrating electrification in the territorial planning rationale.

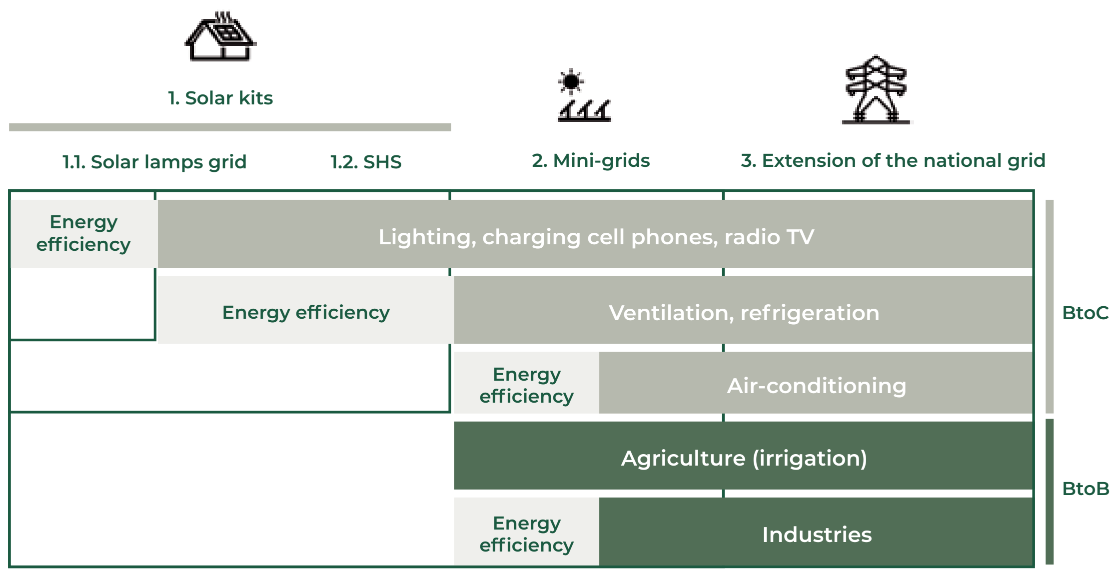
Thus, DRE would appear to be a set of solutions developed to meet the demand of rural communities that are unserved or badly served by the national grids, that aim to provide the widest possible electricity service to the highest possible number of people. Accordingly, DRE is also defined with reference to the national grid, to which it has become an essential teammate. In some way, centralized and decentralized systems are the two sides of the same coin.

"Most of Guinea's electrification planning studies give priority to electrification by the centralized grid, as does the national programme to improve access to electricity in Guinea and its investment prospectus produced in 2015.

In my opinion, mini-grids and individual solutions should take priority to serve the rural population equitably pending the arrival of the central grid. In so doing, mini-grids must simply integrate the technical specifics compatible with the public grid in anticipation of their future connection. Furthermore, provision should be made for compensation mechanisms to ensure that the mini-grid operators recover their investments in full".

Mamadou Saidou Diallo, trained as an electrical energy engineer, has been working in the field of rural electrification in Guinea for 15 years. He is the Joint Director General of the Guinean Rural Electrification Agency (AGER). *Find the whole interview in French on the book's webpage:* ***http://www.fondem.ong/electrifier-lafrique-rurale/***

Electrification models and related uses



Source: AIE, "Energy Access Outlook 2017, From Poverty to Prosperity" (Paris 2017)

2.1.2. The use of renewable decentralized solutions is the only credible alternative to extending the grid to electrify rural Sub-Saharan areas.

Access to an electricity service has become a major national and local political challenge, because rural communities will no longer put up with the lack of electricity and are claiming equal treatment for towns and the countryside. They rightly want to improve their living conditions, get information and communicate easily and develop activities to increase their incomes.

Extending urban grids is not a short/medium-term option to meet this social demand. The required investments (cf. inset) are beyond the national utilities' financial capacities, that are often already hard-pressed (cf. chapter 1.1.2). As for the regional authorities, most of their taxation systems cannot finance this basic service, which calls for heavy equipment and organizational expenditure (cf. chapter 2.3).

Grid extension is too costly an option to become rapidly widespread

Bringing electricity to rural areas is fraught with difficulties that make grid extension very hard to pay off. This limits the implementation of widescale rural electrification plans and in fine explains why access rates to electricity are low in the rural environment:

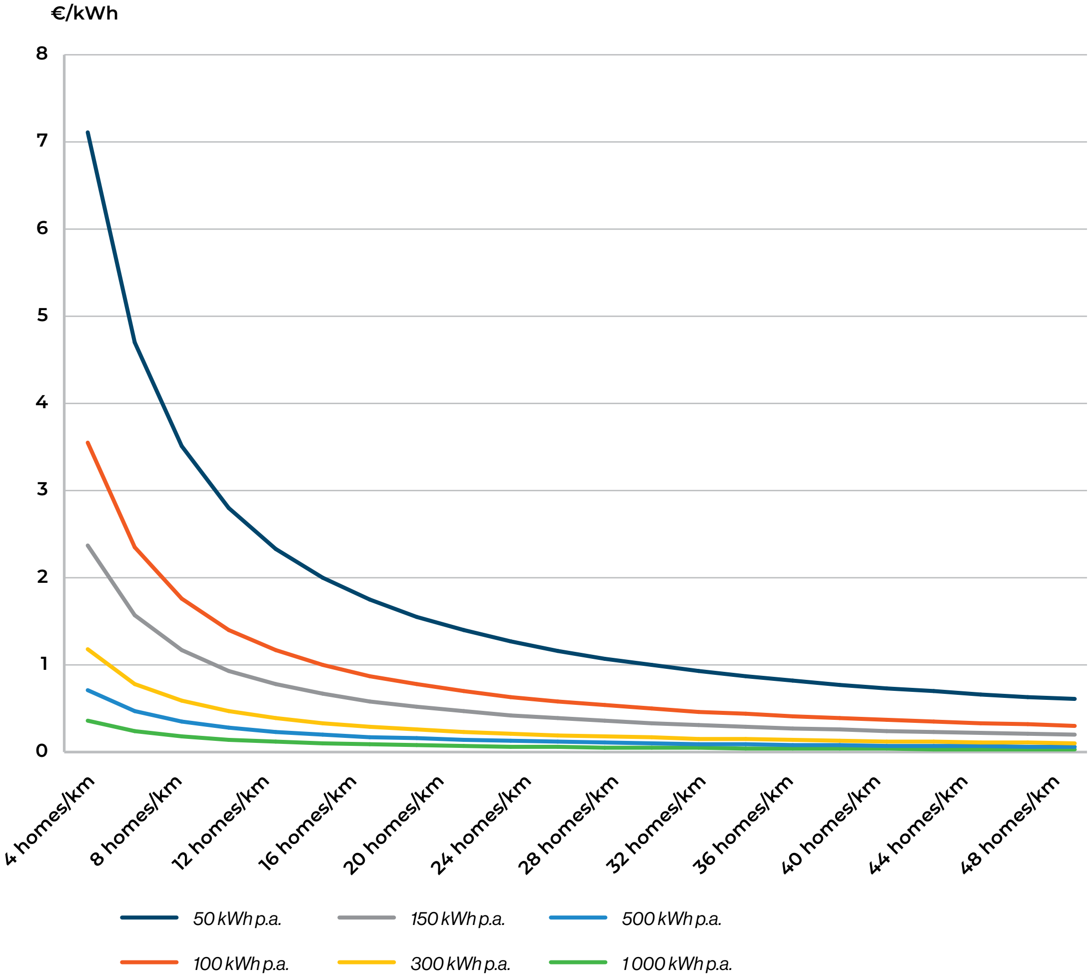
- **the considerable scattering of localities over a territory...** the long distances increase medium voltage line transport cost by € 30 000 per km;
- **the low housing density within a locality** – installing a low-voltage line requires an investment of about € 15 000 per km;
- **the low electricity consumption levels** of about 80-100 kWh per annum, per rural home resulting from their low incomes;
- **the uncertainties surrounding growth in electricity consumption** – activities tend to be stable in rural territories because of their low appeal.

Investment sum required to electrify rural Sub-Saharan Africa

According to the IEA, 370 billion dollars of additional investment will be required from 2017-2030, i.e. about 26 billion additional dollars per annum, to cover universal access to energy in Sub-Saharan Africa (all urban and rural areas taken together) by 2030.

Source: IEA, "Energy Access Outlook 2017, From Poverty to Prosperity" (Paris, 2017).

Cost of transporting electricity on the basis of the number of homes connected per km and their annual consumption



Source: Christian de Gromard, Energy Specialist, French development agency.

It should be noted that the demographic momentum observed in Sub-Saharan Africa could affect some of these factors and change the situation for the comparative analysis of grid extension and implementing decentralized solutions.

From the electricity company's angle, overinvestment by locality and rural customer limits the number of electrified areas

Grid extension to a rural area entails investing in additional equipment to increase production capacities, transport the electricity and connect the users. Provision must also be made for performance dented by technical losses (in transformers and cables) and commercial losses (unpaid bills and pirating can run up to 30%[1]). These two types of losses that the national utilities are all too familiar with in urban settings (cf. chapter 1.2) are rifer in rural installations.

The Ghanaian example... the 20-km rule

In Ghana, the electricity distribution "agencies" (public companies) mainly focus on improving access to electricity in urban and peri-urban areas that are already covered by the grid, as well as rural areas sited at a reasonable distance (less than 20 km) from the existing grid.

Source: Francis Kemausuor, Edwin Adkins, Isaac Adu-P u, Abeeku Brew-Hammond and Vijay Modi, "Electrification planning using Network Planner tool: The case of Ghana", *Energy for Sustainable Development*, n° 19 (2014).

Electricity-intensive economic activities are not found as a matter of course in rural localities... far from it. Thus, the development of activities relating from the arrival of electricity requires sustained awareness-raising, encouragement and guidance schemes to create favourable local momentum... which certainly comes at a cost. Moreover, these schemes fall outside the natural operating scope of the national utilities, who do not seek a multi-sector approach to electrification or involve the local communities, or the decentralized ministerial administrative services.

From the consumers' angle, the connection costs and social tariffs directly or indirectly penalize access to service the largest number of people.

The connection costs borne by users are unaffordable for the most destitute, who often live on the outskirts of the localities. It is one of the main obstacles to increasing the coverage rate by the national grid. Available data suggests that once the distance between the grid and the building to be electrified exceeds 200 metres (which is commonplace in the outskirts of African cities), the majority of inhabitants find the financial terms of connection prohibitive. At the same time, those with the ability to connect to the grid, wherever they live, may take up social tariffs. These tariffs assist small consumers and rarely exceed 100 FCFA/kWh (15 euro cents) yet hits the electricity company's financial equilibrium and discourages it from multiplying grid extensions. So, it comes as a paradox that the existence of these social tariffs also indirectly penalizes access to electricity for rural populations.

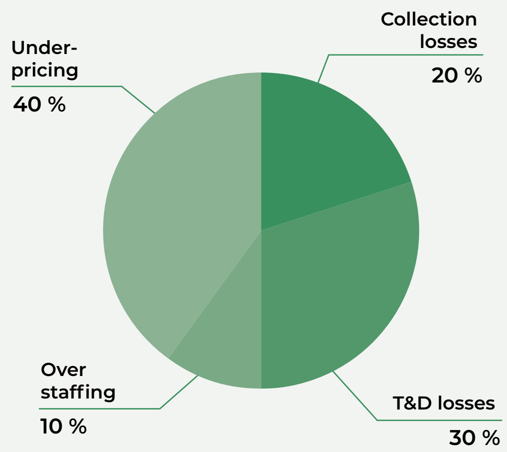
So, in practice, extending the national grid can be envisaged in a limited number of situations for electrifying rural communities. The main response to their electrification lies elsewhere by deploying decentralized solutions.

Coverage rate vs. Connection rate

The coverage rate indicates the ratio of village populations connected to the total population of the area (or the number of electrified villages to the total number of villages).
It must not be mistaken for **the connection rate** (ratio of the population effectively connected to the total population). The coverage rate characterizes the extent of service coverage, whereas the connection rate indicates the effective extent of the service

Example : *100 villages, 50 homes per village, 10 people per home, i.e. a total of 50 000 people.*
If 30 villages are electrified, the coverage rate is 30%.
If the average connection rate per village is 20% (10 homes connected) the connection rate of the area is 30%x20%=6% (300 homes or 3 000 people).

Breakdown of the "hidden" costs in Sub-Saharan Africa (excluding South Africa)



Under-pricing is the largest component of the Sub-Saharan utilities' quasi-fiscal deficits, followed by transmission and distribution losses.

Source: World Bank Group, "Africa's Pulse: An Analysis of Issues Shaping Africa's Economic Future" (Washington, D.C, 2018).

Africa is a hotbed for renewable decentralized electrification solutions, primarily solar.

On the continent, the population served with decentralized solutions has risen from 2 million in 2011 to 53 million in 2016. This growth is essentially driven by solar lamps (particularly those massively distributed in East Africa). In 2016 they equipped roughly 50 million people, while 4 million have a Solar Home System and more than 1 million are supplied by solar mini-grids.

The combined capacity of decentralized solutions has risen from 231 MW to almost 1.2 GW between 2008 and 2017, more than two-thirds (820 MW) of which is taken up by solar technology. Hydraulic mini-grid capacity rose from 124 MW in 2008 to 162 MW in 2017, but its share of the energy mix is gradually falling. It accounted for less than 15% of the total renewable decentralized solution capacity in 2017, compared to 53% in 2008.

Source: IRENA, "Off-Grid renewable energy solutions, Global and Regional Status and Trends" (Abu Dhabi, 2018).

Renewable decentralized solutions enable us to envisage a suitable response to rural demand

When it has been impossible to carry out rural electrification by extending the national grid (for economic reasons), the utilities have tried to decentralize their production. By taking on the investments and part of the operating costs, they have resorted to diesel mini-grids to electrify secondary urban centres not too far away from the grid to be connected to it. Yet, these initiatives have not spread to smaller communities, because of the cost (primarily of fuel supply) and the operating constraints (cf. chapter 3.5).

It is the advent of renewable decentralized solutions that has enabled:

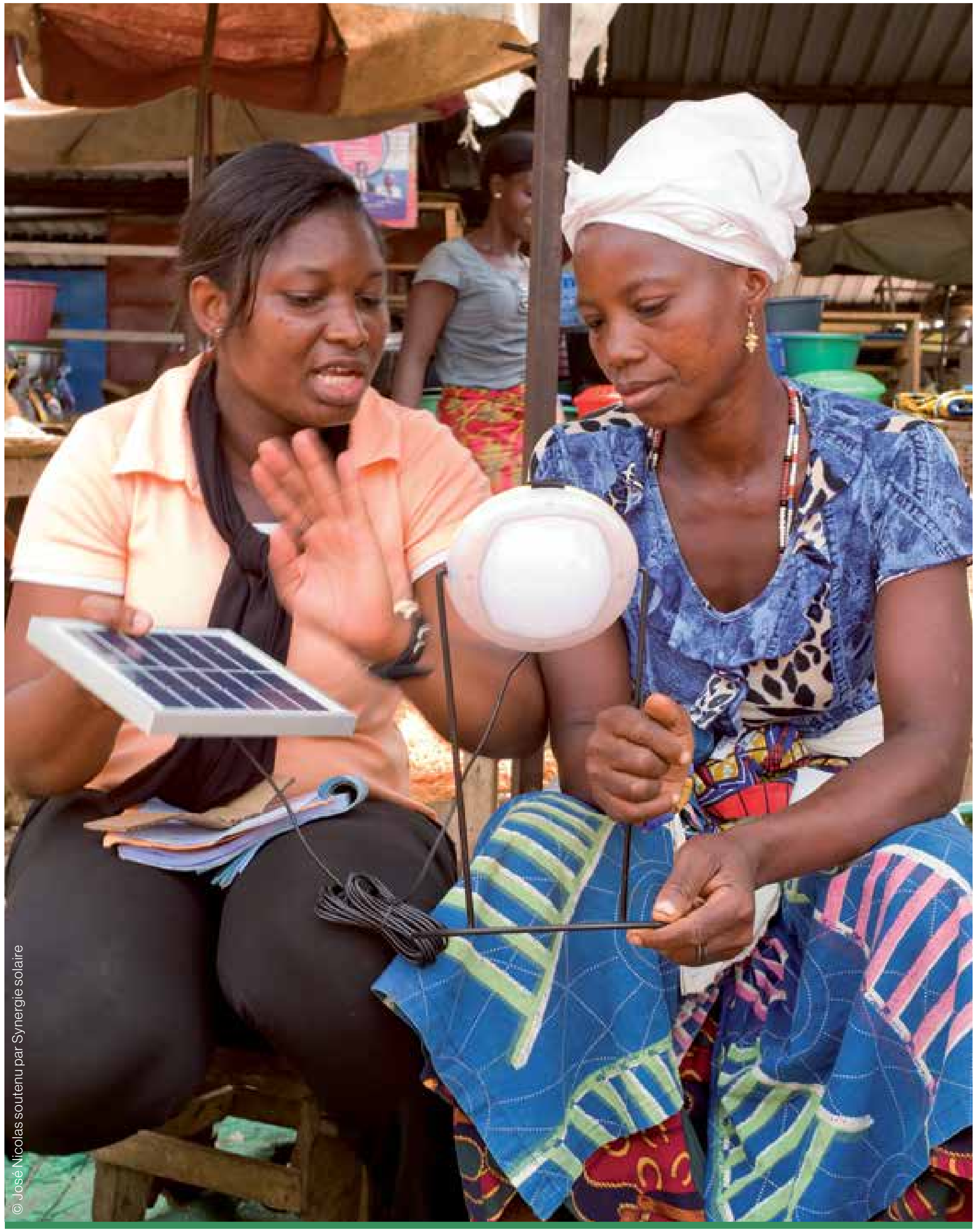
- global electrification of the Sub-Saharan countries to be envisaged and this hypothesis to be tested since the 1970s;
- then, 40 years later, as these decentralized solutions have become competitive, to select the most relevant technical option to the local context.

Countries endowed with plentiful renewable energy sources (cf. chapter 1.1.2) are all ripe for the implementation of solar (most often) or hydraulic (when the context is suitable) solutions, which avoids resorting to thermal generator sets which are incompatible with combatting climate change[1].

The spread of these renewable decentralized solutions is a pre-electrification rather than an electrification success

Between 2011 and 2016, the number of Africans with access to electricity through renewable decentralized solutions multiplied by 25. Production capacities have increased fivefold since 2008, primarily through the deployment of solar technology (cf. inset).

1. In order to limit the use of batteries, power generators must be strictly restricted to the hybridization of sustainable solutions (see chapter 3.1).



Portable solar lamp

The solar mini-grid as a useful interim solution

Much may be gained by initially targeting grid extension to areas with higher potential for significant uptake and expansion of productive uses, while pursuing the provision of smaller-scale alternatives in other areas.

Mini-grids using solar power also have benefited from rapid advances in solar power technology. Accordingly, mini-grids are a very interesting possibility for scaling up electricity availability in areas where grid extension is costly or can only be accomplished some ways into the future.

There has been limited investment in mini-grids so far in Sub-Saharan Africa. A major challenge for inducing private sector mini-grid investment is confidence with respect to cost recovery, and what happens to mini-grid assets when the grid begins to penetrate its service territory. A major challenge for inducing private sector mini-grid investment is confidence with respect to cost recovery, and what happens to mini-grid assets when the grid begins to penetrate the service territory. Additional mini-grid investments in the region would be quite valuable for better understanding their economics and how best to manage them.

Source: World Bank Group, "Africa's Pulse: An Analysis of Issues Shaping Africa's Economic Future" (Washington, D.C, 2018).

This progress is based on the rapid spread of individual solutions (rather than collective mini-grid-type solutions), helped by plummeting photovoltaic technology costs (cf. chapter 2.3.1). **Widespread distribution of the most affordable solution, portable solar lamps, is essentially behind this progress;** a lamp costs about € 10, whereas an individual solar system costs € 200-500.

Yet, the spread of solar lamps will not lead to the achievement of the universality of uses targeted by DRE. So, one should talk of "pre-electrification" rather than electrification that is progressing rapidly.
Solar mini-grids would appear to be the most interesting solution to electrification to back up grid extension to cover more uses (cf. inset) but funding this type of installation is hard (cf. chapter 2.3.2). Additionally, the sustainability of a mini-grid involves allowing for many factors (cf. chapters 3.5.3).

Several criteria make the case for renewable off-grid electrification despite high rates for the users

The price paid by users for a decentralized solution is currently higher than that paid by urban users, because it faithfully reflects all the costs incurred by supplying the goods or the electricity service. Thus, for a local mini-grid, which is de facto outside the utility company's perimeter and the national equalization system, the pricing structure is specific and without the benefit of the subsidies that apply to urban users connected to the national grid.

Yet, renewable decentralized solutions offer several advantages over grid extension:
- **investment optimization:** for a given budget, a few localities and consumers can be electrified, and the service adapted in line with the real contributory capacities of the potential users;
- **offer tailored to the demand:** the available capacity and energy are defined in line with the needs of the various uses (domestic, productive, community) in each locality and their probable development;
- **variety of solutions:** from portable lamps to local mini-grids, the range is wide (cf. Part 3) and enables the cost of access to and use of electricity to be adapted to the financial capacity of each user;
- **rapid response:** even in a mini-grid, the components of a decentralized production unit are modular and easy to install;
- **energy management:** the technical solution incorporates powerful receivers (LED, very low-consumption TV, super-insulated refrigerator, etc.).

Costs arbitrate between grid extension and the decentralized solution, which puts the use of the electricity at the heart of the analysis

If we put aside the political considerations and funding constraints that could shape the decision, the starting point of any rational technical choice between a conventional grid extension solution or decentralized calling on local energy sources must be the comparative analysis of installation, distribution and operating costs (cf. inset).
Primarily, these costs depend on:
- **the distance** between the area to be electrified and the grid,
- **the electrical energy** that the population of each of the localities will use.

Choosing a technical option – the cost approach

Generally, the choice of electricity technology in the context of rural electrification is influenced by various actors and factors – prevailing policy and implementing agencies, distributors, service companies, financing institutions and household socio-economics.

Even though both grid-connected and stand-alone options have their own advantages and disadvantages, **the underlying principle for choice of a particular mode is adopting the least cost, technology options and with minimum maintenance requirements as far as possible.** The technical feasibility may depend on several factors such as terrain of that location, distance to existing grid, size of loads, and local availability of resources.

Source: Francis Kemausuor, Edwin Adkins, Isaac Adu-P u, Abeeku Brew-Hammond and Vijay Modi, "Electrification planning using Network Planner tool: The case of Ghana", *Energy for Sustainable Development*, n° 19 (2014).

The pre-electrification concept and the Lighting Africa initiative

Over and above the special demand analysis and optimization approaches implemented in 1985 on specific, primarily solar projects, AFME (today's ADEME) launched the concept of pre-electrification, proposing an alternative way of electrifying rural areas to the one conventionally implemented by extending urban grids.

The following are the basic principles that this concept attempts to unite:

- The energy efficiency of the electrical equipment, with special emphasis on lighting (in many rural areas it is the main item) and the development of powerful rechargeable portable lamps;
- Two electricity distribution modes: "linear" (with local mini-grid) and "voltaic" (with battery transport or individual solar kits);
- Different types of low-capacity production sources, site-dependent and selected with preference for renewable energies (solar and small hydro in particular).

The pre-electrification concept has given rise to two major DRE programmes in Morocco. It has been given other names, particularly those of Decentralized Service Companies (SSD) promoted by EDF and ADEME in Sub-Saharan Africa. The term DRE, which is more sustainable, has now replaced it.

The "powerful portable lamps" side of pre-electrification, which used the 1980s technologies, has been taken up again by the World Bank twenty years later in the Lighting Africa initiative, using the technologies that have become common over the past fifteen years (LED for lighting and mainly lithium-ion for the batteries). These technological advances, supported by this initiative, have contributed to significantly improving the quality and flexibility of the use of off-grid electrical lighting.

Source: *https://www.lightingafrica.org.*

This rational technical choice cannot be simply based on abstract, officious modelling. It requires a fine qualitative approach, patient observation of the terrain which will help determine the value of its various uses of electricity that must guide the approach. Only this can determine the priority applications of the electricity (current and future) in a given territory and ensure that the potential users are willing to pay (cf. chapter 2.4.1).

The upturn in off-grid renewable energy-based electrification has provided the opportunity to take a new look at the questions about electricity uses. Whereas grid extensions generally preempt similar consumption levels to those of the urban environment (which the findings in the field refute), needs form the starting point for DRE to define collective or individual solutions that can meet them.

The *bottom-up* approach favoured by DRE has gradually been defined and consolidated through experience. The following paragraphs will recount its "history", emphasizing the various phases and development factors that have punctuated it.

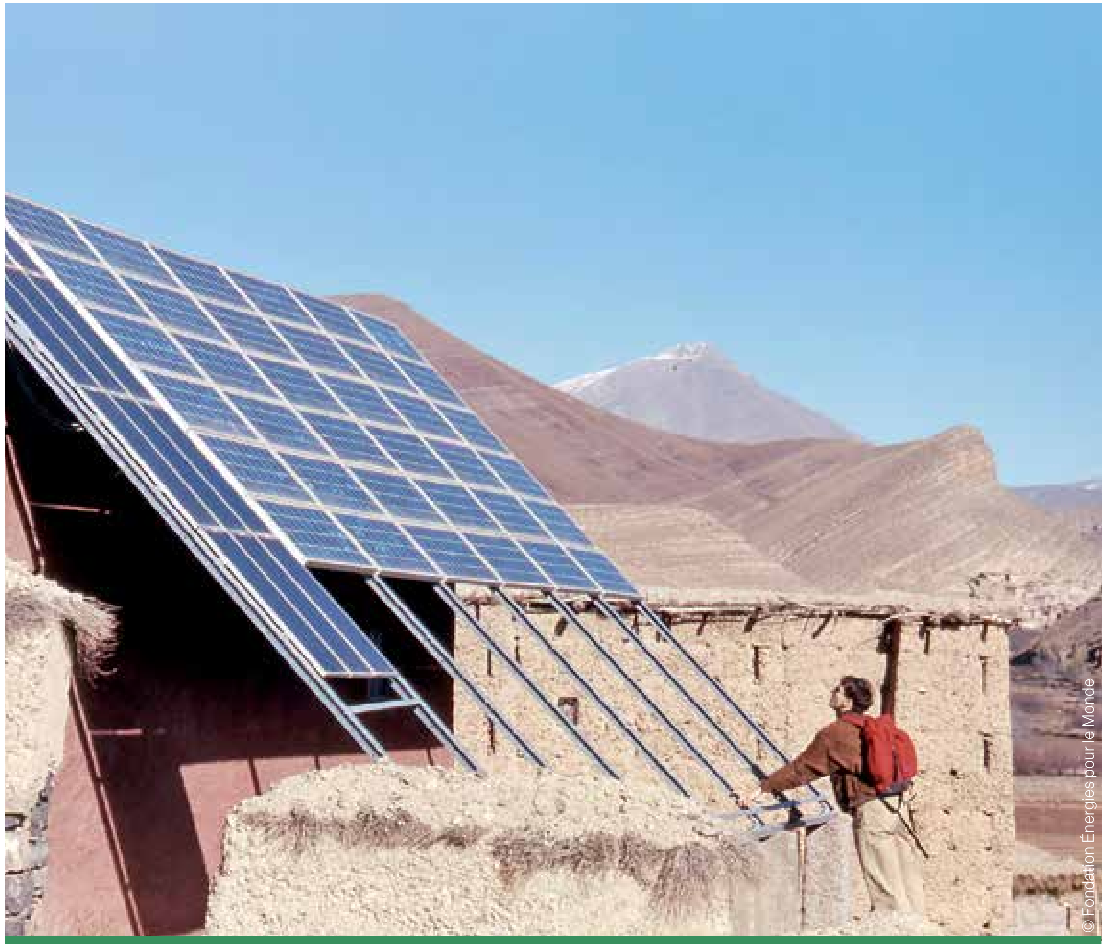
A few of the products tested by the Lighting Africa initiative

2.2. Off-grid electrification solutions are based on 50 years of history

The following developments propose several dips into the past to clarify the present.

We start by making two geographical and historical detours via France and the United States that provide useful insights for understanding the logic behind supplying electricity via a local grid. In both of these countries, rural electrification was a fundamentally decentralized affair, driven at local level, backed by the central administration.

Then it is worthwhile taking a chronological backward look at what has happened since the 70s, to understand the succession of contexts and rationales that have shaped DRE practices in the developing countries, before we reach the breakthrough period that we find ourselves in today and to which the book dedicates detailed developments (cf. chapter 2.3).



The Pilot Rural Electrification Programme in Morocco, pioneering DRE

2.2.1.
The decentralized approach to access to electricity was initially adopted in the rural areas of the industrialized nations

We obtain useful benchmarks for understanding what is at stake in current-day rural electrification in Africa by making a comparative analysis with the electrification history of the industrialized nations. Many Europeans aged over 75 were born in rural areas, which like the current Sub-Saharan rural environment, had few, if any infrastructures (roads, canals, railway lines, mains water, telegraphy, etc.), living in houses without electricity or running water, where paraffin lamps and candles were the main domestic lighting sources. Electrification of France and the United States, only just completed in the 1970s, started and developed in an era on the cusp of the 20th century, when the two countries were much more rural and agricultural than they are today.

Why should we mention French and American rural electrification? Because these two cases testify to the primary role played by local momentum (local communities or rural cooperatives) in a territory's access to electricity. Both examples demonstrate that rural electrification is a decentralized process and that there is a logic to thinking of rural electrification through the rise of decentralized solutions in Sub-Saharan Africa just as anywhere else.

In France, local initiative acted as the catalyst and main driver of the development of electrification

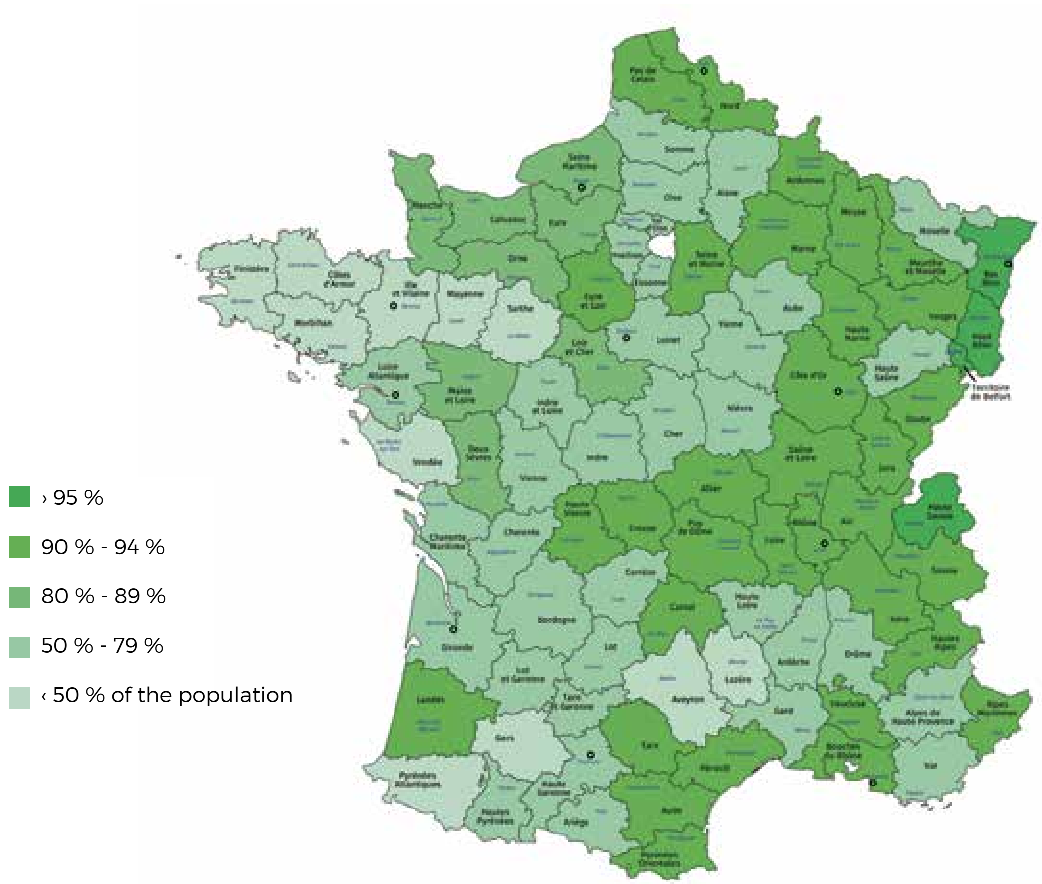
Until the Second World War, as in most of the industrialized nations, access to electricity initially started in a decentralized way, driven by one or more players... a territorial institution, a cooperative, a user group, an electrification company, an industry that produced its own electricity... The interconnection of local decentralized power grids only occurred later and gradually, as the territorial network expanded. Nonetheless the French state always played an essential role, firstly by regulating the sector, then by easing access to funding.

The electrification of France evolved through communal concessions awarded to private companies

Most of France was electrified prior to the nationalisation of the electricity sector in 1946. When the public company, Electricity de France (EDF), was formed, 90% of the country's localities (more than 30 000 communities) were already electrified by firms or electricity utilities operating communal concessions (see map). We continue by relating how the department of the Lot, for instance, perhaps a little poorer than the average French department, but generally representative of rural France, was electrified (see inset).

The example of the department of the Lot highlights the four building blocks that enabled France to achieve better penetration of rural

Electrification of French rural areas by department in 1946



Source: Arnaud Berthonnet, "Rural electrification, or the development of the "miracle of electricity" in the heart of rural France in the first half of the 20th century", *Histoire & Sociétés Rurales* 19, n° 1 (2003).

electrification prior to nationalisation, than most of the other European nations at the same time:
- the resolve of local authorities, particularly of the communities
- partnership with an electricity company;
- appropriate legislative and regulatory framework;
- preferential access to finance.

Electrification relies on the determination of local authorities, particularly of the communities in the first place

Responsibility for electrification was legally transferred to the communities as early as the beginning of the 20th century, even though the latter had limited skills, municipal budgets were often derisory and their populations still partly illiterate.

The department of the Lot... an example of decentralized rural electrification

There were two main phases to the electrification of this rural department before the electricity sector was nationalized in 1946

PHASE 1: making the match between demand of the inhabitants "decided to get lighting as soon as possible" supported by their municipal counsellors and the proposals made by the generally small electrification firms.

Following public enquiries and inspection by the technical services, the communities awarded exclusive 40-year concessions to these firms, approved by the Prefect. The electrification scheme for more than 80% of the communities was made on the basis of totally private investment and management. A few concession holders were subsidized by the communities themselves. The State's role was to define detailed regulations regarding the technical characteristics, safety rules and maximum and minimum pricing levels aimed at the project managers and private operators. For instance, in a number of communities "lighting was to be provided until 10 pm, except for Saturdays, Sundays and fair days, when it could be extended by a quarter of an hour after the legal tavern closing time". Any disputes between the communities and the companies were settled locally by the Prefecture.

PHASE 2: subjecting to the authority of intercommunal electrification boards for the purpose of construction and operation of a distribution grid by private operators in the communities.

This is the phase marked by local community investments and private management. Thus, the board for the North of the Lot, the Syndicat du Nord du Lot, financed works by taking out loans from the Caisse des Dépôts et Consignations, provided that the communities guaranteed the relevant works budget. The board was repaid through the electricity service charges (about 50% of the fees went to the board and 50% to the operator), and it was only in the event of default that the communities were obliged to make up for the loss by raising taxes. Some small communities went so far as to commit to guaranteeing sums equivalent to a financial risk of up to almost 20% of their budget.

Before World War II, the electricity sector of the Lot had eleven intercommunal boards, one community board, three main operating firms, two smaller ones and nine individual operators and a single municipal management board for about 167 000 inhabitants. More than 95% of the localities and 74% of the population had access to the electricity service.

The last communities of the Lot had to wait until the 50s to be electrified by a board, which is still the grid owner to this day, but has assigned its operation to the national utility, EDF, which "has simply professionally and successfully supplemented, modernized and managed the existing system".

Source: Michel Matly, "L'électrification du monde commence à Labastide-Murat", *Revue de l'Energie*, n° 523 (2001).

The communities predominantly prompted the arrival of electricity and fully exercised their responsibility as project managers:

- to deploy this innovation, they identified electricity companies and awarded them long-term concessions
- they also had to acquire in-house skill to provide technical control over them or alternatively delegate this to the State services
- subsequently, they had to choose their intercommunal electricity board and then accept or otherwise to guarantee their loans.

The effective implementation of electrification is based on a partnership between the local authority and the electricity company

Community determination is a prerequisite, but not enough on its own. It must take shape in a partnership (concession) with an electricity company to supply, set up and operate the electrification equipment, either directly or via an intercommunal electricity board.

Few communities chose to take on the management of their electricity distribution. While there was at least one electricity board in the Lot and others still exist in France, most communities and electricity boards have opted for private rather than communal operation. Often electricity companies outside the territories were the first to approach the local authorities (for example, a Parisian firm contacted the community of Labastide-Murat before 1925 to develop its public lighting).

However, the gradual introduction of intercommunal electrification electricity boards led to the creation of local business groups. Private companies were not to be left out of the game, starting with mill owners, small businesses and private individuals, with no aspiration to making their fortunes, but with the security offered by the concession. They invested where the acceptable level of demand made electrification viable, sometimes at very small scales (cf. inset).

"This resolve did not emerge from an urban civil servant sitting in the comfort of an electrified office, but from rural communities keen to change their standards of living through the arrival of electricity. And this resolve was one of the main drivers of electricity's development".

Michel Matly, L'électrification du monde commence à Labastide-Murat, Revue de Energy, n° 523, 2001.

This experience proves that economic equilibrium can be found in very small zones that offer low consumption levels. But success also relies on having a conducive institutional and regulatory framework in place – that is the second lesson to draw from French rural electrification.

Electrification must be regulated by appropriate safety, environmental and pricing rules

The communities had been delegated the responsibility for electrification by law, which they were willing to take, and the private companies were prepared to meet their demand. But it is the regulatory framework set up by the public authorities that enabled this momentum to materialize. The relevant government agencies stepped in to make up for the initial lack of skills and drew up and conveyed a full range of tools to implement the various legal stages of an electrification project:

Labastide-Murat (Lot, France) – A viable project despite the very low consumption level

"The electricity companies arrived without subsidies yet proved that an electrification activity can be profitable even in fairly restricted situations… as in the case of Labastide-Murat. **All it took was 150 customers in the main locality**, microscopic consumers, most of whom used 5 kWh per month".

Source: Michel Matly, "L'électrification du monde commence à Labastide-Murat", *Revue de l'Energie*, n° 523 (2001).

- terms of reference for the study and assignment of electrification concessions,
- technical specifications (safety aspects, possible conflicts with the telephone networks),
- standard template of an application for authorization, specifications defining the financing and inspection terms,
- standard template form for delegating control from the community to the State,
- standard framework statistical document to be supplied by the electricity company to the municipality and public powers,
- standard terms of pricing reviews,
- templates of municipal resolutions and letters from the community for transferring files.

At the end of the day, no projects in France were carried out without State authorization, as the latter was called on to give its verdict on the electricity companies' skills and the technical data and prices, to guarantee nationwide consistency on these matters.

While the State gave strong technical support, it only occasionally gave financial support.

Decentralized electrification calls for specialist access to a number of financial instruments (bank guarantees, subsidized rates, etc.)

More than 60% of French electrification was achieved without public aid. Initially (starting in 1925 and for just over a decade), the State did not have the wherewithal to invest in these projects, let alone assist the development of the electricity sector with grants. The communities sometimes organized collections or released funds, but more often than not electrification came at no cost to the local authority.

However, the small communities, hamlets and isolated houses, that were not a viable market, were excluded from the electricity service. In a second phase, to continue the electrification drive, the public authorities participated by encouraging the creation of intercommunal electricity boards, that managed to raise credit thanks to the community guarantees and State aid. The State sometimes gave grants, but mostly granted subsidized loans that would be repaid by the users.

In the United States, the creation of rural electricity cooperatives made for delayed but faster electrification of the territory

In the middle of the 30s, rural electrification had not really kicked off in the United States. Only 13% of rural families had electricity supplied by the grid, whereas 90% of their counterparts in France, Germany and Japan, 85% in Denmark, 65% in Sweden and almost 100% in the Netherlands had electricity in their homes. At the time, the private companies operating in the electricity sector shied away from investing in rural electrification on the grounds of low profitability prospects. It took more than thirty years of effort for American farms to catch up.

The Rural Electrification Administration (REA), created in 1935 to manage a rural electrification fund, was based on the cooperative model

In the beginning, funds were offered to private companies, that were the only ones to have the necessary technological know-how and qualified technicians. But the partnership envisaged with these companies stalled as the REA felt that their electricity sales rates were too high for the farmers' purchasing power.

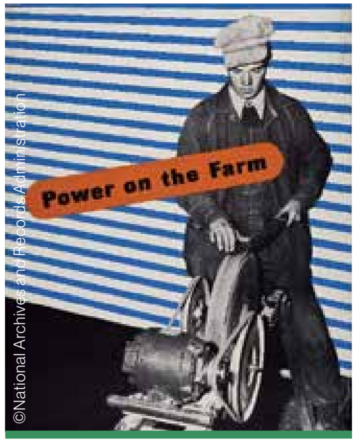
So, the REA used the agricultural cooperative model, self-managed by the farmers and that the populations trusted. These new electricity cooperatives became the key partners to rural

"It amounted to forcible formation of a public service asset in the boards' hands, because private investment could go no further… and it worked. Interconnection levelled out the costs, the ensuing new customers and community guarantees remained virtual. All in all, the public sector came out on top with a small initial financial contribution, it went on to capitalize strongly.

As for the private companies they remained pervasive and operated the grids. They competed vigorously to carve out small empires, and, the new communities could often pick and choose between several boards and operators when they became electrified".

Michel Matly, "L'électrification du monde commence à Labastide-Murat", *Revue de l'Energie*, n° 523 (2001).

Rural Electrification Administration electricians building a grid in the 1930s



Vintage Rural Electrification Administration advertisement for agricultural electrification in the United States

electrification in the United States by accepting responsibility for power grid construction and management, while committing to serve their members at cost price. At the end of 1936, about a hundred cooperatives had already signed a loan agreement with the REA in 26 States.

The private electricity companies were invited to produce, transport and sell their electricity output to the cooperatives (who distributed it on to the users), but they were reluctant to do so. The Federal Government gradually set up five Power Marketing Administrations to sell the electricity generated by the major dams to the national or municipal utilities and the rural electrification cooperatives at specialist rates.

The rural electricity cooperatives joined forces in the face-off with the private sector

This new competition finally persuaded the private electricity companies to lower their prices for the cooperatives, while at the same time they instituted numerous proceedings against them in court and tried to prevent the creation of new cooperatives.

In the 40s, the cooperatives first reacted by grouping into "super-cooperatives", that were capable of constructing and running their own production units and transmission grids. Then in 1942, they created the National Rural Electric Cooperative Association (NRECA), which provided its members support in all areas: legal service, lobbying, insurance, training, technical consultation, public relations and publicity campaigns, research programmes, etc. NRECA is still up and running and provides a support service for rural electrification programmes in developing countries.

The results speak for themselves: in 1946, barely ten years after REA was set up, 50% of American farms were electrified (the number quadrupled) and the United States had practically caught up with the European countries. Electrification of its rural areas was completed at the start of the 70s, at the same time as in France.

Today, we are witnessing production returning as close as possible to the user, like the original electrification initiatives

At the beginning of the millennium, about 1 500 private producers were identified in France... the successors to decentralized electrification. Since then this figure has been far exceeded, primarily with the profusion of private building-integrated photovoltaic installations that inject their output into the grid. The intercommunal electricity boards have kept their jurisdiction as the organizing authority for distribution, and the local distribution companies currently serve 5% of the delivery points in France, i.e. about 3 million inhabitants in 2 500 communities.

In Europe, new sector organization has been established for the new production choices (renewable energies and especially cogeneration). These changes tend to demolish concepts that were so far deemed inescapable (like natural monopolies) and have led to subordinating the electricity sector players. Digital developments and the development of smart meters are changing the situation[1]; they encourage communities, but also citizens, to rethink their vision of electricity, gradually take over their electricity systems and tend towards local energy self-sufficiency, by developing decentralized production facilities on their territories.

Producing one's energy as close as possible to one's needs would appear to be a constant benchmark, a rationale that transcends years and geographies, because it no doubt meets a fundamental need of human groups.

1. They provide a near-real-time monitoring of the production and consumptions, as well as an organisation of electricity short channels. Nowadays, the law allows electricity producers and consumers linked to the same transformer station to create a legal entity in order to sell electricity based on data provided by smart meters.

NRECA in the United States now amounts to about 900 local electrification cooperatives serving 42 million Americans covering 56% of the nation.

833 distribution cooperatives and 62 production and transport cooperatives supply

56%

of America's territory.

Source: NRECA, "America's Electric Cooperatives: 2017 Fact Sheet" (Arlington, 2017).

2.2.2. Renewably-sourced decentralized electrification has the benefit of more than forty years' experimentation.

Renewable DRE in Sub-Saharan Africa is not a 21st-century invention. The principle of using renewable energy was tested before the countries gained independence (primarily by hydroelectricity). It spread during the 1970s, then underwent extension during the 1980s and 1990s, then entered a ramp-up and project diversification phase as technological breakthroughs were made, and the international community committed to universal access to energy

The first experiments were rolled out just after independence backed by international cooperation

The first experiments in the developing countries that used solar and wind energy date back to the 1970, in the aftermath of the first oil crisis of 1973. France, with its many industrial players[1], was one of the first countries to install decentralized renewable systems in Sub-Saharan Africa on the strength of its cooperation in Africa and the experience gained in its Overseas Territories.

These first initiatives covered two standard uses – community structures and business applications.

- **Electrification primarily aimed at collective uses,** which were often part of development programmes... drawing water, electrifying health centres or schools, irrigating market garden areas, watering herds, and so on. These small innovative electrical infrastructures were funded through development aid, and also benefited from the support of technical assistant networks for running them and keeping them serviced.
- **Concurrently, industrial concerns got involved in business applications** –solar power supplies for telecommunications repeaters developed by SAHEL (a Thomson subsidiary), broadcasting networks set up by the Bureau Yves Houssin and the Société Nationale de Télécommunication et Télédiffusion (SNTT) in Niger, air navigation (beacons). Another example is wind energy developed in maritime beaconing.

These initial tests confirm the relevance of photovoltaic technology (more suitable than thermodynamic solar), despite the questions raised by the long-term operability of the equipment (cf. chapter 2.4.3). Small wind energy projects point up the issue of wear in moving parts (ball bearings, bearings), the need to regularly grease them and corrosion.

Several French industrial players embarked on the photovoltaic[2] adventure at the end of the 1970s.

1. Primarily, SOFRETES for concentrated solar power, RADIOCOMPELEC (RTC) and PUMPS GUINARD for photovoltaic and AEROWATT for wind energy.

2. Primarily PHOTOWATT and LEROY-SOMER, through its FRANCE PHOTON subsidiaries for manufacturing cells, modules and SOLARFORCE in photovoltaic systems, ELF, TOTAL ENERGIE and SOLELEC/APEX as turnkey system contractors.

School television sets in Niger, 1968

As early as 1968, in Niger, a national rural education programme was rolled out and created the opportunity to design integrated systems comprising a television set and its energy system.

The investment and reliability challenges caused by the number of sites to be equipped and their dispersal over the entire country, led to the design of innovative systems, based on optimizing energy demand:

- Choice of low power consumption television sets (about 20 W)
- Solar supply by a 33-Wp generator set, comprising 3 11-Wp modules, an 80 Ah/12 V battery and a charge controller.
- Modular design for easy replacement of faulty parts,

In 1977, the price of a solar system installed on site was about 9 000 FF (roughly € 1 500). This amount was high for an individual but was affordable for collective use and the solution enabled village education programmes to be massively broadcast to off-grid areas.

Source: Fondation Énergies pour le Monde.

Solar electrification of the San hospital in Mali, 1979

The hospital at San, in the Ségou region of Mali, was one of the first hospital facilities to be electrified by a solar photovoltaic generator in 1979, under the behest of the Mali Aqua Viva association and Father Verspieren.

The hospital was supplied with electricity to cover its daily consumption of about 21 kWh for lighting, ventilation and medical apparatus, generated by an 8.5 kWp generator comprising dual-glass panels each 10-Wp combined with a 120-volt 500-Ah battery bank and a 4-kVA DC to AC converter. An 800-Wp solar pump supplied the hospital with water at a rate of 26 m3 per day with a head of 27 metres. While the per kWh cost was quite high, this pilot installation gave insight into how PV systems could be dedicated to electrifying small "off-grid" health centres located in tropical areas.

Solar generator of the San Hospital (Mali) – 10 kWp

Nowadays, PV solar systems supply many dispensaries and small hospitals in secondary centres at low running costs and unmatched operating reliability. However, the issues of finance for the equipment and responsibility for their maintenance are delicate.

Source: Fondation Énergies pour le Monde.

ELECTRIFYING RURAL AFRICA: AN ECONOMIC CHALLENGE, A HUMAN NECESSITY

In the 1980s, projects scaled up

At that time, several financial backers levered the first change of scale buoyed by their optimism in the technology, the equipment manufacturers and in-situ installers. A number of projects drew strongly on the private sector and foreshadowed the current transitions in the DRE area.

AFME

The Agence Française pour la Maîtrise de l'Énergie (AFME), set up in 1982, is a public establishment whose mission is to encourage, support, coordinate, facilitate or conduct energy management operations. It is the fruit of the merger between the French Energy Savings Agency (AEE), the French Solar Energy Authority (COMES), the Geothermal Committee, the National Heat Recovery Mission and the Ministry of Industry's Raw Materials Savings Department.

In 1990, AFME merged with the National Agency for the Recovery and Disposal of Waste (ANRED) and the French Air Quality Agency (AQA) to form the French Environment & Energy Management Agency (ADEME).

Some symbolic initiatives, paved the way for organizing today's access to electricity programmes

In France, the French Agency for Energy Management (AFME; cf. inset) drew up the first concepts of decentralized electrification through pre-electrification programmes using portable lamps and small standalone solar systems.
In particular it supported the Pilot Rural Electrification Programme in Morocco to provide isolated douars with access to electricity using individual solar systems and micro hydropower plants, drawing on strong involvement from the local communities.

The European Commission launched two major development programmes involving solar equipment (at a time when access to electricity was not one of the public development aid issues). The first, in 1983, aimed to electrify 850 health centres in Zaire; the second, rolled out between 1991 and 1997, embarked on the installation of about 1 000 solar pumps in 9 countries of the Sahel.
These initiatives proposed new approaches to validating equipment (performance and stress tests in accredited European laboratories) and local player involvement (to manufacture very low-energy consumption refrigerators for example, paying for service and guaranteed after-sales service for 5 years). These procedures and mechanisms contributed to maturing the sector.
Smaller-scale experimental wind energy and micro hydropower projects were also conducted in Senegal and Morocco, without setting up maintenance mechanisms.

Regional solar programme in the Sahel

Context – to improve the response to the demand for water
With European Union support, the Heads of States of the Permanent Interstate Committee for drought control in the Sahel (CILSS) member countries, launched the Regional Solar Programme (PRS) in 1988, following the droughts suffered by their states in the 70s and the early 80s.
At the same time, localities were swelled by demographic growth, so hand pumps were proving insufficient to meet the demand for water.

Goals – Combat desertification by pumping water by:
- Improving accessibility to water in quantity and quality;
- Improving villagers' economic conditions by developing market gardening, creating additional resources
- Reducing the time spent by women and children fetching water

Achievements: from 1995 to 2000, 626 solar pumping systems were installed in the 9 countries of the Sahelian strip, for 1 300 kWp of installed capacity; furthermore, 644 solar generators equipped community buildings with battery charging stations, refrigerators and collective lighting).

Several lessons were drawn from this ambitious programme:
- Photovoltaic is an appropriate technology for wide dissemination over the Sahel;
- It turns out to be a relevant drinking water supply solution provided that the alignment of the size of the village and the dimensioning of the solar pump is optimized;
- The use of solar pumps for market gardening calls for an appropriate intervention method for the market gardeners, namely, sole proprietors or private producer groups;
- The use of photovoltaic for community uses is relevant provided permanent payment mechanisms for service are set up, which turns out to be difficult;
- The choice of quality technical components and service has to be paid for; the breakdown rates are low, and the service is of good quality;
- The involvement of the rural communities in the choice of pump configurations is crucial for system ownership and payment for the water.

PRS is the regionwide programme that really launched solar photovoltaic in Sahelian Africa. Today, thousands of solar pumps are installed to provide drinking water, irrigate crops and livestock watering.

Source: Fondation Énergies pour le Monde.

At the same time, the first mini-grids powered by solar generators came about, primarily in Asia, thanks to French, European or UN (UNDP) funding, through partnerships with the General Directorates for Energy or the national utilities. These types of solar plant were not reproduced on a large scale because they sometime competed with grid extensions and were prohibitively expensive (€ 30 per installed Wp).

Other initiatives, with greater private sector commitment, emerged during the 1990s

These projects prefigure the two main methods for organizing access to electricity by renewable energy, mainly solar, that we find today – direct sales of solar kits and granting of territorial concessions. So, in Kenya, small, very inexpensive family solar systems are sold by local resellers to support the introduction of a national television broadcasting programme to serve the rural areas with the support of the World Bank and through the launch of amorphous silicon modules on the market, with lower yield and cost than the dominant crystalline silicon modules.

In Mali and South Africa, EDF and NUON (a Dutch utility company that has since merged with VATTENFALL) are launching vast regional electrification programmes as part of concessions negotiated with the States. They install then operate several tens of thousands of individual solar systems in exchange for the payment of a fee collected from the customers.

Kankoy solar power plant (Pakistan) - 70 kWp

To sum up, these projects pinpoint the strengths and the limitations of electrification by standalone solar energy powered systems

We are familiar with the problems identified at the end of these large-scale programmes and diverse applications, most of which are still current.

The equipment aspect:

- **modules have demonstrated excellent reliability, since the first manufacturing batches**[1]. Most of them are still in service today;
- **electronic equipment of the technical chain show signs of weakness** (regulators, inverters, receivers) because of their short manufacturing runs, inappropriateness for the usage conditions out on the ground (significant environmental constraints, inexperienced users) and poor after-sales service;
- **batteries are the systems' Achille's heel** – with their short lifecycle (2-10 years), they call for special attention and their conditions of use must be strict adhered to. Any excessive use is lethal to them.

The organizational aspect:

- **small projects suffer viability issues** – the cost of setting up the mechanisms required to sustain the service, call for a minimum project size;
- **it is crucial that the users adopt the devices and use them if the service is to last in time** – understanding of the available energy, in finite quantity, calls for awareness building, or even appropriate training;
- **the project manager's role is pivotal**. Acceptance of the innovative nature of the device by the local stakeholders, accurate estimating of electricity consumption and in fine payment for the electricity service depend on it. In practice, the quality of the project developer (be it as delegated project management or project management) makes or breaks the project;
- **it is essential to set up a maintenance service, backed by a procurement chain**, whose recurrent cost must be covered by the sale of electricity, notwithstanding how difficult that may be;
- **a payment mechanism for the electricity service must be worked out, gain acceptance and be implemented** even if the free nature of using the sources has been highlighted. "The sun doesn't send bills" is chanted far too often.

1. BPX 47, France Photon, primarily in the Sahel.

This assessment has prompted the stakeholders to improve equipment reliability and maintenance

Some project owners* have attempted to set up institutional structures specialized in equipment maintenance, such as the technical unit of the National Directorate of Hydraulics and Energy of Mali to service the solar pump base.

Manufacturers have improved equipment reliability, notably the pumps, which have benefitted from the progress made in electronics, by using immersed motors[1]. As regards regulation and energy conversion equipment, the use of semi-conductors or microprocessors in particular have enhanced system reliability.

However, the encounter between sophisticated equipment and users with no special knowledge of the matter, who are often illiterate, has led to many technical shortcomings, as the notion of daily available energy is hard to grasp.

Capitalization of these experiences has also contributed to the emergence of access to electricity as a development aid priority

In the wake of this feedback and the awareness it raised, the first political initiatives were instigated to electrify the developing countries, in particular the one organized by the G8 for the Heads of States Summit in Genoa in July 2001, followed by the Summit on Sustainable Development in Johannesburg, where access to energy was finally considered as an essential component for attaining the millennium development goals then identified as the priority of the main international financial backers (cf. chapter 1.1.1).

1. Solutions developed by the Danish manufacturer GRUNDFOS and TOTAL ENERGIE.

The four key stages of the history of DRE

Before 1985

- First experiments with collective electrification financed by international cooperation
- Professional applications developed by the manufacturers.

1985-2001

- Standalone photovoltaic solutions developed and the first solar-powered mini-grids
- Change of scale with the launch of national rural electrification programmes
- First rural electrification agencies set up

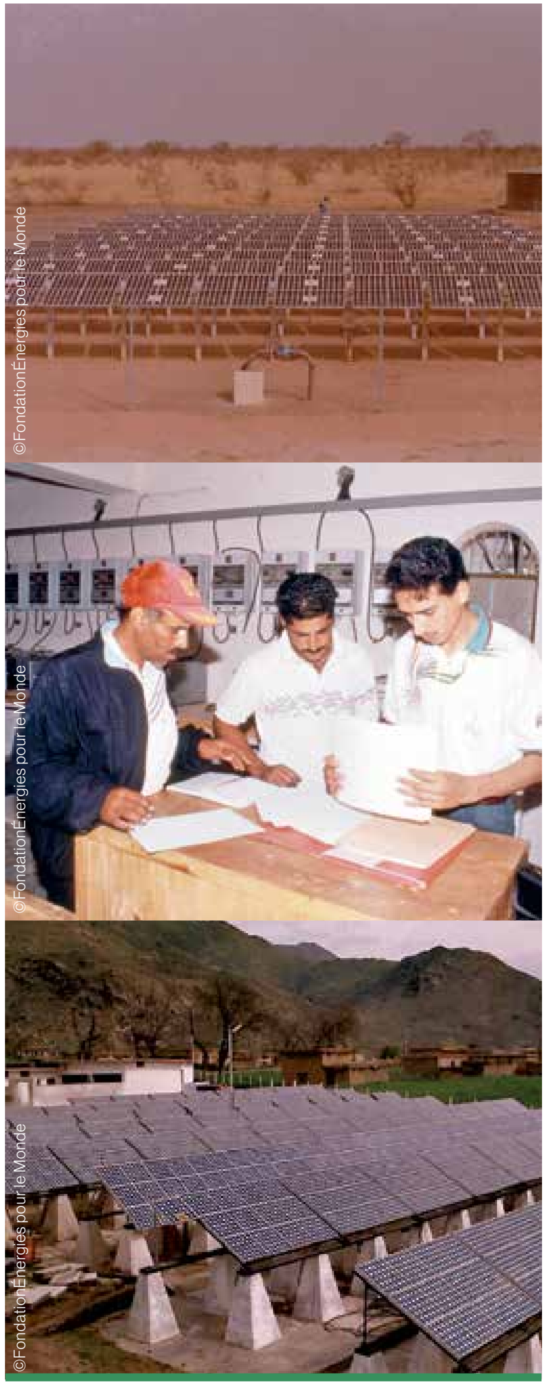
2001-2010

Stronger involvement by the private sector as operators.

2001-2010

- The "3D" revolution – Digitalization, Decarbonation, Decentralization
- Mass spread of individual photovoltaic systems
- Fast development of Pay-As-You-Go solutions

Source: Fondation Énergies pour le Monde.



Some examples of pioneering DRE projects: PPER in Morocco and Pakistan

Pilot Rural Electrification Programme in Morocco

At the end of 1987, France and Morocco agreed to set up a PPRA to contribute to meeting the demand for electricity in the rural areas of the Cherifian realm. The programme was built on three pillars on the strength of previous projects in Morocco and beyond its borders:

- The demand of future users and budgetary constraints was covered;
- Suitable technological solutions free of any technological preconditions;
- Concern about the institutional and organizational aspects that would lead to the involvement of the four main stakeholders... the General Directorate of Local Communities, the Moroccan Ministry of Energy, the French Ministry of Foreign Affairs assisted by the Agence Française de Développement and the French Environment & Energy Management Agency.

The first implementation stage (which ran from 1993–1994 covering 30 villages) was a real proving ground with its teachings in the economic, sociological, organisational and technical areas.

Technical teachings: The flexibility of the energy systems meant that they could be adapted to satisfy the growing energy demand of the users. While the solar system control systems operated well, the limited battery lifecycle, less than 4 years, called for replacements that were difficult to implement because of the users' remoteness.

Economic teachings: The use of electrical systems offering much better service quality, reduced household energy budgets by 10-30% depending on the uses and systems.

Organisational teachings: The user associations played a major role in rolling out the programme, which led to the availability of a single spokesperson in each village and facilitated component replacement. They also acted as local development vectors.

But the programme's main shortcoming was the absence of a long-term contractual operator to act as go-between between the suppliers and users, and to provide lasting collection of dues. Only 8 of the 18 users associations finally broke even, 5 years after they were set up.

Sociological teachings: Although the programme aimed at a collective dynamic, with battery charging stations where users could deliver their batteries, transporting them was so difficult that they were quickly dissuaded. The charging stations were dismantled to create as many solar kits as modules.

Thus, the PPRA contributed to drawing up the outlines of the country's Global Electrification Programme (PERG), which enabled 35 000 villages or roughly 1.9 million homes to be electrified by extending the grid and supplementing that with photovoltaic decentralized electrification.

Source : Fondation Énergies pour le Monde

2.3. Rural electrification which is undergoing major changes still lacks sufficient funding to match the challenges

New technical solutions made possible by a convergence of innovations or favourable technical progress enable a change of scale to be envisaged They give rise to new visions of access to rather commercial off-grid electricity that often run counter to those of its pioneers.

Admittedly, awareness of a climate emergency has given rise to the broader mobilization of players and funds in the area of available financial resources. Nonetheless, it has to be said that the latter still do not cover all the needs. The situation is that foreign capital is still required to make up for the governments' inability to finance basic services through tax revenues.

The energy sector is undergoing a period of profound change marked by what some people describe as the energy sector's "3D" revolution of decarbonation, decentralization and digitization

Some talk of the "3D" revolution – decarbonation started following the Kyoto protocol and gathered momentum with the Paris Agreement, decentralization driven by the drop in renewable energies price and digitalisation, which is expanding with the spread of "smart" meters and the advent of consumers/producers. This movement, which is widely up and running in the OECD countries, now affects the developing countries, and African countries in particular.

Source: Christian de Gromard and Stéphane His, "Evolutions, revolutions and inertia in the energy sector. What are the consequences for Africa?", *Afrique Contemporaine* 1-2, n° 261-262 (2017).

2.3.1. Many changes have widened the scope of possibilities for decentralized rural electrification in the last decade

DRE was the prerogative of the industrial pioneers and a few NGOs for a long time in the developing countries under the initiatives that received financial backing from the international community (cf. chapter 2.2.2.).

But in the last decade, a combination of phenomena has contributed to renewed interest in the actors of the electricity sector in Africa. This includes the major international financial backers, disappointed by the results of aid provided to national utilities to develop access to electricity by grid extensions.
Three convergent, interdependent and simultaneous rifts have inspired new momentum for rural electrification in the developing countries, opening up a promising path for changing the scale:

- **global awareness of the urgency of combatting climate change,** that advocates renewable energies and energy consumption management policies;
- **the technical paradigm shift** based on 4 pillars:
  - the digital revolution,
  - the reduced cost of PV equipment,
  - the spread of low-consumption receivers,
  - the progress made in the area of storage.

These two phenomena have given rise to a third by creating new business opportunities:

- **the distribution revolution**, through the advent of many private players with energy service offers featuring original sales plans in a market which is particularly promising to them as it is loosely regulated.

Thus, the whole access to electricity value chain has changed: production and storage, distribution and steering, use... The following developments present a summary of the various dimensions of this sea-change that is transcending the area, and that continues. Hence it is impossible to report on all the effects at the time of writing.

The urgency of combatting climate change is hastening the implementation of decarbonation policies

The environmental alert launched in the 1960s and 1970s, was heard by the access to electricity pioneers, who developed decentralized solutions based on renewable energies. Now their circle has expanded. Although successive by the Intergovernmental Panel on Climate Change (IPCC) reports demonstrate the overall inability of the economic actors and public authorities to take measures that are commensurate with the challenges, there is no doubt that the energy revolution is underway, because of a threat that is becoming visible (cf. graph).

Decentralized rural electrification and energy efficiency are linked

Energy efficiency which was spawned by the first oil crisis, was long deemed to be incompatible with growth, but now it is customary in industrialized countries. Strictly speaking, energy efficiency is the ratio between the quantity of energy recovered and the energy used (the value ranges from 0 to 100%). But the term's scope of meaning has extended to become a fundamental principle of energy transition. Energy efficiency aims to reduce the (direct and indirect) environmental, economic and social costs incurred by energy production, transport and consumption (cf. inset).

Ramping up decarbonation policy implementation encourages the development of DRE, which cannot elude energy efficiency measures, that are crucial for environmental performance and the service quality of the installed system. The rational use of electricity is a key pillar of the awareness campaigns that support the rollout of a DRE

"Made in Africa" innovations to develop access to electricity for all

Many African initiatives are emerging in an attempt to rise to the challenge of developing access to electricity to everyone on the continent:

BLACK STAR ENERGY, a Ghanaian off-grid electricity generating solutions company, already runs fifteen or more mini-grids. Incidentally its solution was rewarded by the EDF Pulse Africa 2018 Prize. The start-up JACIGREEN, founded by the Nigerian Mariama Mamane, has developed a double benefit solution, that cleans up the River Niger, while producing fertilizer and electricity. Water hyacinths which are harmful to biodiversity, are used to produce biogas, that can be converted into electricity.

Additionally, and to encourage this momentum, entrepreneurship and innovation advice centres specializing in energy are also flourishing on the continent.

The ENERGY GENERATION association, created by the Franco-Congolese Astria Fataki, based in Lomé has been advising project holders since 2016, to support them as they develop innovative, affordable and widely generalizable solutions. "Classes" of student entrepreneurs from the Cameroon, Madagascar, Ethiopia and other African countries have hatched solutions such as *HydroPower*, a generator set that runs on hydrogen or *Hand Crank Power*, a hand-cranked generator that recharges without electricity.

Sources :
Rémy Nsabimana, "Jacigreen : la dépollueuse du fleuve Niger", *BBC News Afrique* (en ligne), 2017.
"4 innovative projects rewarded by the 2018 EDF Pulse Africa Prize", *Le Monde de l'Énergie*, 2018, *https://www.lemondedelenergie.com/innovations-prix-edf-pulse-africa-2018/2018/12/27/.*
"Energy Generation", *https://www.energy-generation.org/.*

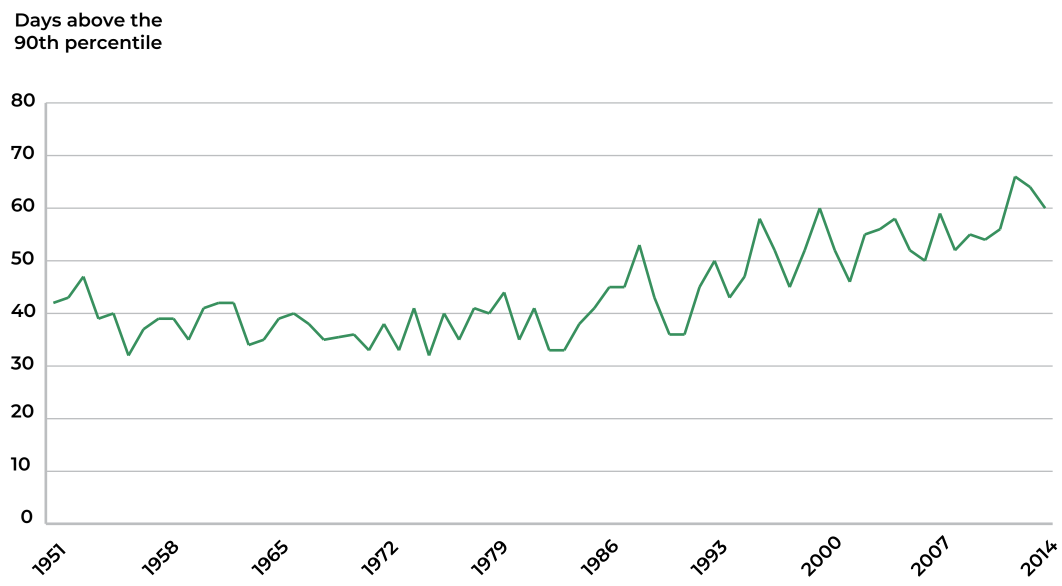
17 of the hottest ever 18 years on record were in the 21st century

2016 was the hottest year ever observed since the first readings were taken in 1880. The land surface temperature was 1.43˚C higher than the mean for the 20th century, while the surface temperature of the oceans was 0.75˚C higher.

Runners up in a dead heat were 2015 and 2017 (14.8˚C on average). While the fourth hottest year was 2018 with a mean global temperature of 14.7˚C.

Source: NOAA, "Annual checkup for the planet" (Washington, D.C, 2017).

Number of days of extreme heat globally



Source: NOAA, "State of the Climate Report" (Washington, D.C, 2018).

Energy efficiency

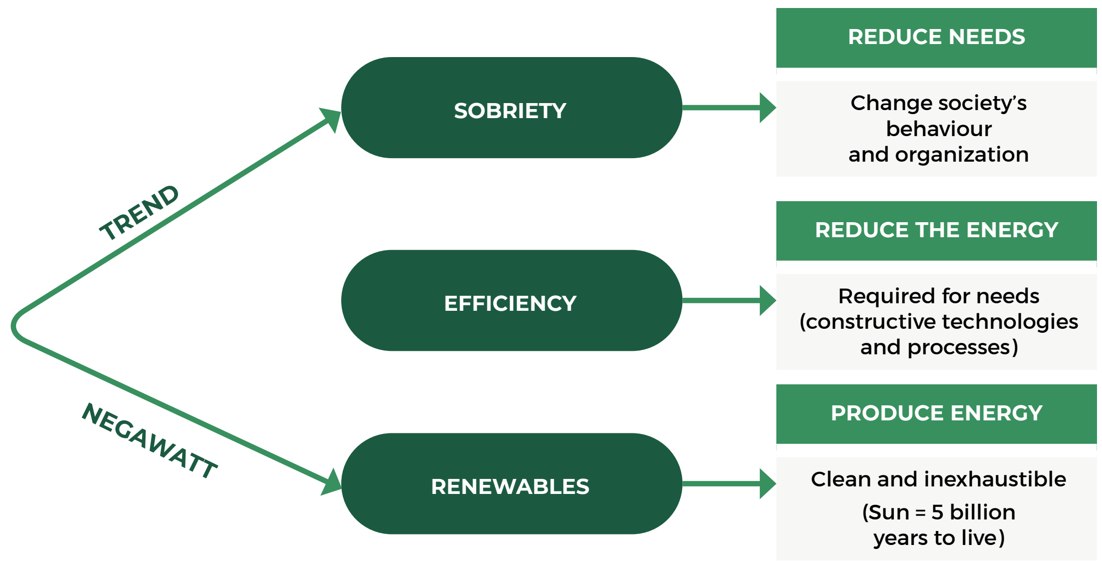
Applying several principles in combination will achieve energy efficiency:

- optimizing consumption (seeking lower energy intensity for equal service),
- rational use of energy (through more efficient processes and tools),
- seeking energy savings (reducing wastage and pointless consumption).

There are many expected benefits:

- smaller environmental footprint (by reducing the energy footprint and sometimes the carbon footprint).
- increasing energy security, by adapting to climate change and combatting GHG emissions.

Controlling the demand for energy



Source: "négaWatt Association. négaWatt's approach". *https://negawatt.org/La-demarche-negaWatt.*

project (cf. chapter 2.4.2.).

Furthermore, renewable energies and energy efficiency are "economically" tied. Although PV prices have been slashed, the Wh produced by small PV power plants is expensive and daily production is limited. The less energy used by the receivers, the higher the number of users can be. For these reasons, PV development has always been accompanied by the search for "low-consumption" solutions for electricity uses (firstly fluorescent tubes then LED bulbs and direct current appliances).

Some analysts, like Jeremy Rifkin, go even further, by suggesting that the generalization of decentralized solutions is the only chance left to achieve the environmental transition we need[1].

Does that lead to the availability of more funding for access to electricity projects?

The goals to fight climate change were set by the Paris Agreement adopted by the 195 delegations in December 2015. Combined with injunctions to open up Africa and its agricultural development, they renewed the interest displayed by the international financial backers on the question of the rural electrification of Sub-Saharan Africa and generalizing the use of renewable energies.

Until 2015, the bulk of access to electricity funding was directed at extending electricity distribution grids. Since then, the share of funding going to renewable DRE projects (in progress or being set up) has increased (cf. chapter 2.3.2), despite the operational constraints that remain partly unchanged (cf. chapter 2.4.1 *et sq.*).

Financial backers follow many strategies, ranging from subsidies, concessional or private loans, to risk transfer (cf. chapter 2.3.2).

Rural electrification through solar energy can be ramped up thanks to the technical paradigm shift Several technological advances, both already generalized or still at experimental stage, are coming together to revolutionize the design of renewable decentralized electrification solutions:

- the digital revolution,
- the falling cost of photovoltaic equipment,
- the progress made in storing electricity,
- the spread of low-consumption receivers.

This combination of factors has placed the use of solar energy at the heart of DRE development, whose economic viability it is also strengthening. In the vast majority of sites, photovoltaic is becoming the cheapest access to electricity solution if we consider the global cost updated over 20 years. Some experts predict that it will be very broadly generalized over the next few decades. According to the IAE, total installed solar capacity will stand at 16% in 2030 compared to 2% in 2016[2] (all types of solution, centralized and decentralized, taken together).

The digital revolution simplifies consumption monitoring and payment for electricity

More convenient and appropriate methods for paying for electricity have been set up in Africa's rural context, regardless of the production scheme thanks to the rapid provision of mobile telephony (cf. chapter 1.3.2.) combined with transaction applications (*Mobile Money*). Prepayment or *pay-as-you-go* (PAYG) for electricity has become possible, even for small amounts of money, inspired by the prepaid card system that is

1. Jeremy Rifkin calls for a third industrial revolution primarily founded on decentralized electricity production and energy circulating in a "smart" grid, like information on the Internet. The second pillar of this 3rd industrial revolution entails transforming every building into a smart micro-power plant capable of injecting its surplus output into the grid and taking additional energy from the grid when its standalone system is not producing enough. FOR FURTHER INFORMATION: Jeremy Rifkin, "The third industrial revolution. How lateral power is transforming energy, the economy and the world" (Paris: Les Liens qui Libèrent, 2012).
2. International Energy Agency, "Energy Access Outlook 2017, From Poverty to Prosperity" (Paris, 2017).

The automation limits of DRE

In Guyana, a decentralized rural electrification programme was launched over 10 years ago to supply electricity to 4 villages in Upper Maroni, including the famous village of Antecum Pata. The Community of Communes of West Guyana is the contracting authority, the power plants are to be operated by EDF SEI.

It entailed constructing hybrid (PV and diesel) power plants and mini power grids to supply electricity to the villages independently without financial constraints. EDF SEI is responsible for management from the Cayenne control centre, using a specially developed monitoring system to transfer all the data measured on site as well as the working status of all the plant components (PV field, batteries, load controllers, inverters, generator set, fuel tank, below-ground fuel circuit, etc.) via a satellite link set up on each totally isolated site.

The complexity of management in a completely isolated equatorial forest environment that is very hostile for the equipment (high humidity, animal pests, etc.), led to a sizeable 3-year delay at the end of 2018 for this electrification programme that has long been awaited by the populations and its representative organizations, the communes and NGOs involved in the project.

The isolated nature of all these sites – with no access road, an hour's flight from Maripasoula then 3-5 hours by canoe to reach the villages – the climatic stress inflicted on all the equipment, the decision to manage remotely without any human go-between on the spot, considerably held back the commissioning of these plants and made their operation very complex.

In principle these hybrid plants use long-established know-how. It is the complexity of the remote management system and the automatic connection between the fuel circuit, the generator set and the PV plant that undermines plant management, made "blindly", at the expense of the service rendered to the populations.

Yet in territories of this kind, that have been broadly developed in Africa for decades, **it is essential to work with simple (and thus robust) systems that deliver the service expected of them and above all rely on the local populations for resources and skills that are much more efficient for managing plants on a daily basis**. This does not entail standing in for the operators but guiding them, helping them with on-site communicating attendance for more reliable systems and working in good faith with the consumer inhabitants.

extensively used for purchasing telephone credit on the African continent.

The economy in the rural environment is day-to-day, or seasonal for farmers who usually sell their produce at the end of the harvests. Apart from civil servants who receive a fixed salary at the end of the month, future income may be hard to determine, so there is only certainty about what is currently available.
Also, monthly billing based on actual consumption is not really suitable. Users who do not have enough available cash are likely to have the service cut off if they default on payment. From the operator's point of view, collecting payments is costly, especially if it includes many recovery operations.

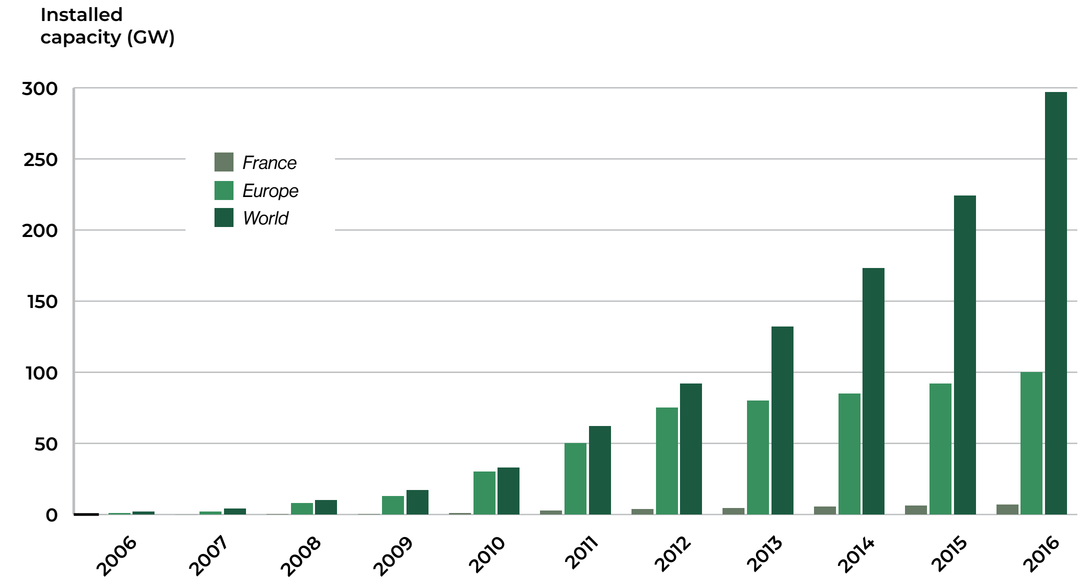
With prepayment, namely purchasing an electricity credit (a volume of kWh, a length of use), individual customers pay their future electricity consumption to the level of their financial capacities. The system ensures that the operator receives payment for the electricity used and reduces recovery expenses (however, the volume of energy used depends on the users' incomes).
This innovation that is applied to individual solar systems (cf. chapter 3.2.2 on PAYG), and also services delivered by energy kiosks (cf. chapter 3.4.1) or by local mini-grids (cf. chapter 3.5), dematerializes much of the sales and management process. Card refill codes can be sent to users by text message and usage can be checked remotely (for overshooting rating or energy thresholds, plugging in unauthorized appliances).
Remote control reduces human resources needs and lightens investment costs. However, these solutions incur additional expenses for the operator, that must not be under-estimated when drawing up a business plan, for example, specific operating costs (subscription, purchasing codes) or expenses arising from the technological fragility of smart meters and computer management (complex in out-of-the-way rural environments).

The drop in the cost of photovoltaic components enables decentralized solar solutions to be broadly democratized

The development of renewable energies, buoyed by the combat against climate change, picked up speed from 2002 onwards through the establishment of incentive policies in Europe, the United States and Japan aiming to enable every individual to become a producer, self-consumer and seller of electricity.
This development has two technical outcomes whose combination brings down solar infrastructure costs and drives up DRE's competitivity via solar energy:
- **the steady reduction in the unit cost of modules,**
- **and the gradual increase in their efficiency.**

The transfer of manufacturing to Asia (mainly China) and the increase in demand have cleared the way for a significant drop in the price of modules, which are the very core of photovoltaic systems (cf. chapter 3.1.2). According to IRENA, the price of PV modules has been slashed by 89% since 2009, while the cost of PV solar energy dropped 73% between 2010 and 2017[1].
The "ex-factory" price of a photovoltaic module* was € 20 per peak watt in 1993, compared to € 0.3/Wp in 2018, i.e. a drop of almost 100% in constant euros, and this trend is set to continue[2]. Thus, the investment budget in a solar infrastructure has melted away since the 1990s for the same required Wp volume.
This drop is coupled with regular improvement in module performance. Photovoltaic conversion efficiency has risen from less than 14% in the 1980s to 20% today, and efficiency tomorrow will no doubt be 30%[3]. Efficiency improvements reduce

Installed photovoltaic capacity trend



Source: RTE.

the collector surface area required to deliver the same amount of energy, which mechanically reduces infrastructure costs (or, enables capacity to be increased for the same budget).

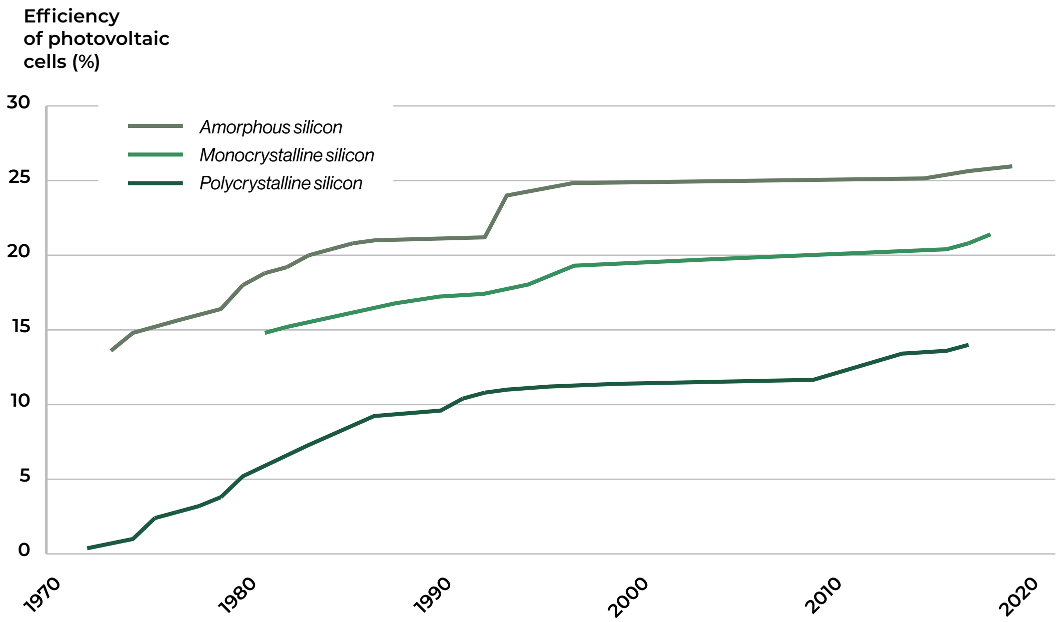
Leaving aside modules, the price of the other solar system elements (components, fastening frames, energy regulators and converters) has been significantly driven down through economies of scale achieved by the increase in the number of installations. **The overall price of a photovoltaic rural electrification infrastructure including production, regulation and storage for capacity of around 30 kWp installed on site has fallen more than threefold since the mid-80s.** It is about € 8 per Wp in 2018, compared to almost € 30 in 1985[4].

However, it needs to be stressed that the cost of a DRE infrastructure is considerably higher than that of an on-grid solar power plant. There is a huge price difference between centralized and decentralized systems per installed Wp:
- 1-2 euros per Wp for PV systems connected to the grid (about 1 MW in capacity);
- 3-5 euros per Wp for decentralized systems (<100 kWp in capacity).

The main reasons for this are the size effect and routing and installation conditions, and the non-use of storage batteries for centralized systems.

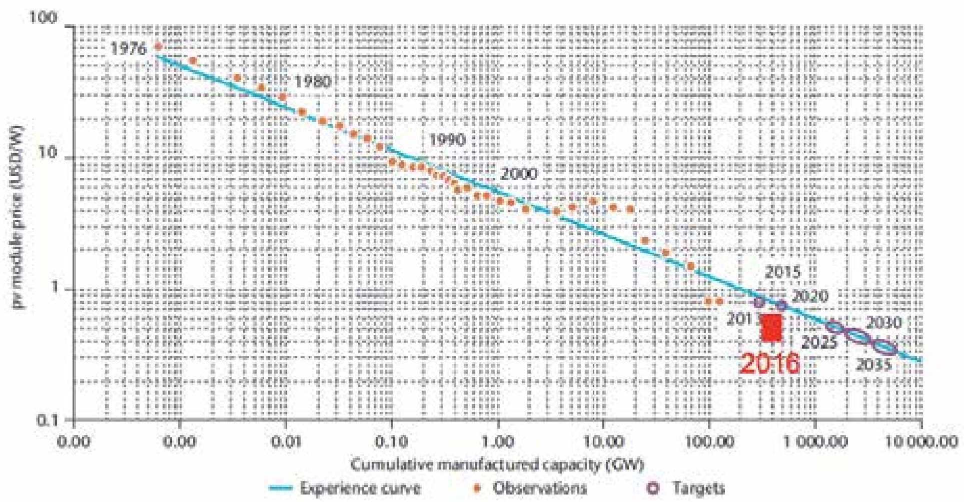
1. International Renewable Energy Agency, "Off grid renewable energy solutions to expand electricity access: An opportunity not to be missed" (Abu Dhabi, 2019).
2. Daniel Lincot, "Où en est la conversion photovoltaïque de l'énergie solaire ?", Photoniques, n° 93 (2018).
3. Source: Institut photovoltaïque d'Île-de-France, https://www.ipvf.fr/.
4. Source: Fondation Énergies pour le Monde.

Trends in photovoltaic cell* efficiency by technology



Source: "NREL, Transforming Energy", *https://www.nrel.gov/.*

Experience curve for photovoltaic module prices



Source: IEA, "Energy Access Outlook 2017, From Poverty to Prosperity" (Paris, 2017).

A storage technology revolution is underway

Electricity storage, which is absolutely necessary when using renewable energies which by their very nature are intermittent and variable, is the weakest part of decentralized systems (cf. chapter 3.1.2.). However, research efforts undertaken to meet the needs of green mobility and decarbonation of the electricity sector are opening up interesting prospects.

Lead storage technology, which equips the vast majority of photovoltaic systems currently in service in rural areas, has several disadvantages, which are galvanizing the decentralized electrification project developers into finding alternative storage solutions.

Firstly, this technology has reached maturity. As lead battery prices are determined by the price of lead rather than industrial earnings, they have dipped slightly while the prices of other

What is the difference between PV systems connected to the grid and standalone decentralized PV systems?

PV systems connected to the grid operate as current generators, they inject the electricity produced as and when the sun shines, without storage. If the grid is stable and present, almost 100% of the solar power can be utilized with simple, robust systems.

These PV power plants connected to the grid, nowadays have unit capacities of several tens of MWp. They benefit from the size effect and very good performance levels that make for optimum OPEX* and CAPEX*.

In Sub-Saharan Africa, >1 MWp on-grid PV power plants are deployed for unit costs of € 1-1.5 per Wp, achieving actualized electricity production costs of 0.5 to 0.1 euro cents over 20-30 years.

The design of standalone decentralized PV systems (cf. chapter 3.1.) is more complex and costly, mainly because of the batteries and associated equipment (chargers, special electrical protections). Furthermore, they yield less because of significant losses in the batteries and irregular recovery of the solar output. As a result, we arrive at:

- installation costs of € 3-5 per Wp,
- a theoretical kWh generating cost over 20 years of € 1 (making allowance for several costly renewals).

At the end of the day, these two photovoltaic energy applications are very dissimilar – the only thing they have in common is the photovoltaic collector field. It is important not to mix up the operating modes with the economic aspects.

Source: Fondation Énergies pour le Monde.

equipment have plummeted. Storage costs take up an increasing amount of project budgets. **Back in 2005, the cost of a standalone PV system battery was about 10% of the total investment, it now amounts to 30-40%.**

Secondly, the limited service life of lead batteries, which is 2-10 years in the particular climate context of rural Africa, leads to frequent equipment replacement. That is an economic constraint that the system designers and users would gladly dispense with (how can this replacement be financed?), and thus is detrimental to installation sustainability. Finally, it raises the problem of end-of-life equipment recycling (cf. chapter 2.4.3.)
Research, started at the end of the 90s, has involved testing around ten alternative stationary electricity storage technologies to lead. New electrolytic couples – for instance, lithium-ion or nickel-metal hydride – can meet the needs of decentralized electrification:

- **Europe's manufacturers have already made the shift.** Most of the product ranges provided by PV system manufacturers (regulators, chargers, bidirectional converters) are compatible with the various types of battery. The energy leaders are testing containerized solutions equipped with new-generation batteries to supply solar hybrid mini-grids (cf. chapter 3.5.1);
- **small decentralized rural electrification systems have already adopted these new technologies.** Primarily we find Lithium-Ion or Nickel-Metal Hydride batteries in most individual PAYG

Storage technologies. The batteries of a solar mini power plant in Madagascar

2008 vs. 2018: technical comparison of two installations

Let us compare the technical architecture of a first standalone photovoltaic system designed and installed in 2008 with one designed and installed in 2018... both must meet the same demand for electricity of about 15 kWh per day.

2008		2018
• 36 x 130-Wp photovoltaic modules • Average yield 12%, i.e. a photovoltaic surface of about 40 m²	**MODULES**	• 15 x 320-Wp photovoltaic modules • Average yield 17%, i.e. a photovoltaic surface of about 28 m2 • Cost 5 times less
• Several PWM regulators in parallel	**REGULATOR**	• A single high-efficiency, more powerful and less expensive MPPT regulator
• A single inverter	**INVERTER**	• A bidirectional smart converter that can accept a hybridization source (grid generator set)
	MONITORING	• A GPRS telemetry device for remote monitoring at a trivial additional cost
• An OPzS type lead battery	**BATTERY BANK**	• Slightly more powerful batteries at a slightly higher cost

Our findings – **the whole technological ecosystem surrounding a standalone photovoltaic electrification device has radically changed except for the storage device.**

Source: Fondation Énergies pour le Monde.

solar systems (cf. chapter 3.2.2) and solar street-lights (cf. chapter 3.3.3);
- **the announced price cuts point to fast development in the biggest systems.**

The energy efficiency revolution is continuing with increasingly powerful and affordable receivers to developing country populations

In the Northern Hemisphere, putting a stop to wastefulness has prompted research and industry to make massive performance gains for most common electrical receivers: lighting, electrical appliances, multimedia and so on. In 10 years, modern electrical lighting has moved on from incandescent bulbs to LEDs, after a transition through fluorescent equipment.

Today, **taken together, domestic electrical appliance consumption is 30% lower than it was 20 years ago**[1]. Consequently, while it took 400 Wh every day to light a home properly in 2005, the same service can be obtained today for 40 Wh, with much more even and sustainable lighting.

The development of these high energy efficiency receivers aids access to electricity for the economically vulnerable developing country populations. The reduction in equipment consumption lightens household energy budgets. These energy efficiency gains can be observed in many other common electrical receivers (televisions, computer equipment, refrigeration production), which also become accessible to rural populations who have decentralized electricity available to them.

This accessibility has a "rebound" effect (cf. inset p146) which may cancel out the saving effect, for as the number of electrical appliances in families proliferates the overall energy bill tends to stabilize.

To conclude, the on-going technological revolution that is vested in photovoltaic technology (at least temporarily relegating other options such as small wind power to the back burner) has fast repercussions in Africa, but leaves a question hanging in the air. **How can we ensure that these repercussions are combined with skills and technology transfer? This transfer is the only guarantor of the continuity of the works and thus of possible impact of electricity's advent to a territory,** and the ultimate end to which every access to electricity project is directed. It is an essential question, to which this book attempts to provide concrete answers, firstly by highlighting best practices for project bearers (cf. chapters 2.4.1-2.4.4), and then by making recommendations for the various sector players (cf. Part 4).

The private sector is proactive and providing new solutions, and taking advantage of the opening of a real market

The upturn enjoyed by photovoltaic, along with the prospect of several tens of billions of euros being committed to promoting access to electricity in Africa (cf. chapter 2.3.2.), has created a market that the private sector relishes. Some players are returning to it after a withdrawal period, while others are making an entrance.

Even though the business models are not yet stabilized, new players are appearing in the emerging industrialized countries, and in Africa (promotors, engineering offices, manufacturers, turnkey contractors, operators, and so on). The programmes funded by cooperation agencies and development banks act as a springboard for their development.

1. Fondation Énergies pour le Monde.

The sourcing risks of some battery components

The possible answers presented in this inset primarily stem from a recent memorandum issued by the French Strategic Metals Committee (COMES)[1]

Global demand for batteries is surging, buoyed by the rapid development of renewable electricity production and above all by electric mobility. Estimates put annual battery sales multiplying by 25 by 2030, and by 40-50 by 2040[2], without including the boom in connected objects and other high tech products.

These forecasts raise questions about the medium-to-long-term sourcing risks of the raw materials that commandeer 50-70% of battery costs. Market growth will have a strong impact on the demand for cobalt and lithium, that are used in the batteries that are gradually replacing lead batteries[3].

Cobalt, which is used by most battery technologies, is identified as the most critical substance given the concentration of mining production in the Democratic Republic of the Congo (RDC), a region which is being increasingly abandoned by Western mining primarily for ethical reasons.

Lithium could be subject to tensions, especially if consumption habits do not become more subdued. In Europe only 5% of lithium batteries are recycled today[4]. Research is underway to substitute it with sodium, which offers lower performance, but is much more available.

Incidentally, **lanthane**, a rare earth used in Nickel Metal Hydride batteries (NiMH), is classed by the French Geological and Mining Research Bureau (BRGM) as having high sourcing risks.

Sources :

1. COMES, "Métaux de la transition énergétique" (2017).
2. Bloomberg New Energy Finance, "New Energy Outlo 2017" (Washington, D.C, 2017).
3. "Epuisement des ressources naturelles", Encyclo-ecolo, *https://www.encyclo-ecolo.com/Epuisement_des_ressources_naturelles#La_disparition_du_plomb.*
4. Clément Fournier, "Les batteries de voitures électriques : notre prochaine catastrophe environnementale ?" e-RSE, 2017, *https://e-rse.net/batteries-voitures-electriques-impact-environnement-27293/.*

The entry of private actors, capable of raising their own funds from private investors, is intensified by a wide variety of value propositions, essentially geared to individual solar systems and primarily tested in the Sub-Saharan territory... an abundance that is helping turn the region into a DRE "proving ground" (cf. Part 3).
While French players, who were initially thick on the ground in the access to electricity sector, left it during the 2000s because of the markets' then small scale, new ones, who may or may not be in the French domestic renewable energies' market are embarking on this sector anew.

To sum up, the technological breakthroughs that the photovoltaic industry has made over the past decade, stimulated by the need for a green energy revolution, has created a tangible market that now has a multiplicity of service offers. Is this boom enough for universal access by the 2030 timeline? Is it backed by suitable, available and sufficient funding? This is obviously a critical issue in an area where tangible and intangible investments are significant and crucial.

ADEME and the French Ministry of Environmental Transition and Solidarity back innovation

In 2017 for example, the Ministry of Environmental Transition and Solidarity and ADEME put out a Call for Projects on "Innovative solutions for access to renewable energy for off-grid populations". Its aim was to underpin the emergence and launching of access to energy projects borne by companies, NGOs and/or French communities in cooperation with local actors.

Nine innovative projects were retained out of the 94 bids submitted. They were rolled out in Africa (Benin, Burkina Faso, Cape Verde, Madagascar, Mauritania, Uganda and Togo) and were rewarded for their innovative technological (energy production, storage, energy usage technologies) and/or organizational nature (funding, payment mechanisms, business models, governance methods, etc.).

Further information on the supported projects is available on: https://www.ademe.fr/solutions-innovantes-lacces-a-lenergie-hors-reseaux

Source: Bubacar Diallo and al., "Solutions innovantes pour l'accès à l'énergie hors réseaux" (Angers: ADEME, 2018), *https://www.ademe.fr/solutions-innovantes-lacces-a-lenergie-hors-reseaux.*

*"Without an educated population that is capable of benefiting from access to energy, the economic efficiency of its use would be very disappointing. The **"rebound effect"** is the phenomenon whereby populations often squander the economic gains that result from an increase in energy efficiency by increasing their energy consumption".*

Gaël Giraud, "Energy Challenges for Sustainable Development: How to Avoid a Collapse?", *Revue d'économie du développement* 23, n° 3 (2015).

2.3.2.
The crux of the matter is that funding is a conundrum for most rural electrification projects

While technological advances remove most of the obstacles to the spread of decentralized solutions, the issue of funding operations is still an uphill struggle. Yet it is crucial for achieving universal access to electricity on the African continent.

The rural electrification risk profile does not tempt investors

Although access to decentralized electrification by renewable energies is the most relevant and cheapest option in a growing number of cases in rural Sub-Saharan Africa (primarily rather than extending the national grid; cf. chapter 2.1.2), the fact remains that it is plagued by the same constraints as conventional electrification:

- **it is highly capital-intensive**, yet it is directed to financially strapped users;
- **its implementation is high-risk** given the national and local contexts while return on investment tends to be long.

Whatever form a DRE solution takes, its capital need is governed by whether or not renewable energies are used.

- renewable decentralized solutions are characterized by high initial investment or CAPEX cost and relatively low running cost or OPEX (no fuel, limited personnel costs);
- in contrast, conventional (thermal) solutions are characterized by limited CAPEX and high, random OPEX (primarily fuel, paid in cash by the operator). This uncertainty undermines viability –users may have difficulty settling their contribution if the fuel price increases faster than their incomes (cf. case study of diesel mini-grids in chapter 3.2.5.).
- the falls in the price of PV components have made decentralized solutions through solar energy economically beneficial in the long term.

Return on investment time (ROI) is closely tied to the products (usage paid for by users). The lower their payment capacities and electrical consumption, the longer and more random payback is (cf. inset), which form the grounds for the generally long concessions awarded to electricity operators (20-30 years).

OPEX/CAPEX

CAPEX or capital expenditure designates the development and supply costs of non-consumable parts for a product, enterprise or system which in the case of an electrical system cover the preliminary studies, system component acquisition, technique support with installation, etc.

OPEX or operational expenditure designates the current expenses for operating a product, enterprise or system, which in the case of an electrical system cover operating personnel expenses, maintenance costs, feedstock (e.g. fuel), spare parts, travel, communication costs and so on.

Mini solar power plant vs generator set (for about one hundred users and annual consumption of about 10 000 kWh)

	Generator set	Solar power plant
Installed capacity	12 kVa	10 kWp
Investment costs (off-grid)	€ 5 000	€ 30 000-60 000
Operating costs, excluding personnel costs and component replacement costs of (inverters, batteries) during the installation's lifetime	€ 5 000 p.a.	€ 600 p.a.
Personnel costs are similar.		

Source: Fondation Énergies pour le Monde.

DRE is highly dependent on international funding, which still falls far short of the mark

Rural electrification, like many basic services, is plagued by the lack of fiscal resources (cf. inset p173), in a context where the states are faced with immense social needs, yet their economies are still largely based on the informal sector*[1].

Key figures

Today, a mini-grid user in Sub-Saharan Africa pays **5-10 euros per month for daily consumption of 500 Wh and a price of 200 FCFA per kWh, i.e. 30 euro cents** (exchange rate on 15 September 2019).

Source: Fondation Énergies pour le Monde, Noria studies

1. In particular see the International Monetary Fund report, "Regional Economic Outlook, Sub-Saharan Africa: Restarting the growth engine" (Washington, D.C, 2017).

The situation of the national utilities, that often make heavy losses, slows down peri-urban electrification and prevents rural electrification from going ahead by national grid extension. Therefore, like many public service infrastructures in developing countries, **access to electricity in the rural environment makes significant use of international funding sources**.

So far, these international fund raisers have made it possible to launch:

- **essentially, grid extension projects** in the most conducive areas (cf. chapter 1.2.1);
- **occasionally, DRE projects** (cf. chapter 2.2.2.), that primarily operate the two main service modes – PAYG and mini-grids.

But this contribution falls far below needs. Only 5 billion USD per annum have been allocated to electrification projects in Sub-Saharan Africa over the current decade according to the IAE. This only covers **10% of needs** (cf. inset), if not less in a context where the Sub-Saharan population is set to double by 2050.

The IAE plans to mobilize 52 billion USD in investments needed to enable access to electricity for all by 2030[1] (cf. chapter 1.1.1). Nonetheless, one could query the absorption capacity of this amount. Today we see that finance is often available via institutional cooperation, but that not all of it is used. Specific and eligible projects that meet the financial backers' conditions have difficulty getting off the ground (too small or too risky).

Yet in any case, financial support for electrifying the rural world is justified in terms of the social and economic benefits of access to electricity (cf. chapter 1.1.1).

Thus, the challenge is to find financing solutions that will make basic electrification possible, at a lower, sustainable cost, and maximize the public and private resources that can be mobilized at all levels for the large-scale development of decentralized access to electricity projects drawing on renewable energy sources.

There are two main approaches to off-grid access to electricity by renewable energies, that result in two funding rationales

Two complementary rationales coexist for implementing projects at the time of writing:

- **a liberal approach:** this recent approach is founded on a commercial exchange between a private actor and a client for the acquisition of goods or an electricity service, against *cash* payment or by instalment (credit and several part-payments).

It is particularly suitable for the development of individual access to electricity for domestic uses (portable lamp, individual solar system; cf. chapter 3.2.), to supplement collective solutions (cf. chapters 3.4 *et seq.*).

- **an interventionist approach*:** this time-honoured approach is founded on the institutional coordination and involvement of civil society to implement a collective electrification solution along project management lines.

Its implementation is complex, and it encourages the coverage of all electricity uses and the most inclusive provision to the local populations (primarily by installing a mini-grid; cf. chapter 3.5). It may also be geared to on a collective use (solar pumping, public lighting, electrification of public facilities... cf. chapter 3.4).

The two approaches are correlated to different financing circuits whose organizational implications are detailed further on (cf. chapter 2.4.1.).

2. International Energy Agency, "Energy Access Outlo 2017, From Poverty to Prosperity" (Paris, 2017).

The issue of fiscal resources and financing public services

Improvement of the mobilisation of fiscal resources is a major development challenge for the states of Sub-Saharan Africa. Tax revenues are actually vital for the states as they provide the resources they need to invest in development, supply public services or reduce poverty.

Although tax revenues are steadily rising, through economic growth and improved capacities to tax, which took the amount up to 19.1% of GDP for the continent in 2017, this average is lower than the world's other regions (Latin America: 23%; OECD: 34%).

Several factors provide the explanation for this difference:

- **African taxpayers' relationship to tax**, is marked by colonial heritage and still negatively perceived, which penalizes the tax administration when recovering their contributions
- **The tax administration shortcomings** (human, technical)
- **The "tax gifts"** awarded to a number of economic operators.

Fiscal reforms, primarily favourable to private sector development, the inclusion of major informal bodies and the strengthening of tax administration capacities, are called for by the sector's players. Some countries have already started to set up new systems. In Ghana, the tax collection system is in the throes of conversion, to include informal sector companies; Rwanda has also set up a proactive policy in this regard.

Sources :

OECD, "Revenue Statistics in Africa 2017" (Paris, 2017).

Salif Yonab, "Collection of Public Revenue in African States: A Worrying State of Affairs", *Revue française d'administration publique* 144, n° 4 (2012).

Foly Ananou, "Et si la fiscalité africaine était déséquilibrée", Le Point (en ligne), 2018, *https://www.lepoint.fr/economie/et-si-la-fiscalite-africaine-etait-desequilibree-27-02-2018-2198250_28.php.*

Sylvain Vidzraku, "Ghana : un nouveau système de collecte des impôts intégrant les sociétés du secteur informel", *La Tribune* (en ligne), 2018, *https://afrique.latribune.fr/afrique-de-l-ouest/ghana/2018-03-11/ghana-un-nouveau-systeme-de-collecte-des-impots-integrant-les-societes-du-secteur-informel-771411.html.*

Sabine Cessou, "Le poids du secteur informel", *Le Monde diplomatique* (en ligne), 2015, *https://www.monde-diplomatique.fr/mav/143/CESSOU/53893.*

Nergis Gülasan and Gail Hurley, "Financer le développement avec des ressources nationales", ID4D, 2015, *https://ideas4development.org/financer-le-developpement-par-une-meilleure-mobilisation-des-ressources-nationales/.*

Two types of solution, symbolic of these two circuits, now dominate the off-grid access to electricity landscape:

- ***Pay-As-You-Go* or PAYG** (liberal approach): distribution of a sustainable capital good by private operators bundled with finance facilities (lease-purchase);
- **the mini-grid** (interventionist approach): distribution of a sustainable service to users by public or private operators working through delegation of a public commercial service or a public-private partnership.

While the development of these dominant models calls for financing in both cases, their fund-raising rationales differ.

After examining the special case of PAYG, the rest of this section deliberately focusses on the interventionist approach, for two reasons:

- **the interventionist approach has the hindsight of fuller feedback** than the liberal approach, which has only recently taken off (cf. chapter 2.2.2.)
- **but above all, it is this approach that is starving from the lack of suitable financing, even though funds are vital if the universal access to electricity goal is to be achieved.**

Where, by definition, the liberal approach aims to develop a commercial activity and either finds customers to pay cash (direct system sales), or investors interested in its profitability (PAYG), the interventionist approach aims to develop a basic service that is unlikely to make a profit. The constraints, particularly social engineering constraints, arising from setting up, then running this service are a burden on the economic model, which calls for subsidies and continuous investments over time.

Although the two approaches deal with different distribution and financing rationales, they are not incompatible and even complement each other in the common drive to achieve the goal of access to electricity for all. They can thus coexist effectively within a single area. Some mini-grid projects, for example, plan to provide portable solar lamps or individual kits to isolated homes when their connection to the grid cannot be countenanced.

In all fairness, mini-grid project developers should seek this complementarity as a matter of routine, as they can directly perform or assist initiatives to equip off-grid populations with individual systems during the implementation phase.

Pay-As-You-Go is financed in the same way as any other commercial service

This method requires finance for its various phases – activity launch, build-up and change of scale. It is based on the business-to-customer distribution of individual electrical equipment by a private operator as part of a lease-purchase arrangement (cf. chapter 3.2.2). It primarily targets relatively well-off peri-urban or rural customers, concentrated within a defined perimeter, who have stable incomes and secure payment means.

As the risks are restricted, PAYG operators have been able to count on investors to:

- pre-finance the equipment and sales teams needed to launch the activity;
- then finance growth and gradually expand their markets.

Thus, the sums injected into PAYG companies increased between 2013 and 2016 (cf. inset). The detail and allocation of these sums are hard to identify as most of the companies use private funding sources.

Nonetheless, the somewhat brief history of the PAYG leaders shows their ability to arouse the interest of a wide array of actors.

Firstly, they successfully garner the whole range of **private finance mechanisms** through the various phases of their development:

- **the creation or pre-launch phase,** which includes research and development in equipment, software and communication facilities suitable for individual solar systems and also the preliminary studies and the construction of the *business plan*, has caught the attention of corporate foundations such as the SHELL FOUNDATION (4 million dollars for M-KOPA, for example[1]).
- **the start-up phase** tends to use social investment funds of companies like SCHNEIDER ELECTRIC (*Electric Energy Access*) or ENGIE (*Rassembleurs d'Energies*), which both have commitments in a number of start-ups[2]. Their medium-/long-term interventions take the form of minority holdings in the capital, debt, and occasionally grants for sums of several hundred thousand dollars.
- **lastly, the last upscaling stage** tends to use independent investment funds capable of supporting all the growth stages, by holdings in the capital and reduced-rate debt. M-KOPA, the global leader managed to use the American *Gray Ghost Ventures* and *Acumen* funds, amongst others. In December 2018, the Japanese group *Sumitomo Corporation*, acquired a minority holding in the capital of the East African start-up[3]. At the start of 2019, its nearest challenger, BBOXX, obtained 31 million dollars in financing from the *Africa Infrastructure Investment Managers*[4] fund manager. It also raised 6 million euros through a crowdfunding initiative (cf. chapter 2.3.2).

Secondly, the PAYG operators have attracted commitments from **development agencies** – the DFID, DEG, USAID and the Asian Development Bank. These agencies have financed technical assistance programmes, their grants running to several million dollars... mainly exercising national bias. Thus, we note the support offered

Investors are enthralled with PAYG

PAYG drew 85% of the investments in off-grid solar between 2012 and 2017, for the sum of 773 million dollars, and of this sum 67% went to only four companies.

Source: World Bank, Off Grid Solar Market Trends Report, 2018

The PAYG commercial off-grid solar sector received more than 210 billion dollars in debt and capital investment in 2016, compared to 20 million in 2013. With a few odd exceptions, the immense majority of these investments were made in East Africa.

Source: Bloomberg New Energy Finance Data Report, 2017

1. Grégoire Jacquiot, "L'émergence du picosolaire dans les initiatives d'électrification rurale" (Paris: French development agency, 2015).
2. Promotion et Participation pour la Coopération économique, "Financing start-ups to build tomorrow's African economies", *Revue Secteur Privé & Développement*, n° 29 (2018).
3. Chamberline M o, "La firme kenyane MKopa lève des fonds auprès du japonais Sumitomo Corporation", *Agence Ecofin*, 2019, *https://www.agenceecofin.com/solaire/0801-63041-la-firme-kenyane-m-kopa-leve-des-fonds-aupres-du-japonais-sumitomo-corporation.*
4. "BBOXX lands USD 31 million deal with AIIM", BBOXX, 2019, *https://www.bboxx.co.uk/bboxx-lands-usd-31-million-deal-africa-infrastructure-investment-managers/.*

by the DEG to MOBISOL, a German company, that of USAID to PEG GHANA, created by two Americans and the DFID grants to M-KOPA, one of whose founders is British[1].

The momentum of PAYG bears out the appeal of this model. After being mainly rolled out in East Africa, it has recently started to spread to West Africa, through African and French start-ups as well as large-scale initiatives led by ORANGE[2], ENGIE[3] and EDF[4].

That said, it is still too early to confirm PAYG's long-term profitability. Upscaling is fraught with challenges (cf. chapter 3.2.2.). Some investors even suspect that there is a gulf between the enthusiasm aroused by the model and the companies' real capacity for profitability (cf. inset). In May 2019, one of the PAYG pioneers, MOBISOL, exposed its difficulties and announced its compulsory liquidation[5].

In the interventionist approach, project financing depends on a complex mechanism that is struggling to mature

The interventionist approach is more complicated than the liberal approach because it includes the extensive element of social engineering and is likely to meet the full array of social, domestic and economic uses in a dynamic process that aims to be a public electricity service. This effectiveness has its contra – the schemes require many grants and aid.

The distribution of CAPEX is marked by the sizeable burden of research, assistance and capacity-building expenses

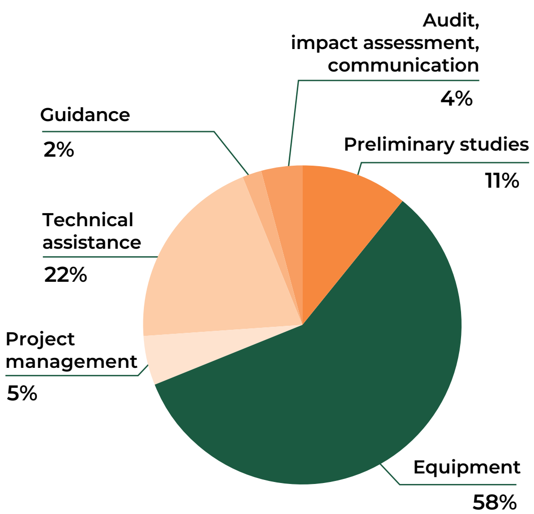
Let us take the example of renewable mini-grids. There is naturally much more information available on financing this electrification model – whose track record is longer and whose implementation is based on projects whose results are usually made public – than there is for PAYG.

Whatever the operating mechanism (delegated public service management, public-private partnership), project owners try to secure funds to cover the investment and make up for the lack of local funding.

The funding requirements for carrying out the various mini-grid project phases (cf. diagram) increase in line with the expansion of the programme's scale – which is desirable, particularly to regional scope, to create a scale effect and promote a territorial development process (cf. out recommendations on this issue in part 4 of the book).

By way of illustration, **the investment is about 150 million euros for a regional electrification programme of a hundred or so rural localities with 3000-5000 inhabitants each**, and breaks down as follows :

More than half the investment is channelled into equipment



Source: Fondation Énergies pour le Monde.

PAYG: Growing over-exuberance?

In our opinion, this may be too much, too fast for a sector that still has not fully solved core business model issues and may struggle under the high growth expectations and misaligned incentives of many venture capitalists. Would we like to see a healthy amount of thoughtful, well-aligned capital deployed in the sector? Absolutely. Do we think that there are select enterprises intensely focused on profitability and capital efficiency that are deserving of this capital? Certainly. But, in general, we fear that we are headed up a broader Hype Cycle and we do not like the trajectory of that ride.

Source: Diane Isenberg, Greg Neichin and Mary Roach, "An Impact Investor Urges Caution on the 'Energy Access Hype Cycle", Next Billion Blog, 2017, *https://nextbillion.net/an-impact-investor-urges-caution-on-the-energy-access-hype-cycle/.*

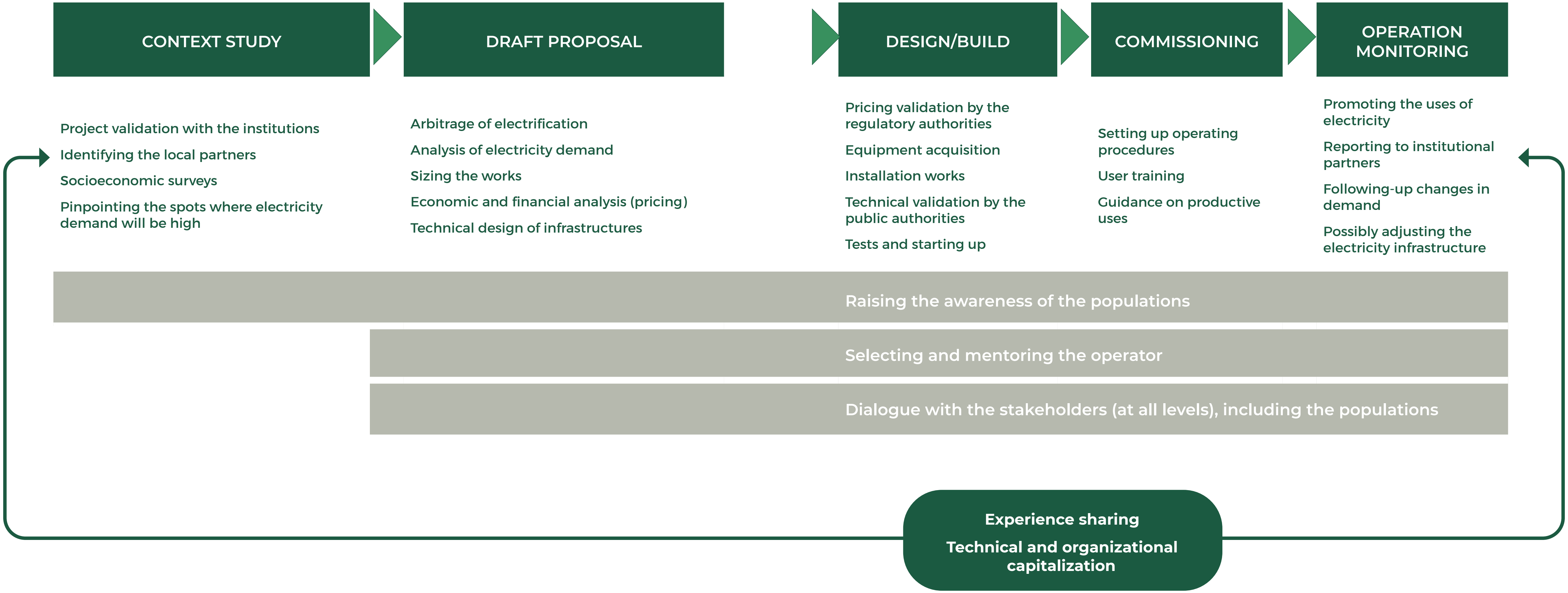
Hype Cycle: a graphical representation of the life cycle stages or maturity curve of emerging, global or sector technologies, that can identify their precocity, potential and any business and operating problems to assess the opportunities associated with their possible use. Each hype cycle drills down into five key phases:

1. Technology launch (prototypes, tests);
2. Hype (over-exuberance by the media and financiers, creation of many start-ups for development and sales);
3. Anti-hype (bubble bursts, sometimes combined with a market crash);
4. Creation of second-generation products with gradual, steady market development (founded on a realistic assessment of the extent and value of the technology's specific applications);
5. Plateau of productivity (proven technology enables third-generation products to be developed).

Source: Fondation Énergies pour le Monde.

1. Grégoire Jacquiot, "L'émergence du picosolaire dans les initiatives d'électrification rurale" (Paris: French development agency, 2015).
2. Since 2017 in Senegal, Mali, Burkina Faso and Cameroon.
3. After buying out FENIX. In September 2019, French energy company ENGIE has announced that it will acquire the company for an undisclosed fee.
4. From 2016 in Côte d'Ivoire then in Ghana.
5. Before the takeover of Engie (September 2019).

The phases of a DRE project



Source: Fondation Énergies pour le Monde.

The tangible production facilities (hardware) account for just over 50% of the budget, which means that **almost half the costs stem from the analysis, assistance and capacity-building activities[1].**

This assertion is only true for mini-grids. These intellectual services (*software*) that are essential for the success of an interventionist approach programme, must never be underestimated whatever the scale:

- **preliminary studies** are required to produce the Preliminary Design followed by the Detailed Design, which will dimension the mini-grid.

They are expensive because it is difficult to access the rural study terrain: the journeys are long and sometimes hazardous, information sources are few on the ground and not very reliable, they must be reconciled and there are many stakeholders.

- **technical assistance for project management** is essential given the innovative nature of the sector and diversity of the ecosystem of the stakeholders it must bring together (cf. chapter 2.4.1)
- **the presence of a project manager** is needed because of the technical aspects of the electrical infrastructures
- **the support measures**, primarily awareness-building and training initiatives directed at the users and operator, are essential given the target audience and the importance of the operation quality of the installed infrastructures (cf. chapters 2.4.2 and 3.5.3)

When the cost of these various operations is borne by the project promotors without subsidies, it is reflected in the pricing, which restricts access to electricity capacities and undermines the project's relevance.

1. Note that a regional programme comprising many mini-grids requires more project management than more localized projects.

This is an essential point for improving the financing mechanisms whose coverage expenses other than those of equipment fall far short of the mark (cf. the recommendations made to financial backers in part 4).

A hybrid financing rationale should be encouraged to take on the hybrid nature of the projects

At the end of the day, DRE, in the interventionist approach, is neither purely commercial nor purely social. It seeks economic equilibrium and this quest complicates the financial arrangements.

Funding sources and mechanisms keep up with rural electrification scale changes, from implementation technique changes to and risk assessment. A broad array of very different players (individual donors, NGOs, communities, philanthropists, international financial backers) enabled the first DRE initiatives to be completed, through grants and/or specialist term loans.

The most relevant funding pattern involves a combination of loans and subsidies. This mix minimizes the investment cost for the promotor and adjusts the price paid by the user. The players primarily use concessional loans that are adapted to projects with high social and economic externalities, such as DRE projects:

- the loans are concessional because they are extended on very generous terms for the lender;
- they may be sovereign (awarded to a state or its emanations) or non-sovereign (cf. more detailed presentation below).

The fact remains that DRE raises internal organization issues for financing bodies and states:

- **they are unfamiliar with its hybrid nature – a cross between rural development and electrification** and it is ill-suited to the usual division of responsibilities and exchange of information between these organizations' departments;
- **every project is tailor-made** and requires masses of field data to be gathered, that is not always forthcoming;
- **every project takes considerable time** to cover the study and preparation costs that are proportionally higher than they are for urban and industrial electrification;
- **the financial aspects are relatively complex**, even for small projects, primarily because much of the investment is written off over the long term, which increases the risks and makes them harder to gauge (while private operators keep certain useful observations to themselves).

Despite these difficulties, several project-specific general-purpose financing tools are now being used by the private or public players to support a DRE programme in interventionist rationale.

Funding accessible to public-sector actors

Grants and subsidies have met many demands from the field, primarily from NGOs, local associations, communities and states to meet the financing requirements for social uses. The outcome is mixed:

- these mechanisms enabled DRE pioneers to experiment with the first installations to use renewable energies, justify their relevance and improve them;
- combined with follow-up actions, they meet specific social needs of rural populations: improved health through appropriate vaccine storage, water supply through solar pumping, etc.;
- experience shows that these aids that take up the whole of certain investments are sources of vulnerability. If the collectivity miscalculates the long-term maintenance costs, the system is often abandoned when the first breakdown occurs or when the most fragile component is replaced;
- even if they are part of the solution, these mechanisms, alone, are powerless to deal with the urgency and scale of the demand.

The mobilization of additional funding has thus been needed to increase the states' or public authorities' intervention capacities and to conduct large-scale programmes without having to sacrifice the public interest goal.

Concessional sovereign loans benefit the states and their emanations (ministries, national utilities), which are in a position to mobilize funds from multilateral (World Bank, African Development Bank, for example) or bilateral (AFD, KFW, etc.) development banks:

- concessional loans that propose low, if not very low interest rates, generally have long maturity terms in excess of 20 years, and come with grace periods (completely free);
- the difference in the lending terms between a concessional loan and a commercial loan is thus called the "grant element".

The lender must meet two conditions to be awarded this type of loan, relating to the inherent risks of developing countries (cf. below):

- it must have experience of this type of financial tool and be able to control its management,
- it must obtain a state guarantee, deemed to be sovereign ("a state cannot default").

In practice, only electricity companies are eligible for sovereign guarantees in the developing countries' electricity sector through the Ministry of Finances. The rural electrification agencies are not considered to offer the same reliability and solvency profiles as the national utilities as they are outside the conventional electricity sector, inadequately structured and inexperienced in financial management.

Aid on demand and aid with the bid

The subsidy mechanism, which has long been sought to meet the needs expressed out on the ground, are now part of a new, and questionable dynamic. **Many industrialized countries use this financial tool to support their national industrialists' bids.**
The equipment is delivered pro bono to demonstrate its quality, often without checking that the conditions required to adopt them are ripe. Therefore, while this funding method a priori appears right for the financial situation of the beneficiary countries, it actually has serious limitations:
- Local stakeholder responsibilization, and in particular by the main contractor and end users, is restricted because they did not have a financial stake in acquiring the equipment;
- The payment mechanism for the electricity service is viewed as incoherent (as the equipment is free), which points up great difficulties when components need to be replaced, starting with the battery after 2-10 years in use, or if a piece of equipment breaks down.

Source: Fondation Énergies pour le Monde.

We must bear in mind that the rules on country indebtedness may block the introduction of these sovereign loan mechanisms.

It is important to emphasize **two things regarding the lender:**
- the OECD member countries meet so-called consensus conditions, when granting concessional loans to justify the very generous rates they award (cf. inset). This does not apply to non-member countries of the OECD, who have become development aid's central players, as they are free to set their own loan conditions (China and India);
- national bias characterizes concessional sovereign loans. By way of example, the concessional loans granted by the French Treasury involve buying goods and services worth at least 70% of the total loan amount in France.

OECD consensus conditions – the exception of public interest

A number of OECD countries have embarked on discussions since 1976 to coordinate their national export credit policies. To follow up on this "Consensus", the Arrangement on officially supported export credits was prepared, before it came into force in April 1978.

As a *gentleman's agreement*, this non-binding agreement aims to provide a framework for public intervention and ensure transparency to maintain uniform financial discipline and fair competition conditions. Thus, competition between exporters should be founded on the quality and price of the goods and services exported, rather than on the most generous financial terms that the members can offer. The agreement sets the export credit conditions and methods (interest rates, loan period, risk premiums). Ten participants are linked by this agreement, Australia, Canada, the European Union (and its Member States), Japan, South Korea, New Zealand, Norway, Switzerland, Turkey and the United States.

Although this is not an OECD act, this voluntary arrangement is still in force today.

Source: OCDE, "The Arrangement on Officially Supported Export Credits" (Paris, 2018).

The public funds accessible to the private sector

Different types of financial actors are likely to support DRE projects applying interventionist rationale borne by private-sector players. These projects that are often too unattractive or risk-laden for traditional financial markets, are primarily supported by public-sector financial backers.

The public development agencies that have traditionally supported the states (loans, grants) and NGOs (grants), have diversified their partnerships. They have devised new innovative schemes to support a new type of player on the basis of a two-fold observation:
- in developing countries, the states have exposed their limitations as regards public infrastructure project formulation, setting up, operating and management and particularly in the area of rural electrification.
- the private sector has filled the gap left by the exiting public-sector financial backers in the 80s, with some success (as for example Bouygues in the Côte d'Ivoire) through the skills of its teams and its flexibility.

The development banks, especially the World Bank, have thus broadened their eligibility criteria for loans and grants to players capable of introducing leverage on public funds. Thus, they accept to finance private operators:
- if the private operator undertakes to **increase and operate the installed infrastructures;**
- through traditional financial instruments – **concessional non-sovereign loans and also, increasingly, through grants** (cf. inset).

This recent development, which paves the way for imagining new public infrastructure financing methods in general, is beneficial to DRE by renewable energies (primarily solar, hydraulic or hybrid). With this additional support, private operators are in a better position to devise balanced financial arrangements that enable them to:

- **deliver electricity services** that are suited to the rural environment;
- **and boost the economic viability** of their activities.

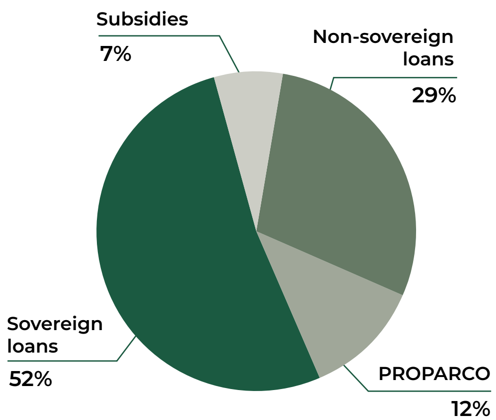
The analysis of funding and the projects' financial arrangements are decisive while appropriate resources must be used for these types of operations (long-term loans, grant elements), because an electrical system offers low profitability (users with very restricted contributory capacities) and the long return on investment (20-year concession terms).

Several conditions need to be met to generate profitability:

- **the size of the production units** must make allowance for the users' capacities, namely, their objective contributory capacities and also their willingness to pay for their electricity use at the agreed price;
- **the service price** must include recurring management and maintenance costs, replacement of average service life equipment, batteries, regulators and generator sets, depreciation of the equipment and the grid, risk and insurance cover cost, loan servicing, capital repayments and the profit margin;
- **operation phasing** should ideally be scheduled and aim in time to ensure that geographical coverage reaches sufficient numbers of users ranging from 10 000 to 30 000 connections, as experience has shown us;
- **the operation** must be entrusted to one or more operators that have suitable management independence for the projects' rural nature (isolation, satellization of production units, etc.).

Private players account for about 20% of the 2012-2017 commitments of the Agence Française de Développement, which has stated that this proportion is set to rise.

Distribution of the AFD group's commitments for energy in Africa from 2012 to 2015 by financial tool (total: € 3.5 Bn)



Source: French development agency, "Speed up the energy transition in Africa" (Paris, 2016), 3.

Example of a grant that benefited a private operator – the Off-Grid Clean Energy Facility-OCEF in Benin

The Off-Grid Clean Energy Facility (OCEF), set up under the terms of a Grant Agreement signed in 2015 between the United States and Benin Governments, is a competitive tendering **financial support mechanism directed at off-grid project promotors.**

The OCEF aims to increase access to electricity for the majority of the population currently without electricity in the rural and peri-urban areas by reducing the initial connection costs and the barriers to investment in the electrical energy sector. It seeks a multiplying effect through partnerships with private enterprises, NGOs, communities and other structures that proffer viable off-grid solutions (commercially) and alternative clean energies suited to Benin's reality.

The financial contribution provided by OCEF is a co-investment whose purpose is to increase the activity's profitability to an acceptable level for the investor and OCEF. Every demand submitted is appraised by its business plan and its financial plan. The bidder must provide a minimum contribution of 25% of the total project investments. This contribution may take the form of own funds, the financial contributions of a partner or another financial backer, a bank loan and/or the valuation of a contribution in kind.

Business units are recommended to set themselves their own contribution target of at least 50%. The available envelope for the last call for projects in November 2018 was 20 million USD.

However, the local actors currently capable of this independence are few and far between, insofar as very few have the required field experience (operation of several rural systems in parallel). This leads some operators to attempt solutions without human intervention that can be moved in the event of an extension to the interconnected grid or failure in a locality (containerized solutions).

As these conditions are familiar, a financing request can be prepared from a business plan and submitted to the various expected financial partners of the project.

The operating and accounting team – a crucial element of installation management

The sensitivity study – testing business plan resilience

Financial analysis is inescapable. If it is inadequate, it often causes projects to fail. It is transposed into a tool – the business plan – together with its various components, such as the sensitivity studies and risk analysis.

Once the business plan has been drawn up bearing in mind the various stakeholders' aims, it must go through a series of tests or a "sensitivity study", to address certain factors that are hard to predict, such as for example the number of users, the acceptable price, the time the project takes to come on stream, the service lives of the main components.

The sensitivity study is used to define any stopgap measures to consolidate the project's sustainability and profitability and refine the performance tracking indicators (risks/opportunities to be monitored).

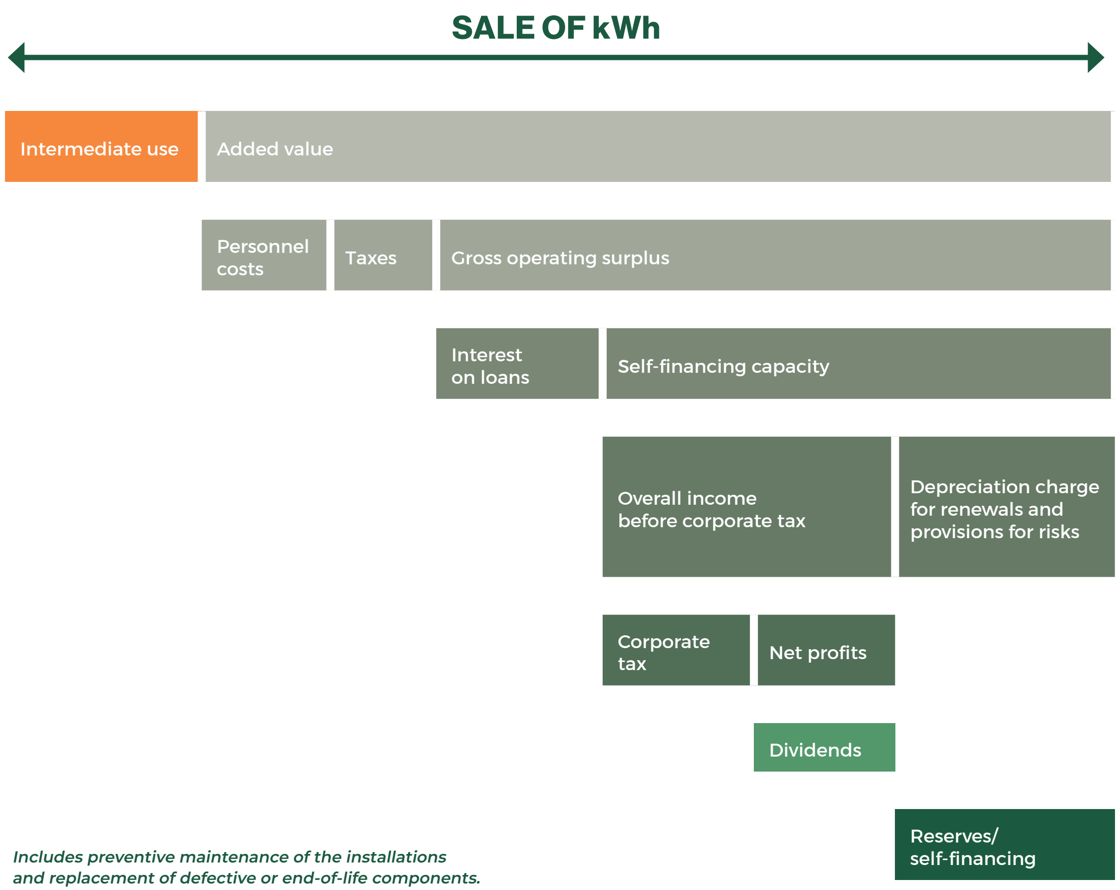
The business plan is the reference document for the financing decision

It includes a precise analysis of the events that may occur during the repayment period (based on the infrastructure analysis and generally planned for 15-30 years), and a sensitivity study to demonstrate its resilience (cf. inset).

The business plan, which is founded on the findings of pre-project studies to collect detailed and quantified information on all the projects aspects:
- harmonizes all the constituent elements of a project,
- identifies the risk factors and appropriate control measures;
- identifies which indicators to use to assess performance once the project has been rolled out.

In rural electrification, and more particularly in its decentralized manifestation, drawing up a balanced business plan, or even generating self-financing after all the costs and cover for the sector's inherent risks have been paid, is an essential, but particularly hard task.

Structure of the operating costs of an electrical system



Source: Fondation Énergies pour le Monde.

The risks to the economic viability of access to electricity projects in the rural environment

Several factors play a dominant role when drawing up a business plan, while sensitivity analyses show how much their variations on products such as costs can affect the results, as indicated in the following sketches.

On the products:

- **achieving the expected coverage rate**, as the years pass, will have a decisive impact on users' participation in the investment of the interfaces and the amount of electricity sold;
- **the actual payment of the amount of electricity sold** or, in the event of pre-payment, the availability to pay the expected amount of electricity, will have an impact on the volume of collected products;
- **proper equipment functioning** as it is proven that a breakdown significantly affects users' confidence in system reliability.

On the costs:

- **adhering to operating costs**, and in particular, travelling costs (for example: vehicle repair costs);
- **maintaining battery performance levels** as expected, as this equipment accounts for approximately half the Production item investment amount.

Thus, these factors that are closely linked to local context knowledge, its history, the local economy and human relations must be controlled if a realistic business plan is to be produced.

Many DRE project risk levels are such that they are likely to dissuade many investors and operators. The main risks are:

- **commercial:** overestimating the market in terms of volume or growth pace, overestimating the equipped users' contributory capacity or willingness to pay, underestimating the operating costs;
- **political:** breach, termination or biased application of the concession contract (act of state), inadequate mobilization of financial resources at the various territorial levels (state, province, municipality), non-payment by public users (schools, health centres, etc.), unfavourable regulatory change on fund transfers outside the country or local currency convertibility, risks of war and civil strife;
- **technical:** non-compliance with installation pace, error of judgement on the equipment base technical failure probability, poor use of equipment by the users, theft or vandalism, equipment damaged through a natural or accidental event (fire);
- **socio-economic and cultural:** users contesting or questioning the proposed methods, regional economic crisis that seriously affects payment capacities and/or leads to mass migration.

The operator can resort to some transfer or coverage mechanisms for a few of these risks. However, insurance cover and guarantees incur operating costs that depress the profitability of the activity.

These complexity, cost-increasing and vulnerability factors of projects cannot be separated from the DRE context. The financiers take note of them, so that the social and environmental benefits stemming from the electrification of a territory can be made.

The following table lists a non-exhaustive inventory of the funders and development agencies involved in access to electricity projects in the rural environment, in addition to their working methods:

Their main challenge is to evaluate the risk level run by their investments considering the political instability that is still prevalent in many regions. It is important to note however, that the small number of projects limits the avenues for diversifying their assets and thus, reducing the risks.

Institut Choiseul, "Africa – The key actors of energy" (Paris, 2017).

Who to approach to finance a DRE project?
The funders and their financial offers available to electrification

Types of funders	Multilateral Bilateral	Funding offered
"Donors"	UNDP, EU... GIZ, DFID, USAID...	Grants
International Financial Institutions (IFI) (Development banks)	WB, AFDB, EIB... AFD, KFW, JICA...	Concessional sovereign/ non sovereign loans Loans close to market rates Support grants (studies, tech. assistance, pilot projects...)
IFI subsidiary banks (= DFI, Dev. Finance Institution)	IFC... Proparco, DEG, FMO...	Loans at market conditions Participation (equity)
Banks or private investment funds	International Local	Loans at market conditions Participation (equity)

Source: Fondation Énergies pour le Monde

The Agence Française de Développement's support for rural electrification

DRE started to receive significant sums from 2013 onwards, averaging € 35 M p.a. funded for the last six years.

- Every year an average of 8 or 9 projects have been undertaken since 2013 with DRE making considerable progress (5-6 projects on average per annum).
- "Grid electrification" and DRE taken together, AFD grants averaged € 180 M per annum from 2016 to 2018, 70% of which were in Sub-Saharan Africa.
- Between 2016 and 2018, the grants for grid electrification were about € 40 M per project, compared to € 6-7 M for DRE projects
- Mainly on grid extensions and connections, primarily with the national utilities
- Primarily in the form of onlent sovereign loans with, on some projects, a European Union support grant.

Action priorities in DRE:

- Target areas: Sub-Saharan Africa, some countries in Asia
- Emphasis on off-grid linked with the interconnected grid and the construction of public policies
- Individual PV pay-as-you-go equipment programmes
- Conversion/roll-out of mini-grids (primarily PV)
- Multimodal electrification programme, with institutional and technical assistance and "public policy" support (operational schedules, pricing studies, regulatory frameworks, etc.)

The available instruments:

- Combination of financial instruments in line with demand: direct loans (sovereign, non-sovereign, private), dedicated lines, grants for technical support or innovation support, etc.

Source: Christian de Gromard, Energy Specialist, Agence Française de Développement, DRE Forum, Valpré, May 2018

Can the required change of scale be financed?

As mentioned in the introduction to this book and recalled at the beginning of this chapter, the development of Sub-Saharan Africa is driven by inclusive rural development and thus the rural territory electrification action must be much more ambitious than the current action.

The traditional financing mechanisms have reached their limits

The previously described financial backing will not enable the change of scale to be achieved to meet the SDG goals or those of the United Nations' *SE4All* initiative.

Between 2000 and 2015, the World Bank financed large-scale programmes (Senegal, Mali), that could not be fully completed at the planned pace thus demonstrating the limitations of this type of strategy.

At the same time, smaller-scale programmes (300 000-1 million euros depending on the size of the localities and the socio-spatial morphology of the territory), suffer from under-funding, and there are several reasons for that (most of which have already been mentioned but no doubt are worth recording here):

- access to electricity projects in decentralized mode for a locality are small compared to the amounts that development agencies are accustomed to handling, and thus they generate proportionally heavy loads for them.
- their transaction costs, i.e. appraising then following up loan files are unacceptable to funders wishing to commit to projects of this type.
- project standardisation, which is required to aggregate projects within a programme at an amount that matches the funders' criteria, is to date impossible given the diverse nature of contexts and the financiers' idiosyncratic criteria;
- the context of Sub-Saharan Africa's countries, marked by recurrent crises, incurs major risks that no guarantee mechanism is in a position to cover[1].

As it stands, amid states with limited resources, risk-averse development agencies and private operators tied by profitability criteria, most of the rural populations of Sub-Saharan cannot hope to see electrification within the near future.

For reasons of lasting ownership and management rationale, DRE financing should ideally prioritize national resource mobilization before calling on international funds, that will play a subordinate role. But this prospect appears to be unrealistic: **the countries in question have very limited own funds** in spite of the existence of several taxation mechanisms on consumption, (cf. insets); **the countries' commercial banks have been solicited,** but they still have little experience in this innovative and complex area, so they are unready to suggest appropriate solutions. Nonetheless, they are in the best position to grasp the local contexts and risks fully.

Yet, if they were backed by international partners, they would play a key role in generalizing access to electricity in the rural environment, thanks to their proximity with the local actors and familiarity with the context[2].

1. Nergis Gülasan et Gail Hurley, "Financing development through better domestic resource mobilization", ID4D, 2015, *https://ideas4development.org/financer-le-developpement-par-une-meilleure-mobilisation-des-ressources-nationales/*
2. It is the intent of the Attijari Bank project quoted by Lionel Zinsou in the foreword to this bo and whose results will certainly provide interesting capitalization results.

A professional has his say
Olivier Oriol

What are the obstacles you come across when penetrating the vast African rural electrification market that is currently undergoing rapid change?

"As it stands, the lack of uniformity in rural electrification is one of the greatest difficulties. The fact that each country or fund raiser imposes its own technical specifications on every project denies us the visibility to develop products that satisfy a uniform need. Added to that, some financial arrangements preclude us from taking part in projects, which restricts our scope of action".

Olivier Oriol, a developing country specialist for 10 years, currently works on the issues of access to energy in the rural environment in Africa. He is the Africa Market Manager for Michaud Export.

Find the whole interview in French on the book's webpage: ***http://www.fondem.org/electrifier-lafrique-rurale/***

So, who else is left to finance DRE programmes on the required scale?

New forms of finance and/or new actors are emerging in turn, in the same way as donations and grants anticipated the involvement of development finance institutions. DRE's specifics and positive externalities stimulate new forms of funding. They make a sizeable contribution to an investment without contributing 100% of it, in line with their size and characteristics.

Decentralized cooperation is particularly meaningful for implementing DRE projects. The impetus of the developing countries' authorities is backed by their industrialized counterparts' resources. The international policies of the main French authorities (particularly the regions) also act as springboards for backing local energy sector businesses in their export drives. Two examples are the initiatives launched in 2019 by the Nouvelle-Aquitaine and Hauts-de-France regions.

However, it is hard to foretell the future of French decentralized cooperation in the area of DRE. The mechanism is still in its infancy (e.g. the FICOL device supervised by the AFD, whose first projects are starting at the time of writing).

Environmental financing is a potential staging post for specific access to electricity financing. The low environmental impact of DRE infrastructures through the promotion of renewable energies and energy efficiency encourages organizations involved in reducing GHG emissions to come on board. By way of example, the Global Environmental Fund (GEF) and the French Facility for Global Environment (FFEM) may award grants to top up other financial sources (cf. inset). These funds are not specifically earmarked for access to electricity.

Backing from the French Facility for Global Environment (FFEM)

The FFEM's mandate gives it a twofold aim to preserve the environment and sustainable development. Its goal is to finance projects that rise to the global environment's challenges in developing countries and to test solutions and capitalize on the lessons learned from them to facilitate their take-up.

Level of funding (2017):
- € 2 527 k allocated to energy transition (about 20% of its annual commitments), including:
- € 500 k for an on-grid solar streetlight project in Senegal;
- € 400 k for a self-consumption photovoltaic power plant project in the industrial sector);
- € 390 k for the sustainable industrialisation of solar lamp manufacturing (Benin, Burkina Faso, Mali, Senegal);
- € 574 k for reducing the environmental impacts of Ylang essential oil distillation;
- economic uses linked to access to electricity in Vanuatu and Indonesia's rural environments.

Strategic orientations:

• The new 2019-2022 strategy set new Fund priorities.

One of the 5 new thematic areas, **energy transition and resilient cities**, targets three new challenges in particular: adaptation of cities to climate change and to natural risks, low-carbon energy efficiency and new technologies for energy system management.

• Special attention is paid to innovation tools: digital technologies, nature-based solutions, frugal innovation, the "One Health" approach

Intervention priority:

• Target areas: Africa (77% of the projects funded in 2017), the Middle-East, Latin America, Central Asia, South-West Asia.

• Priority given to projects leading to "sustainable and affordable access to energy for all and that encourage the use of renewable energies for energy production".

• Support for projects that are part of a local strategy, adapted to the local contexts.

Available instruments:

• The FFEM contributions to projects take the form of grants, or contributions in kind. The maximum co-funding rate is 30% (50% for highly innovative projects) for sums ranging from 0.5 and 2 million euros.
  - Calls for projects
  - Small-scale Initiatives Programmes (PPI): structuring the new civil society actors of the developing countries (200 projects backed since 2006)

• Support for the private sector:

Private-sector Innovation Facility (FISP): contribution through grants or repayable advances.

Sources : FFEM, " Strategy 2019 2022" (Paris: FFEM, 2019). FFEM, " Annual Report 2017" (Paris: FFEM, 2018).

Impact investment funds are showing increased interest in access to energy initiatives, over and above those taking a liberal approach. The positive social, economic and environmental externalities associated with off-grid rural electrification projects encourage the involvement of a new generation of investors. In contrast with the conventional funders, impact investors go further than offering simple financing to back projects but do so with a view to ensuring their completion, through to verifying their impacts.

The fact remains that impact studies are rarely conducted for decentralized electrification projects, hence they are hard pressed to be quantitatively assessed (cf. inset), which is likely to curb investors' intervention capacity.

Incidentally, the expected ROI by the latter is not necessarily in line with the time required to gauge the effects of electricity's arrival on local development in the rural environment.

Companies are also receptive to these positive externalities. They hold the key to a variety of participations deriving from sponsorships or foundations that firms set up as part of their Corporate Environmental Responsibility (CSR) or "societal commitment". One avenue involves developing joint responses with the NGOs to develop productive uses in the communities that accommodate their operations and strengthen their activity value chains through electrification. The food-processing sector, pharmaceutical industry, networks and building of infrastructures are directly affected. The finance sector, and particularly the insurers and reinsurers, who have to deal with major financial risks in the event of inadequate climate change measures, have every interest in supporting the massification of renewable electrification in the emerging and developing countries.

Diasporas are often part of a local development drive and make up for the state's shortcomings, by financing access to water, education or health-care. For this reason, DRE is capable of involving the people who have left the localities to live abroad to electrify them.

Their members may contribute, in cash, but also in aid, to drawing up applications to pave the way for local electrification. During 2017, contributions by Africa's diaspora amounted to 65 billion dollars (€ 58 Bn, namely double the public development aid which amounted to 29 billion dollars (€ 26 Bn)[1]. Two-thirds of these funds are used as a social safety net and contribute to making up for daily financing needs. In some countries, such as the Gambia and the Comoros, the diaspora's contribution may be as much as 20% of the country's GDP[2].

Lastly, crowdfunding cannot be totally ruled out from the array of new forms of financing. It would even seem possible for large-scale

1. African Institute for Remittances, "Progress report on the African Institute for Remittances" (Nairobi, 2018),
2. World Bank Group, "Migration and Remittances: Recent Developments and Outlo Transit Migration" (Washington, D.C, 2018), 24.

projects, which are well beyond the usual spectrum of *crowdfunding* operations that enable associations to appeal for the public's generosity for small amounts. The operator BBOXX recently raised 6 million euros[1] as part of a *crowdlending* operation. In this specific case, the arrangement set up looks like a traditional investors' roadshow. Incidentally, one could query the compatibility of the remittances made to the lenders (up to 11%) with this PAYG actor's claim to be a social enterprise.

This overview of the funding of renewable and decentralized access to electricity illustrates that there are several outstanding obstacles to overcome for a real change of scale.

Since the 90s, many papers targeting innovative approaches to financing have been written (primarily prompted by the European Union and the World Bank), without any fast tangible findings.

While the technological developments have provided fertile ground, political urgency may pave the way for removing the last barriers to financing the electrification of rural Africa that is really inclusive and devised for a community rather than individuals.

1. "BBOXX receives largest crowdfunded debt raise", Next Billion Blog, 2019, *https://nextbillion.net/news/bboxx-receives-largest-crowdfunded-debt-raise-in-history-of-solar-energy-in-africa/.*

Can the impacts of electrification on local development be assessed?

There is no easy answer to this key question because impact studies are not legion, except for pico-solutions, which are easier to gauge. Assessment of actions out on the ground generally gives "globally encouraging" results for the majority of pico/micro/mini solutions, even if the information tends to be qualitative. Impact quantification needs to be handled very carefully.

Many externalities are indirect, intangible and long-term. We mention a few indirect impacts identified through various HYSTRA surveys (2017): savings made on fuel purchases (that may absorb 10% of annual earnings), additional income through night-time working, gaining an additional hour for homework every day, improving socialization and general well-being.

Source : Pierre Jacquemot and Marie-Noëlle Reboulet, "Technological options and organizational models for rural electrification in Africa", *Afrique Contemporaine* 1-2, n° 261-262 (2017): 179

A professional has his say
Guilhem Dupuy

Do you feel rural electrification projects can be economically viable without sacrificing the social impact?

A real philosophical debate is called for. The input made by the local populations can never be enough to bring electricity to the most destitute, it requires subsidized programmes. Short-term profitability is the wrong approach to adopt for analysing rural electrification. The social impact of the operations carried out by most private firms, entails distributing SHS. That does not go far enough. Some solar firms that run profitable businesses in urban/peri-urban zones plough back part of their profits to finance operations in the rural environment, as a social gesture, without making a profit or even making small losses.

Do you think the NGOs can help the private sector find equilibrium?

The impact investors' community has been wondering about productive uses for many years because the populations' incomes can be improved, and jobs created through the distribution of systems. But the issue is not straightforward. Bigger systems (which come at a higher investment cost) must be made available, they need to interact with the professions, explain how solar power can work for them, come up with commonly used equipment (for pumping, mills, etc.), provide quality after-sales service to ensure fast repairs of the whole system, develop strong customer relations…

Thus, the NGOs have vital feedback to offer, especially for training users in processing agricultural produce or structuring a sector with an energy component, even if some value chains are complex (biomass). So coordinated action models need to be built between the companies and the ONG on productive uses…. It's in the companies' economic interest to do so.

Guilhem DUPUY, is 34, studied at the Ecole Normale Supérieure and graduated in economics, statistics and sociology. He is the Investment Director for Gaia Impact Fund. He has worked for Ecofi and Crédit Coopératif, where he contributed to structuring the impact finance sector.

Find the whole interview in French on the book's webpage: ***http://www.fondem.org/electrifier-lafrique-rurale/***

A professional has his say Rodolphe Rosier

Do you think that the diaspora could be a major sales target for the deployment of your systems?

"Yes, the people of the diaspora living in France have high expectations of aiding their family members who have stayed in the country, in Africa. In the middle of July, we launched a preliminary offer of about € 10 per month for a 3-year term. This offer aimed to make up for a gap in the market and it has got off to a good start. However, our main development priority is to sell our SHS directly in West Africa where our partners let us take up the advantage of their location and networks".

Rodolphe Rosier, a career engineer with a PhD in management, has worked in the energy sector for 15 years. He founded the OniriQ start-up in December 2016 with Mohamed Sarr and Michael Hernandez.

Find the whole interview in French on the book's webpage: ***http://www.fondem.org/electrifier-lafrique-rurale/***

To sum up, all the DRE sector breakthroughs are broadening the array of technical tools that will broker the change of scale. Furthermore, the general trend inspires optimism about the capacity to finance this change of scale, even though the financiers quickly need to find more appropriate solutions for the interim projects.
Nonetheless, certain operational constraints, that are structural to DRE must be borne in mind and factored in irrespective of individual project considerations.

"It all comes down to money at the end of the day, so if the money and the finance aren't available it's going to be very difficult for us to achieve the multiple benefits that mini-grids offer. Accomplishment of SDG 7 – universal access to electricity by 2030 – is fundamentally underpinned by the ability to unlock capital flows at bigger scales into this sector. We aren't going to get there without solving the finance challenge".

Alexia Kelly, climate finance expert and co-chair of the Low Emission Development Strategies Global Partnership (LEDS GP)[1].

1. Quoted by Charlie Zajicek, "How solar minigrids can bring cheap, green electricity to rural Africa", Overseas Development Institute, 2019, *https://www.odi.org/blogs/10730-how-solar-mini-grids-can-bring-cheap-green-electricity-rural-africa.*

A project to build 12 wind turbines in Morocco that benefited from crowdfunding via the crowdlending platform Lendosphère

2.4. The key factors to the success of a decentralized rural electrification project remain unchanged

Over and above the technical changes and uncertainties that have just been mentioned, the sights of DRE are set on supplying a sustainable and accessible electricity service to the greatest number. But on a more operational level, which methodological points of reference can help the practitioners?

Sub-Saharan Africa is a set of 49 highly distinctive countries marked by their history, culture, geography and also their institutional and administrative structures. Nonetheless on the strength of the experiments that have been conducted there for almost half a century decisive common points can be discerned for successful implementation of a DRE project.

They all boil down to a single observation – the human factor is crucial. The acceptance of the service and its ownership by the population and the local authorities are what make or break its sustainability. Yet, this adoption is a pre-condition of the positive social and economic impact of electricity's advent.

Experience identifies 4 types of constraints that cut across geography and technical changes, and thus 4 conclusive fields of expertise for DRE project initiators (at the very least those who seek to provide long-term access to electricity and not simply exploit a short-term market opportunity):

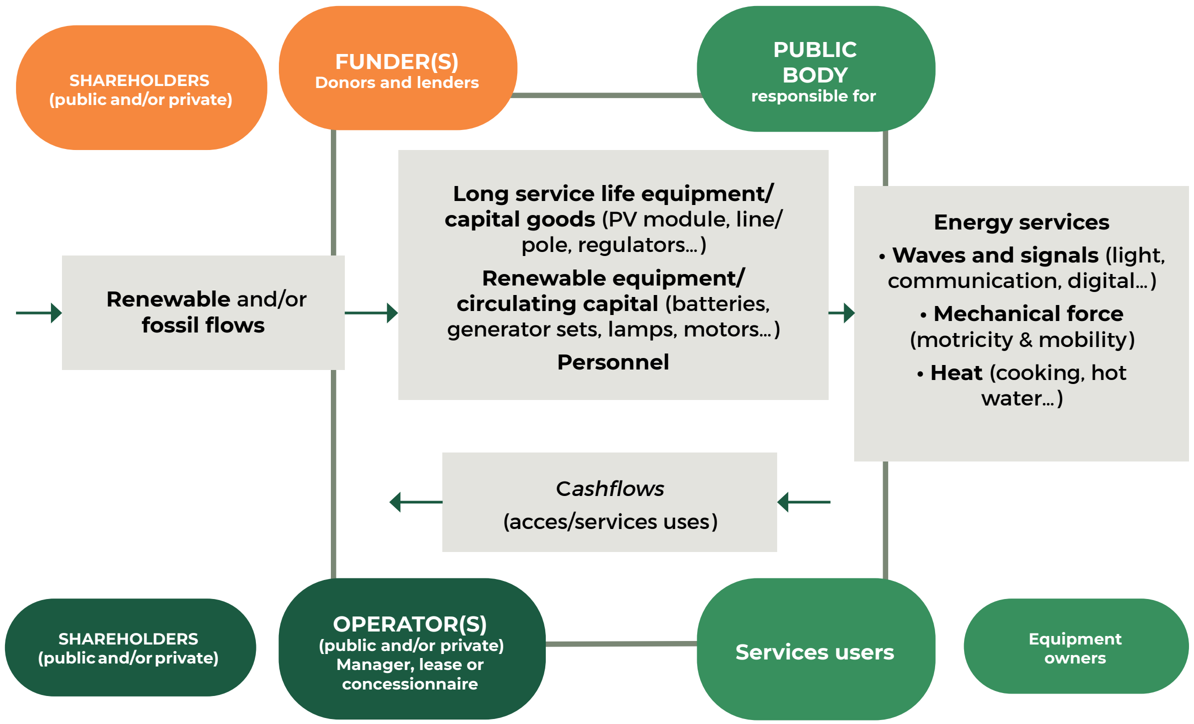
- because the implementation of DRE projects is characterized by more or less complex patterns of players depending on the type of electrification plan, **the success of a project also depends on the orchestration quality of the stakeholders** (2.4.1.).
- because access to electricity is far from simply being a technological issue, **feedback first leads to preferring a persevering sociological approach and the establishment of specific budgets** to be able to provide all the required awareness-building, and mediation guidance activities before, during and after the service is introduced (2.4.2.).
- because the sector deals with a number of perpetual product quality and installation servicing and maintenance capability issues, **the project must plan, from the design stage, for the factors that lead to equipment being abandoned after installation** (2.4.3.).
- because whatever the solution is, electricity implies investments by the operator and a contribution from the users to access a sustainable service, **pricing is a key element of the economic model of an electricity service** (2.4.4.).

ELECTRIFYING RURAL AFRICA: AN ECONOMIC CHALLENGE, A HUMAN NECESSITY

2.4.1.
Building an ecosystem of actors that will ultimately become self-sustaining is no light matter

Today, thanks to the use of renewable energies, the decentralized rural electrification development conditions are ripe in technical and environmental terms. But that goes only part of the way. Regardless of which system is installed, an ecosystem of actors must be set up to ensure that the service covering the territory operates sustainably.

Pattern of rural electrification actors – operators, users, funders, public bodies and project owners



Source: Christian de Gromard, Energy Specialist, French development agency.

© Fondation Énergies pour le Monde

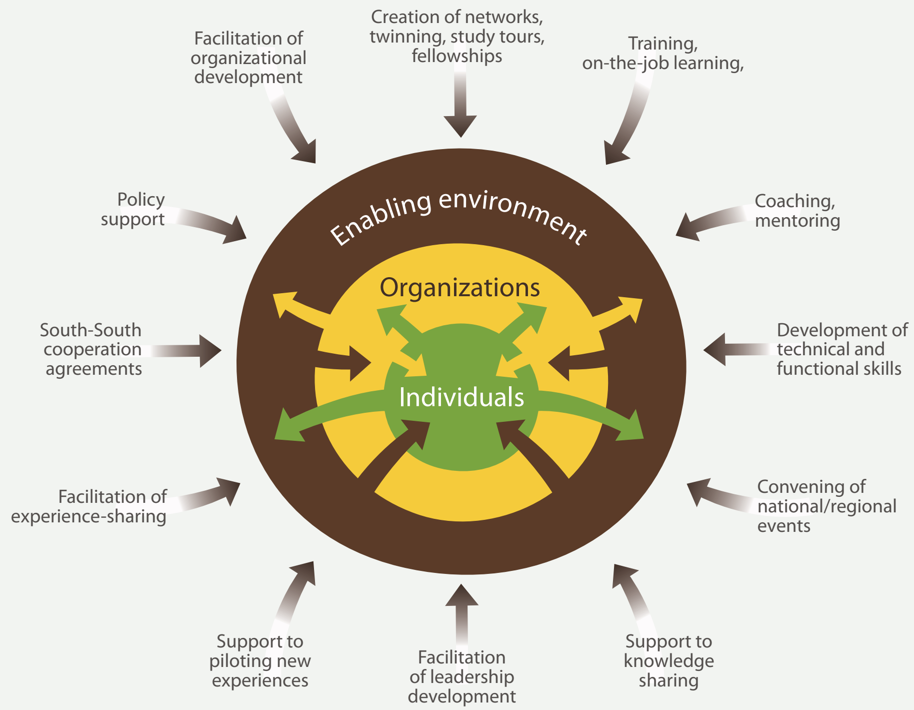
Typical meeting of institutional and field workers

Creating a self-sustaining ecosystem by developing the capacities of the various stakeholders at all levels

Capacity development is defined, and there is a degree of agreement on this in international development circles, as the **process through which individuals, organizations and societies unleash, create, strengthen, adapt and maintain the capacities to set and achieve their own development objectives over time** (OECD, 2008. UNDP, 2009). It is a process that encompasses a plethora of actions and beneficiaries, whose challenge is to make an impact on three interdependent levels (individual, organizational, global environment), to ensure the local ecosystem is fully self-sustaining in time (cf. diagram).
Faced with the failure of the international cooperation actors in the 90s , this notion has become a major priority of development policies, as financial backers prefer real implication and the empowerment of local actors in project design and implementation, which must extend beyond the mere strengthening of "technical" skills.

Some good intervention practices:

1. Upstream of the project, achieve better understanding of the capacity development needs with the various local actors.
2. Develop a capacity development strategy with the local partners
3. Diversify the capacity development approaches – technical training, administrative and financial management, engage the actors in networks, provide advice.
4. Define specific aims for each type of actor, for different timescales (short-, medium- and long-term) with precise follow-up indicators.
5. Allocate a budget and specific resources for the strategy rollout, follow-up and appraisal.



Source: FAO, "Learning module. Capacity development – Basic principle" (Rome, 2010).

1. Organization for Economic Co-operation and Development, 1991; United Nations Development Program, 1993; European Centre for Development Policy Management, 1992.

The development of decentralized electrification relies on myriad technical solutions. In Sub-Saharan Africa, we find the two approaches previously mentioned (interventionist, liberal) behind this diversity, that present each of the operational patterns and therefore, specific sets of restrictions that depend on the nature and number of interests involved.

The interventionist approach places institutional cooperation rationale at the centre of building a technical solution

The interventionist approach, which implies intervention by the public authorities, (primarily the state) at several levels, regards decentralized rural electrification as contributing to the economic and social development of a territory. This rationale mainly (but not only) results in installing local mini-grids supplied by their own renewable production means and applying an all-in rate.
Deployment of this type of project entails mobilizing and rallying many very different actors to guarantee improved living standards and a viable electricity service:

- project owners,
- users,
- local and territorial institutions that represent them,
- operators that run the electrical infrastructures,
- equipment suppliers,
- public institutions that organize and regulate the electricity sector,
- financial partners.

The very different level of understanding and knowledge of the electricity sector issue and electricity uses by these various actors, as well as their sometimes divergent interests, seriously hamper the development of decentralized rural electrification projects.

Project owners

Until rural electrification agencies were created, project owners (NGOs, local communities, enterprises) brought DRE initiatives to the territories. Henceforth, while these organizations, outside of tenders or calls for projects, can themselves take the initiative to devise and develop an electrification project on a territory of their choice, they generally submit bids for the tenders launched by these agencies.
The agencies define the zones to electrify and the access rate targets, and select projects on the basis of several criteria:
- number of users to be electrified,
- implementation schedule,
- fee structure and its index-linking,
- technology choice,
- business plan,
- financing plan.

Initially the ministries of Energy, through their energy directorates and the sector-specialist NGOs, were the two main types of project owners. Their attention was mainly directed at social uses of electricity. Now they have been joined by private actors, who regardless of the model, target the higher-added value uses – telecommunication, lighting, broadcasting and economic activities.

The users and their representatives

The viability and sustainability of the installed electrification systems depend on the behaviour of the end users of the electrification that must provide the best match to their various needs and expectations. The volume and regularity of their electrical consumption and payments are the keys to success.
Whatever the category of electricity users or the infinite profiles inside each one, special attention must be paid to their awareness and information on the possible uses and risks of electricity, and on the contribution to be paid for enjoying the service (cf. chapter 2.4.2.).

Access rate

Ratio between the total number of inhabitants (or homes) in a territory and the number of users (or homes connected) of the electricity service.

Households form the most numerous potential DRE user category, and are characterized by:
- low electricity consumption (about 4.5-24 kWh/month, most of which is less than 10 kWh/month[1]) because of the limited use: one to three lighting points and recharging a cell phone, sometimes additional lighting points, audio-visual and/or ventilation appliances, and in the case of the better-off, refrigerators and/or freezers.
- very different types of dwellings, ranging from mud huts with straw roofs to building block and corrugated metal roofs, each of which presents specific constraints for indoor electrical installation and connection to any distribution mini-grid there may be.
- often very little knowledge and understanding of how to use electricity and electrical appliances, limited to their representations when travelling to the nearest electrified localities.

There are relatively few **economic actors** who want to be electrified today in the rural areas of Sub-Saharan Africa, often through ignorance of the associated opportunities and/or lack of financial capacity to get equipped and/or for lack of additional infrastructure (transport, access to water).

Yet, the active presence of these entrepreneurs is essential for the economic viability of a project:
- they are a significant component of the electricity demand in the rural environment, primarily for drawing water and irrigation, processing and preserving farm products or timber.
- in addition to the uses stemming from farming or forestry, the development potential of commercial and trade activities must be considered that may be fostered by access to electricity (local shops, repair workshops, welders, joiners, tailors, hairdressers, garages, etc.).

However, experience shows that transition to the use of electricity is not clear – it calls for awareness building but also guidance to exploit all the positive externalities connected to the arrival of electricity.


© Fondation Énergies pour le Monde

Economic use of electricity in Senegal (Low Casamance) – conservation-sale of chilled products

The users' representatives play an essential role, in that the success of projects is also founded on a good grasp of the service strengths and limitations and on social cohesion. The involvement of collective structures or elected representatives is crucial, and the project owner must bring them together and rely on them:
- the councillors and traditional chieftaincies are transmission vectors for common and shared information, for the acceptance of different electrification
- the local NGOs (who have already contributed to the acceptance of innovations in the areas of health and education, for example) know how to convey useful messages on the changes brought about by electricity to avoid tensions and encourage the number of users and consumption to take off.

The territorial institutions, that may also be users of the service if public buildings are electrified, play a variable geometry but nonetheless very important function:
- they are in the best position to understand... often after being made aware of the socio-economic impacts of the availability of electricity and its contribution to land use planning and their economic development;
- depending on the skills that have been effectively

1. By the average monthly electricity consumption of a French household was 412 kWh in 2017 (sources: RTE and CRE) i.e. 16-80 times more.

transferred to them on electrification, their commitment may include carrying projects through to full project management with the electrification companies or by creating cooperatives or electricity boards.

While the involvement of these actors (domestic and economic users, elected officials and councillors, local NGOs, territorial institutions) enables the short- and medium-term electricity demands to be appraised, it cannot occur without prior approval by the national institutions responsible for the electricity sector.

The national public institutions

Several public-sector structures take part in the political and strategic choices, the organization, as well as the regulation of the DRE area. While institutional frameworks vary by individual country, they generally include:

- political bodies,
- a regulatory authority,
- and technical and financial structures.

These bodies and structures are supplemented or followed up by other bodies and institutions at territorial community level depending on the skills transfers deriving from the decentralization processes.

The Ministry for Energy, the electricity sector's supervisory authority, defines the national electrification policy, including the decentralized rural division, as well as the regulations and technical standards. Depending on the country, it approves the national DRE programmes, and issues rural electrification authorisations or concessions. If necessary, it checks with the electricity company for the absence of grid extension plans over the area within the 5-10-year timeline.

The Ministry of Finances and Budget approves the electrification financing policy and fiscal policy, budgets the public funds allocated to decentralized rural electrification, seeks funding from international financial backers. It may also set up incidental taxation to contribute to financing technical structures and projects. For instance, taxes on electricity bills have been introduced in Senegal, Madagascar and Burkina Faso. In Burkina Faso, the Rural Electrification Development Fund (FDE) in favour of rural localities is financed by a tax of 2 FCFA on every kWh sold by the national electricity company[1]. It supplements the rural electrification fund to a very minor extent.

A number of countries have set up an extended rural electrification supervisory committee comprising representatives from the ministries for Energy, Finances and the Budget, and others such as Health, Education Agriculture or Industry to promote inter-ministerial coordination and the development of social uses of electricity. Public lighting, the electrification of administrative buildings, training establishments, community amenities, health centres, and so on. Access to electricity is a key factor to improving services provided to the population.

The main tasks of the **electricity sector regulatory authority** are to approve the competitive selection procedures for electrification companies, the relevant contracts, and sales tariffs and index linking methods to users applied by the electricity service supply companies. When a decentralized rural electrification mini-grid is connected to another grid, the regulatory authority must approve the wholesale electricity purchase-sale tariff to the company operating the grid.

The technical and financial structures vary by country. They may boil down to a division or department responsible for rural electrification within the Ministry for Energy, or a rural electrification agency, a public establishment that is generally supervised by the Ministry of Energy, sometimes backed by a rural electrification fund.

The rural electrification agency is tasked with:

- promoting and informing,
- developing service offers and local capacities,
- assisting with setting up and implementing programmes and projects,
- contributing to mobilising funding and administering this funding,
- monitoring and checking that the rural electrification activities run smoothly.

When rural electrification funds exist, they are earmarked for implementing the funding agreements set up for each programme or project. They may be managed by a trust institution under agreement with the rural electrification agency.

All these structures, generally based in the country's capital, are rarely relayed to the regions by deconcentrated services. This limits the field intervention facilities, which is detrimental to the effective implementation of national policy and hinders local actors' compliance with regulations, procedures and commitments. See the recommendations on this topic in part 4.

The electricity sector professionals

While the presence of the above actors is required while the implementation of a DRE programme is being prepared, supervised and controlled, it is up to the sector professionals to carry out the system installation.

A large access to electricity operation involves at least four types of technical intervention under the supervision of the project owner (the project sponsor, who hands over the equipment to the operator after the industrial commissioning):

A design office responsible for project management which has a predominantly local component (including subcontractors) designs the electrical infrastructure, from production to user connection, not to mention the connection, metering and prepayment systems. It also provides technical assistance, trains the local stakeholders (operator, users, councillors), acceptance of the works, and usually, guiding the operator during the required learning period.

One or more suppliers look after the procurement, installation and start-up of electrical and electromechanical production (renewable energy generators – with or without generator set hybridization – storage, energy regulation and conversion), low voltage distribution and management equipment (metering, prepayments).

Entrepreneurs working in various trades (civil engineering, electricity, metal construction, joinery, etc.) build the infrastructure on the basis of the project owners' plans.

The operator is considered to be the electricity service's core longevity element (especially for a mini-grid; cf. chapter 3.5.3). It is selected once the project is set up or as a result of a call for candidates and will be responsible for the electrical infrastructure smooth running after obtaining the right to operate with a permit or concession endorsed by the Ministry of Energy.

These various functions can be carried out by a single service provider, which enhances coherence between the conception, the choice and supply of the equipment and their operation (including maintenance) but may lead to excessive dimensioning and budget overruns. In any case, fair appraisal by the various parts of the context and its changes will depend on:

- the correct dimensioning of the infrastructures;
- the right construction quality;

1. Pierre Jacquemot and Marie-Noëlle Reboulet, "Technological options and organizational models for rural electrification in Africa", Afrique Contemporaine 12, n° 261-262 (2017): 175-176.

A professional has his say
Mamadou Saidou Diallo

How does the Guinean Rural Electrification Agency (AGER) guide mini-grid operators on rolling out their projects?

"We supervise them as they prepare their financing and concession applications, primarily by making available to them tools such as: feasibility study and business plan outlines, model concession contracts. Then we help them throughout the administrative approval circuit for these applications. We assist them on the issues of customs and tax exemptions and procurement and supply contracts. We support them out on the ground with monitoring and inspecting the works, training operators and their management teams, and with informing and raising the population's awareness of the constraints associated with the sustainable supply of an electricity service".

Mamadou Saidou Diallo, trained as an electrical energy engineer, has been working in the field of rural electrification in Guinea for 15 years. He is the Joint Director General of the Guinean Rural Electrification Agency (AGER).

Find the whole interview in French on the book's webpage: ***http://www.fondem.org/electrifier-lafrique-rurale/***

• user satisfaction;
• and the operator's sound financial health.

The financial partners and investors

No DRE project can come to fruition without them. They provide investment funding in various ways (cf. chapter 2.3.2) in the form of grants or concessional loans provided by the major international financial backers.
The reduction in the price of electrical components (particularly solar modules) and focussing on solvent customers, paves the way for possible new players: local financial establishments, government-owned and merchant banks, decentralized financial services (micro-credit organizations, mobile telephone operators, etc.) and investors who are now interested in DRE.

The liberal model is based on a much simpler and faster to implement operational pattern

In the liberal model, without state intervention or financial support, there are far fewer actors, which aids the use of equipment that currently covers the range from solar portable lamps to individual solar systems. Thus, the amounts of energy at stake are low (cf. chapter 3.2). Solutions founded on this approach are developing strongly. This has been made possible by a combination of factors conducive to opening up a market (cf. chapter 2.3.1.).

These initiatives, founded on a standardized marketing process of direct solar system sales, installation on users' premises, after-sales, invoicing and collection service, call for just a few actors:
• **the developer** who, as distributor and operator,

Case study – BOREALE project

In 2009, the national electricity and rural electrification coverage rates in Madagascar were 28% and 7% respectively, while in the rural regions of Androy and Anosy with 1.4 million inhabitants, coverage was no more than 5%. Although generator sets are expensive to run and thus unsuited to the payment capacities of rural households, far from sites and environmentally harmful, their use was widespread.

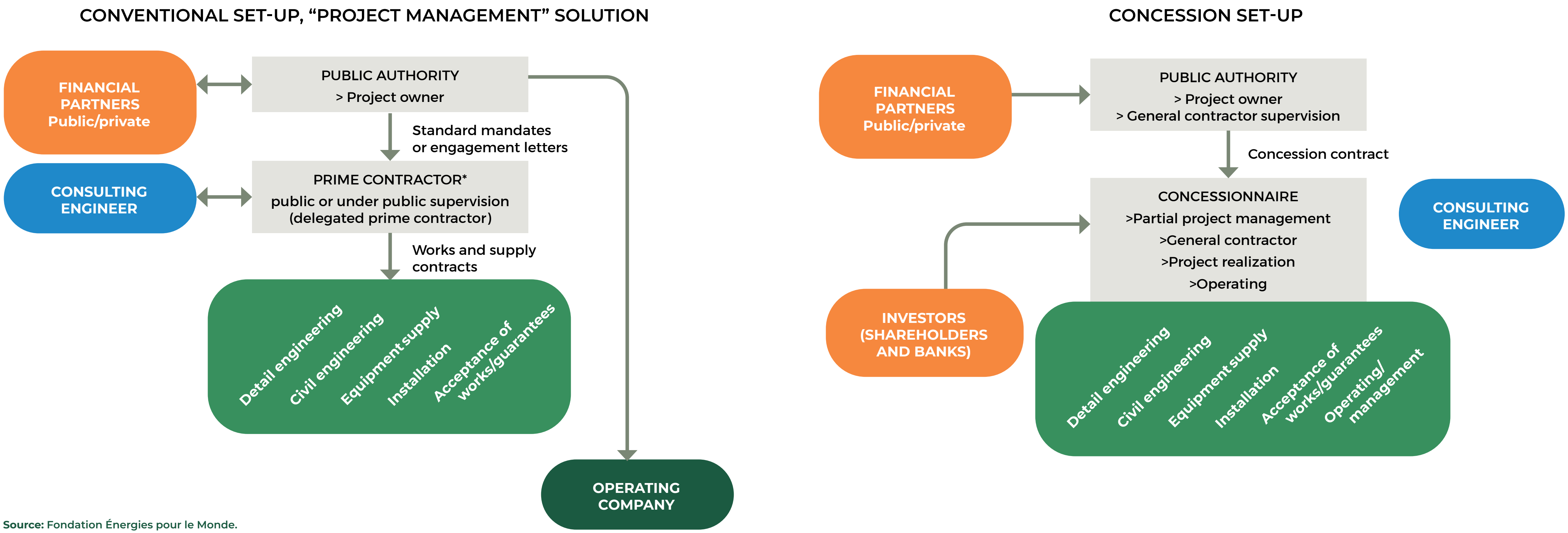
Fondem drew up the BOREALE project (2012-2018) a decentralized rural electrification (DRE) programme against this backdrop, using renewable energies (RES) in partnership with the local NGO Kiomba, the WWF, the General Directorate of Energy, ADER and the Board of Electricity Regulation. As part of the company's national energy strategy, it aimed to tap the country's high renewable energy potential, "show the way" in regions hit by a difficult socioeconomic context where off-grid electrification via RES were rare.

This ambitious project to change scale, was built on the feedback from earlier programmes such as RESOUTH (the electrification of two Malagasy localities) with three components:
- **Energy and infrastructures:** installation of solar power plants and the associated distribution grids to deliver round-the-clock service that would be taken up directly by more than 4 000 people in the seven target localities (in the Androy and Anosy regions);
- **Operation:** selection, training and guidance of 4 operator for up to a year after the project ended, so that they would be completely self-reliant;
- **Electricity uses and the development of socioeconomic activities:** development of some thirty economic activities (sewing, welding, cyber-café, cinema-video, etc.), creation or bolstering of some ten community actors (village halls, schools, health centres, etc.), improving the services of some ten community amenities (schools, health centres, village halls, etc.).

Although the project faced difficulties (connections progressed at a slower pace than expected, fragile operating structures), the feedback from it is crucial and such that future DRE projects will be able to count on when drawing up their action plans and throughout the rollout stages.

Further reading. Find the whole case study in French on the book's webpage

Two examples of operational patterns under public supervision for an infrastructure project



Source: Fondation Énergies pour le Monde.

offers standardized solar kits gradually paid for by the customer on the basis of electricity use;

- **the financial partner(s)**, called by the developer, who participate in the capital or debt from incubation until satisfactory profitability is achieved;
- **the telecommunications operator**, a key partner of the developer, sets up the mobile payment facility and monitors the main system data by telemetry;
- **the equipment supplier,** who produces the equipment, from solar module to very low consumption applications (mainly LED and television);
- **lastly, the customer**, who pays for the service, often including lease-purchase of the system of which he eventually becomes the owner.

The PAYG version of the liberal approach has the advantage of being based on techniques that enhance the operation's viability through debt collection control (prepayment).

Each of these approaches – interventionist or liberal – has its limitations

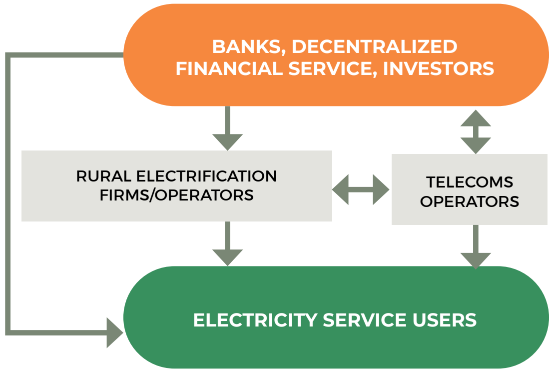
Not all the obstacles, which are often structural, are likely to be removed in the short term or even in the medium term. But some of them are not inevitable: which is why they are addressed by the recommendations in part 4, organized on the basis of which stakeholder they are directed.

The main limitations of the interventionist model

As part of a project that aims to install an electrification system for the highest user number, **it is firstly hard to identify and assess the electricity service needs of the potential users**, bearing in mind:

- the diversity of users and their unfamiliarity with the uses of electricity and electrical appliances (even if in a geographically and sociologically uniform area, the populations, their representatives,

Operational pattern for a private project



Source: Fondation Énergies pour le Monde.

the entrepreneurs and professionals gradually learn by "capillary action");
- the difficulty of conducting professional preliminary socioeconomic surveys on the capacity and propensity to pay for the service in localities far removed from the capital.

Often, restricted resources or time prevent reliable data on the potential electricity demand and its load curve from being established, yet this data is indispensable for designing a DRE project, which is particularly capital-intensive.

Another difficulty is that institutional patterns are often ineffective for lack of decentralization, human resources and adequate funding to create a real change of scale (cf. chapter 1.2.2). The technical teams and financial services cannot deal with the complexity and burden of the procedures required to select projects, obtain funding, enter into contracts with service providers, or monitor and verify installation compliance with the rules and standards in force.
The financial backers' different, if not divergent demands and conditions create an additional constraint. They do nothing to facilitate safeguarding the local institutional patterns, nor innovative technological approaches, nor applying the public market rules. This lack of coherence creates confusing, if not competitive situations between and within a single territory (grant rate, remuneration levels, etc.).
There is also no, partial or ambiguous transfer of the Energy competence to the territorial institutions, which are nonetheless an essential staging post for making decentralized rural electrification effective. This situation presents two major faults that hold back project development:
- coordination difficulty, if not the risk of conflict over a project, with the centralized or deconcentrated structures of the Ministry for Energy.
- the lack of human and financial resources and skills in the area of energy in the institutions or at local level (local councillors, chieftains, religious leaders).

The issue of skills and resources is not exclusive to the public sector but also affects the local electricity firms. Although they are indispensable, they more often than not have neither sufficient experience of decentralized rural electrification nor sufficient financial standing. These drawbacks disqualify them from participating in large-scale projects.

The main limitations of the liberal model

While technological progress enabled this relevant model to emerge about fifteen years ago and develop rapidly, its deployment reveals at least two shortcomings.

Firstly, although it should target the whole of the rural population at the base of the pyramid, **it currently addresses a mainly relatively well-off customer base that is urban or peri-urban, for domestic needs.** Furthermore, as it stands, the liberal approach does not make for the emergence of broad economic activities, despite the tests carried out by energy kiosk developers (cf. chapter 3.3.).
Secondly, **the economic model is fragile**. Many operators who are still loss-making, regularly seek investors, which suggests companies going out of business (as we have already observed, mainly in East Africa, where most of them are based). In the case of certain PAYG operators, the absence of close links between the customer of the service and the supplier, due to dematerialized payment, also creates some mistrust. Operators win new customers but find it hard to retain them.

Therefore, neither model, *interventionist* or *liberal*, globally satisfies the challenge of electrifying rural Africa. The debate surrounding electricity as a "public service" or a "commercial commodity" is launched.

In the interim, the practical side of DRE must find its own way on the ground. It entails searching for complementarity between the solutions, taking all approaches together. It also calls for the development, alongside the indispensable skills in technical engineering*, social engineering capacity that are just as expert.

2.4.2. Social engineering is essential at all stages of a project if the rural community is to accept it

The distribution of portable solar lamps and individual solar systems has effectively ramped up access to electricity in the rural and peri-urban environments. Are we to draw the conclusion that "digitized" electrification with its lower running costs devoid of human intervention has a future?

Quite the reverse. Recent discussions between actors (at GOGLA, the off-grid solar energy industry association) backed up by conventional DRE project feedback, show that **intense awareness-raising work and guidance** for the rural communities and local and regional bodies is needed to develop decentralized access to electricity in the rural environment sustainably and satisfy the highest numbers.

This work primarily aims to:
- **better identify the needs** of future users and the community served;
- **better anticipate the risks** associated with the advent of electricity that are likely to affect the successful completion of the project or undermine its benefits;
- **specifically guarantee proper ownership** of the electricity service installed by local actors, which is a prerequisite of that service.

The socio-cultural, economic, geographic, political and demographic contexts affect the understanding of how energy is made up and the electrification possibilities. Each project has its own new, context-dependent parameters.
Thus, the sociological approach is here to stay – it is not a one-off analysis but a position, an awareness that permeates all project stages. It is primarily based on:
- listening to and observing communities;
- understanding the quality of their relations;
- raising awareness and guiding future users;
- mediating between the local stakeholders.

This sociological approach is not economically neutral:
- **firstly, it takes time and comes at a cost**; as many parameters must be incorporated from the design stage in the schedule and the operation's budget.

In the absence of real project ownership by the community or its representatives, the installations are not serviced and soon stop working. The project's sustainability is then clearly compromised, and the equipment will soon be consigned to the "aid cemetery" which is already quite full.

Pierre Jacquemot et Marie-Noëlle Reboulet, "Technological options and organizational models for rural electrification in Africa", Afrique Contemporaine 12, n° 261-262 (2017): 175-176.

Feedback from the field: Guyana, Maroni

A rural electrification programme was launched over 10 years ago to supply four villages in Upper Maroni with electricity including the village of Antecum Pata. This territory, which is several hours by dugout and plane from Cayenne, is home to about a thousand inhabitants, off the power grid.

The 12 million euro project aims to install hybrid photovoltaic and diesel power plants, as well as mini power grids. It is carried by the West Guyana Community of Communes, the project owner, and EDF SEI, responsible for its operation. The latter also remotely manages the infrastructures from Cayenne, using a specially developed monitoring system to transfer all the data measured on site as well as the operating states of the power plant components – via a satellite link set up on each totally isolated site.

While they were eagerly awaited by the populations of these villages, the power plants were only commissioned in the first quarter of 2018... more than two years overdue. The geographic isolation of these sites, combined with the climatic stress placed on all the equipment compounded by the resolve to manage remotely without any in-situ human go-between, significantly slowed down the commissioning of these power plants and complicated their operation.

Now, all the community buildings have access to electricity, but the power plants are almost idle, for want of house connections. In this region where the families have low incomes, grid connection is a formidable financial barrier.

Source: Representative working on the projects for the company SUNZIL.

- **secondly, it avoids cost overruns or earning losses** for the project developer, the operator and the users.

Access to electricity unsettles practices and incurs risks that need to be anticipated

Firstly, the advent of electricity shakes thing up. It presents users with a break that may be radical, whatever their previous experience of electricity:
- it **stands for improved living standards** in a territory, and economic development, if the project intends to back productive activities;
- but experience also shows that like any innovation, it **has adverse effects**.

Not only does it change pre-existing energy behaviour patterns by providing refrigeration, television or lighting, but it influences many individual and collective behaviour patterns (eating habits, ways of socializing and communication, etc.). This lifestyle transformation can "unpick" a collective (cf. inset), or at the very least, weaken it. Yet, to guarantee smoother operating conditions and ensure the service's sustainability calls for cohesion of the local community around the project to be led, followed by the installed system.

Furthermore, electricity, which is often eagerly awaited in a village, is also an "idea", cloaked in many fantasies. The specific constraints of installation and use of an electricity service are unknowns and using local energy sources (rather than the familiar generator set) introduces a new technology that has to be come to terms with… yet an additional destabilizing factor.

A proper grasp of how the service operates, what we call its "ownership" is vital to ensure that it is correctly used and operated and hence, its lasting availability:

- **making no allowance for these various risk factors ruins the chances of an electrification project's success**, whereas it is expected to be lasting and make a positive social and economic impact for the electrified territory;
- **their proper foresight and suitable action (information, training) are on the contrary, indispensable** (cf. inset). Time must be taken to flush out these risks, that tend to be imperceptible on initial analysis.

This sociological approach is particularly important where interventionist rationale is applied (for instance, electrification of public works or installation of a local grid), which calls for fundamental adoption by the populations, at individual and collective level.

Nonetheless, even with the liberal approach (which tends to be more guided by economic pragmatism than by searching for social impact), it makes sense for the risk analysis to include the

A professional has her say Marie-Christine Zélem

"Electrifying a rural territory cannot be summed up as providing electricity. It comes with a set of sea changes to shape everyday life that may be experienced as major upsets… social disorganization, political conflicts, the loss of know-how, changes to diet, and so on.

Therefore, electrifying a territory entails taking several precautions, firstly upstream (funding, training, information, participation, etc.), but also downstream and throughout its implementation: raising awareness of the challenges and pitfalls of electricity, dietary, functional and health education, making available compatible appliances and equipment (low-consumption lamps, energy-saving appliances), after-sales service, and so on…"

Marie-Christine Zélem is a Professor in Sociology at the Toulouse Jean Jaurès University co-director of the "Environmental Policies and Social Practices" at CERTOP-CNRS.

Find all the articles on the book's webpage: ***http://www.fondem.org/electrifier-lafrique-rurale/***

socio-cultural dimension, as poorly anticipated or badly managed risks undermine the economic model. This dimension of teaching and guidance of the local populations is found elsewhere in many service offers borne by private-sector actors (cf. Part 3).

While they are not exhaustive, the following observations and suggestions, all based on feedback from the field, stress:

- **the importance of "social engineering"** at all project rollout stages,
- **and the need to have a purpose-formed multidisciplinary team**, several of whose members have built the trust of the local populations. The actions to accompany the population and its representatives cannot be carried out by the technical engineers alone.

During the electrification project preparation phase, careful attention and co-building ensure that the project is relevant and accepted.

Various best practices should be applied during the upstream phase of electrifying a rural territory to ensure that the affected communities accept the project.

Choice of locality, collective and individual interviews, defining the electrification area… every rural electrification project preparation stage must factor in the "non-technical" aspect of the operation, namely, a whole set of sociological, cultural

Palabres, Guinea.

ELECTRIFYING RURAL AFRICA: AN ECONOMIC CHALLENGE, A HUMAN NECESSITY

and political variables that characterize each individual territory.

The choice of locality: the territory's "political neutrality" is a factor in the service's long-term success

In the interventionist rationale context, mainly local grid installations, the choice of which locality to electrify is driven by a dual objective process checking that:

- **the Ministry of Energy and electricity utility have not earmarked the locality for an electrification programme by grid extension;**
- **its place in the ranks of the localities to be electrified, has been set on the basis of previously established objective criteria** (cf. chapter 3.5.3 on feedback about mini-grid planning).

This approach helps avoid projects guided by purely political considerations. Experience shows that they are rarely viable. In most cases, the political figure who hails from the locality (and by extension his kin) is tempted to seek privileges once the service has been installed. That undermines the principles of controlling electricity consumption and payment for the electricity, in which case no rules or constraints can be applied, leading to tensions and ultimately interruption of the service.

Interviews... a key component that sets the composition of the team formed by the project developer

Once a locality has been retained, the initial determining surveys are embarked on for a period of variable length, to ensure that the later project phases are successful. In order to conduct productive interviews with all the contact people on the ground, local authorities, traditional chieftainships, users, and so on, the field project team must include:

- **people who are very familiar with the territory**: who speak the local dialect, are conversant with the rules of etiquette, taking up the right position, silences and so forth
- **female interviewers:** they will be more adept at conversing with women, who play a major role in managing the use of a domestic electrical system, in making the most of electricity in the home and in managing the budget required to make regular payments for it (cf. mini fact file).

Village meeting in Guinea to develop a DRE project

Planning: a few examples of tools

While the demand for access to electricity is strong but the financial means to meet this are poor, decentralized rural electrification must be scheduled.

It ranks the communities to be electrified along the lines of several criteria that aim to maximize the human and economic development impacts of electrification, **limit the risks of failure and also define the project implementation methods**, be they technical, financial or organizational by providing information on the target community or communities and their environment.

Several decentralized rural electrification scheduling tools have been developed alongside rural electrification software suites that integrate a decentralized component (Laper and Elvira by EDF and Géosim by IED). Fondation Énergies pour le Monde (Fondem) has devised the Noria software programme. As the number of communities to research is growing, **it has become vital to automate survey processing**, which is possible using the Fondem Octave tool.

MINI FACT FILE

The gender approach in rural electrification projects

The 1995 Beijing Conference, followed by the Millennium Goals for Development and the Sustainable Development Goals, mark a breakthrough in the international agenda by positioning equality between women and men as fundamental for reducing poverty. At the same time, the successive forums of Paris (2005), Accra (2008) and Busan (2011) also identified it as a priority issue of aid effectiveness.

A major change was introduced in development practices as an outcome of this growing awareness. The "Women in development" approach initiated in the 70-80s, targeting women through isolated actions in projects or programmes, was succeeded by the **"Gender and development" approach**[1], which, in the goal of achieving equality of rights and its application, means **considering the opportunities offered to women and men and their roles in society distinctly, to act on unequal situations.**

© Fondation Energies pour le Monde

A shopkeeper at Ambondro, Madagascar, with a fridge

Why should the gender approach be adopted for access to electricity in rural environment projects?

Access to energy is a fundamental issue for the development of women and men. However, women and men do not experience the lack of access to energy or the situation of energy poverty in the same way. Their expectations and needs are different.

- As women are responsible for most of the domestic activities that require energy, they are the first to be affected by the lack of energy and can make up for this lack by increasing their working time.
- access to credit or vocational training is generally harder for women. Furthermore, family decisions (investments, etc.) are more often than not made by men.
- other structural inequalities, like illiteracy, sometimes disqualify them from benefiting from certain projects.

Thus, the technical choices for a DRE project are not gender neutral. Preference for a particular energy production source may, for example, work in favour of men's rather than women's activities thereby reinforcing inequalities. So, it is vital to take gender into account in DRE projects.

Some studies emphasize that making allowance for gender paves the way for, i) reducing

"Women need to be included in the governance structure, the decision-making structure, and awareness has to be created across [the] board. Most of the time when people go to create awareness in communities they just concentrate on the men. What we are saying is concentrate on the women as well – they are the end users. Once you empower one woman you've empowered a nation".

Rhoda Mando, Assistant Director to Business Development and Gender Mainstreaming at the Nigerian Rural Electrification Agency.

Source: Charlie Zajicek, "How solar mini-grids can bring cheap, green electricity to rural Africa", Overseas Development Institute, 2019, *https://www.odi.org/blogs/10730-how-solar-mini-grids-can-bring-cheap-green-electricity-rural-africa.*

1. The notion of gender designates the relations, duties, socially and culturally constructed roles of women and men. It is a political and social construct that is differentiated from the notion of sex, which covers individuals' biological characteristics.

poverty more effectively, ii) improving grid connections through the active prescriber role played by women, iii) encouraging professional equality and improving the management of the energy supply chain (Dutta et al, 2018), and so on.

Some methodological best practices[1]

- **Context analysis including the gender approach**
- distinct analysis of the negative impacts suffered by women and those suffered by men, defining mitigation measures
- making allowance for the differences in needs and interests in relation to access to energy between women and men.
- **Use of sex-specific data and indicators and analysis of the findings**
- Analysis of women's demand for energy, their willingness and capacity to pay and their uses of electricity.
- **Partnerships and actions with positive impacts on reducing the inequalities between men and women**
- introducing grants or specialist access to credit targeting households run by women (Energy 4 Impact Sénégal)
- supporting the development of women's entrepreneurship (wPower)
- creating IGAs in the formal, more lucrative sectors
- promoting female employment in the energy supply chain (Programme WE d'Energie, 2014-2017)
- raising the awareness of households to ensure that the release of domestic time does not take the form of the consequential increase in women's working time in their productive activities (Cecelski, 2004)
- improving the education of young girls, by raising households' awareness so that they can study in the evening
- **Participating by the direct and indirect beneficiaries, women and men**
- organizing separate consultations if the women are generally absent from decision-making
- integrating women in technical training in the energy trades.

1. Taken from the AFD, Southern Coordination, methodological tools as well as Energia documents (2017)

Further reading :

Gender and energy

International Renewable Energy Agency. "Renewable Energy: A Gender Perspective". Abu Dhabi: International Renewable Energy Agency, 2019.

Cecelski, Elizabeth. "Enabling equitable access to rural electrification: Current thinking and major activities in energy, poverty and gender". Breibacher: Energy, Environment & Development, 2000.

Cecelski, Elizabeth. "Energy and Poverty Reduction: The role of women as a target group". The Hague: ENERGIA International Network on Gender & Sustainable Energy, 2000.

Cecelski, Elizabeth. "Rethinking gender and energy: Old and new directions". The Hague: ENERGIA International Network on Gender & Sustainable Energy et Enabling Access to Sustainable Energy, 2004.

Cecelski, Elizabeth, Soma Dutta, and Annemarije Kooijman. "Energy access and gender: getting the right balance". Washington, D.C: World Bank Group, 2017.

Clancy, Joy S., Margaret Skutsch, and Simon Batchelor. "The gender – energy – poverty nexus. Finding the energy to address gender concerns in development" London: UK Department for International Development, 2002.

Clancy, Joy S., Tanja Winther, Margaret Njirambo Matinga, and Sheila Oparaocha. "Gender equity in access to and benefits from modern energy and improved energy technologies: world development report background paper". The Hague: ENERGIA International Network on Gender & Sustainable Energy and Nord/Sørkonsulentene, 2012.

Dutta, Soma, and Sheila Oparaocha. "Gender and energy for sustainable development". Current Opinion in Environmental Sustainability 3, n° 4 (2011): 265-271.

Habtezion, Senay. "Gender and energy. Gender and climate change Africa". New York: United Nations Development Program, 2012.

Haves, Emily. "Does energy access help women? Beyond anecdotes: a review of the evidence". London: Ashden, 2012.

Kohlin, Gunnar, Erin O. Sills, Subhrendu K. Pattanayak, and Christopher Wilfong. "Energy, Gender and Development: What are the Linkages? Where is the Evidence?". Washington, D.C: World Bank Group, 2011.

O'Dell, Kathleen, Sophia Peters, et Kate Wharton. "Women, energy, and economic empowerment". New York: Deloitte University Press, 2014.

Orlando, Maria Beatriz, Vanessa Lopes Janik, Pranav Vaidya, Nico lina Angelou, Ieva Zumbyte, and Norma Adams. "Getting to Gender Equality in Energy Infrastructure : Lessons from Electricity Generation, Transmission, and Distribution Projects". Washington, D.C: Energy Sector Management Assistance Program and World Bank Group, 2018.

Rao, Narasimha D, and Shonali Pachauri. "Gender impacts and determinants of energy poverty: are we asking the right questions?" Current Opinion in Environmental Sustainability 5, n° 2 (2013): 205-215.

Johnson, Oliver, Vanessa Gerber, and Cassilde Muhoza. "Gender, culture and energy transitions in rural Africa". 2018. *Energy Research and Social Science* 49 (2019): 169-179.

Wamukonya, Njeri. "A critical lo at gender and energy mainstreaming in Africa". 2002.

Impact of decentralized rural electrification projects

Beguerie, Victor. "Impact de l'accès à l'énergie sur les conditions de vie des femmes et des enfants en milieu rural : Analyse d'impact du Programme des PlateFormes Multifonctionnelles au Burkina Faso". Université d'Auvergne - Clermont-Ferrand I, 2015.

Burney, Jennifer, Halimatou Alaofè, Rosamond Naylor, and Douglas L. Taren. "Impact of a rural solar electrification project on the level and structure of women's empowerment". Environmental Research Letters 12 de IOP Science, n°9 (2017).

Raub, Viviane. "Rural Electrification in Senegal: Access to Electricity and its Impacts on Women's Needs". Lund: Lund University Master of Science in International Development and Management, 2013.

Torero, Maximo. "The Impact of Rural Electrification: Challenges and Ways Forward". *Revue d'économie du développement* 23, n° 3 (2015): 55-83.

Methodological tools

Repussard, Clément. "Gender Toolbox, Energy". Paris: French development agency, 2015.

French development agency. "Gender Profile: Africa" (Accessible online). Paris: French development agency, 2016.

Capitalisation Documents

Alliance for Rural Electrification, and ENERGIA International Network on Gender & Sustainable Energy. "AREENERGIA Position Paper: Women and Sustainable Energy". Brussels: Alliance for Rural Electrification, and ENERGIA International Network on Gender & Sustainable Energy, 2017.

Mizrahi, Simon, and Geraldine Fraser-Moleketi. "Empowering African women: Plan of action. African gender equality index" Abidjan: African Development Bank, 2015.

Clancy, Joy S., Nthabiseng Mohlakoana, Yacine Diagne Gueye, Lydia Muchiri, and Indira Shakya. "Mainstreaming gender in energy sector practice and policy: lessons from the Energia International Network" The Hague: ENERGIA International Network on Gender & Sustainable Energy, 2016.

Rojas, Jackeline. "État des lieux de l'intégration du Genre dans les organisations françaises de solidarité internationale" Paris: Coordination Sud, 2016.

Dutta, Soma. "Supporting last-mile women energy entrepreneurs: What works and what does not". The Hague: ENERGIA International Network on Gender & Sustainable Energy, 2018.

The preliminary interview with the local authorities

The project developer, adhering to local customs, starts by holding meetings with those who will have to convey the message to the population and whose support is therefore essential, namely:

- the locality's councillors,
- the traditional chiefs and/or religious leaders of the Elders Council.

This step is the prelude to meeting the whole population, over and above the only people who are comfortable speaking in public. These preliminary interviews with the public and local moral authorities aim to clarify and share basic information by:

- **setting the general framework and the major project implementation steps**,
- **pointing out its implementation conditions** (uncertain until the business plan has been settled),
- **defining the involvement required from the authorities** during the various project stages.

It is essential to ensure that each participant fully understands, to mitigate the risks of misrepresentation to the population (which cannot be totally ruled out). In communities where verbal commitment takes precedence over writing, the words spoken during an initial meeting are of crucial importance. Any subsequent change to the methods stated orally will require long explanations before they are accepted.

If the natural presence of women is very rare, it is important to ask for their presence and explain the reason why.

Individual interviews with the future users

The project developer organizes a reciprocal exchange of information between the users and mandated trusted intermediaries. Individual interviews are held in the presence of the officials and direct users (parents, doctors, nurses, midwives, officials and teachers, entrepreneurs and apprentices, etc.).

The sessions are long enough (1-2 hours), to build trust for the purpose of:

- **specifying the electricity requirements** as expressed by the potential users;
- **explaining** how it envisages operating the electricity service, the benefits and limitations;

"Ruchi Soni, Energy Access Manager at the UN Foundation, explained to me why community engagement is so important:

Community engagement is essentially the heart of the whole [mini-grids] process. The private sector needs to engage with communities and locals on literally a day-to-day basis to understand their needs, why they would want mini-grids in the first place, and also how they intend to use their applications"

Charlie Zajicek, "How solar mini-grids can bring cheap, green electricity to rural Africa", Overseas Development Institute, 2019, ***https://www.odi.org/blogs/10730-how-solar-mini-grids-can-bring-cheap-green-electricity-rural-africa.***

And thereby:

- **gauge the difference between the expectations and constraints**, between the representation of the use of electricity (often formed by experiences in other already electrified localities) and real-life factors that will limit this use (limited electrical capacity or availability, cost to the user, etc.).
- **identify the risks associated with the advent of electricity** and the possible negative impacts, such as further deepening of social divides (cf. inset).

Interviews, when they are well conducted, gain support for the project and create the right conditions for ownership of the service when it is commissioned. Their role is crucial. In some cases, the exercise is delicate, like that of mini-grid installation. Even though the project has still to be approved by the electricity regulatory authority, the business plan has not been finalized and there is no precise information to be given at this stage, the issues of pricing, payment for the electricity and the budget that will be devoted to it must be raised and discussed.

All the teams involved in the survey and field visit process must convey a consistent message. As it stands, word circulates and is soon distorted when it comes to innovative projects such as electrification. Whatever the chosen solution, the unknown triggers strong, mixed feelings ranging from enthusiasm, scepticism to anxiety, that depend on personality and social standing or the vagaries surrounding project implementation.

"Electricity very quickly encourages families to acquire a television. The latter competes with the option of reading or writing for educational purposes. This is particularly true when families live in a single room. Hence, children in families that have several rooms or spaces in their dwellings are more likely to concentrate on their homework than those who live in crowded conditions".

Marie-Christine Zélem is a Professor in Sociology at the Toulouse Jean Jaurès University co-director of the "Environmental Policies and Social Practices" at CERTOP-CNRS.

Find all the articles on the book's webpage: ***http://www.fondem.ong/electrifier-lafrique-rurale/***

Defining the perimeter to be electrified

When installing a local grid, another important step is setting the perimeter for electrification as it calls for understanding and support from the locality's officials.

The grid route is set by factoring in two types of constraint:

- advance registration by the future users;
- the location of the main economic activity zones.

The latter are preferred because they are likely to use more electricity than households. If proper allowance is made for them, their development will be enhanced by using electrical appliances (higher productivity, increasing their catchment area).

Burkinabe garment maker using electricity

In fact, this route excludes a more or less significant proportion of the population:

- the dwellings sited on the outskirts of the locality whose connection is not economically viable;
- the most destitute families, whose resources are too low to take on the cost of the connection and payment for electricity use.

With electrification, feelings of exclusion and injustice are exacerbated by not being connected. Alternative solutions individually tailored to context and buying power, may be suggested to those left on the outside the grid's perimeter: portable lamps, individual solar systems, even an energy kiosk. As long as they have been clearly explained, they avoid aggravating a pre-existing social divide or creating new discrimination. Tensions, if not confrontations between the project developer and the "grid outcast" may occur once the perimeter is approved.

Support from the mayor, the deputies and the traditional chiefs is vital to:

- approve the chosen route,
- explain the reasons for its limits,
- and aid the acceptance of alternative solutions by households left outside its perimeter.

Furthermore, the grid route includes an aspect that should not be underestimated... namely land tenure. Regardless of the country or culture, it is particularly important. The issue of siting the production infrastructures, primarily the solar modules (that take up sizeable footprints near the localities), must be addressed at an early stage to find out which lands are available in order to obtain rights to use or lease the land.

Madagascar, Boréale project

"Today, you have to travel 40 km to have access to woodworking machines. Once electricity arrives, there'll be no need to make that journey anymore and that will save a lot of time. We will be able to work with other joiners and pool our machinery purchases".

The Kouramangui joiner
(locality electrified in 2019 by Fondation Énergies pour le Monde)

Alerting populations to the advantages and constraints of the electricity service

Ample awareness-building efforts must be made among local stakeholders, who should receive regular information throughout the various stages of project. The campaign will ensure support for the project, prior to the ownership of the electricity service, which is the essential for the long-term operability of the equipment and thus the benefits of electrification.

The harder the project is to grasp, the more essential and arduous is the task of educating the users and their representatives. Becoming a user of a mini-grid, whose installation is eagerly awaited, and may be what dreams are made of, is not simple choice for a rural family. The team carrying the project must explain and convince them.

The primacy of economic activities when defining the route of the local grid – is this selective access to electricity?

While the first DRE programmes that were part of the development aid drive of the 1980s to 2000s, focussed on collective, then domestic uses of electricity, its economic uses are now attracting an increasing amount of attention from financial partners and investors. These economic actors are value and employment creators. They use electricity, primarily during the day, when it is at its cheapest because it does not need to be stored.

However, if they are exclusively targeted, they will set the stage for a new social divide, while most of the rural population lives off subsistence farming, following the seasonal patterns

Being convincing is all the more important when the decision of whether or not to be connected to the power grid strongly influences the decision of a neighbouring household to follow suit.
Most of all, awareness-building efforts aim to ensure that the future users fully grasp the strengths and limitations of renewable decentralized electrification. They primarily deal with two basic constraints:
- **the need to use energy rationally** following energy efficiency principles,
- **the need to pay for electricity** even if its source is free and inexhaustible.

In practical terms, these awareness-raising sessions and information campaigns can take several forms:
- orally, in groups and individually, firstly to ensure that identical instructions are given to all, then explained individually if needed,
- using graphic material to keep track of the oral exchanges and provide aid in case of doubt,
- communication campaigns on the local radio can be regularly used to remind the users consistently of the most important messages.

Officials and elders may initially view the creation of a user association with pride of place for women, from the mini-grid design phase, as creating a counter-power, but it offers several advantages that ensure the system is properly managed:
- **conveying relevant information** on the uses of electricity, their benefits and risks;
- **addressing the questions or apprehensions** expressed and having a channel through which to answer them;
- **if necessary, limiting political cronyism** that is often created when setting up an electricity service.

Lastly, experience shows that the diaspora living in electrified urban environments must also be targeted. Broadcasting clear messages on the electrification arrangements of their original locality and particularly on the rational use of energy dissuades them from sending second-hand energy-intensive appliances to the families left behind in the village.

Cooperation must be continued during and after the commissioning phase to ensure that the service is properly owned by the users, and that it is long-lasting.

The work carried out with the local actors prior to commissioning aims to create project acceptance and encourage the support of its implementation. **Once the works are underway, the challenge is to create ownership**, the feeling of responsibility with regard to the service and the equipment, adoption of the rationales associated with the presence of electricity. Instigating and making it last are not that easy (cf. inset).

During the work through to power up

The installation of an electricity infrastructure in a locality is always a major event, an announced revolution... and a source of temptation. In the case of a mini-grid, the equipment generally comes from the capital, as well as the team of fitters. They represent an investment whose sum, even when undisclosed to the inhabitants, is rightly viewed by

Co-construction of awareness-raising and information tools

*"**When it comes to communication, local actors are in the best position to know which words to use to address populations** and users to designate a particular concept (bringing up to standard for example), word (kilowatt) or expression (saving energy), how to explain the risks of electrocution, the possibilities of over-consumption or being in arrears with energy payments...*

***Likewise, when information material needs to be designed** on how to use a refrigerator, on the interests and characteristics of lighting systems, or even the dangers of electricity, co-authorship would seem of the essence (translation into the local language(s), design with figurative drawings... »*

Marie-Christine Zélem is a Professor in Sociology at the Toulouse Jean Jaurès University co-director of the "Environmental Policies and Social Practices" at CERTOP-CNRS.
Find all the articles on the book's webpage: ***http://www.fondem.org/electrifier-lafrique-rurale/***

them as far exceeding a lifetime's income even for the most fortunate inhabitants.
Making sure of the population adoption to mitigate the risks of theft and to create the feeling of ownership involves going further than the prior awareness-raising and information already mentioned:

- **by involving the community in performing the installation work** – seeking local labour to carry out the civil engineering work (digging trenches, unloading or transporting equipment inside the locality) in the best of worlds may also identify a potential technician to manage the equipment.
- **when commissioning, by arranging an open day at the installation.** A guided tour of the plant rooms enlightens the inhabitants on the transition from the natural radiation offered by the sun to the current delivered all the way to a dwelling or a structure, explains how each component works, with supporting illustrated diagrams, shows the storage device for night-time or days without sunlight, the maintenance work to be carried out, etc.

After the grid has been powered up

The first moments of access to electricity are particularly important. Care must be taken to ensure that the electricity usage routines that set in do not create any misleading adverse effect.
The advent of electricity, handmaid to modern society and its material expressions (television, internet), often comes with an increase in the number of electrical receivers in the home. Yet, this

Installation ownership – the biases of development approaches

Over and above the ownership of the infrastructures and equipment depends on the development paradigm that prevailed when the electrification project was designed and coordinated.

Grants and free service have their limitations
Development models are based on what is often regarded as a form of grant… the "experts" install technologies free of charge, which gives no information on their value and even less so to learn to value them. This perception, regardless of the technology, makes it hard to own them. When the service rendered comes for free, the notion of "being due" is underpinned. Every problem, breakdown, triggers wait-and-see or exasperation feelings without knowing what needs to be done or who to turn to.
For example, when hydraulic wells were installed in Madagascar, the villagers of Amberiveri, who had not been involved in the project, refused to manage the wells, that they did not qualify using the possessive pronoun "our", as in "our wells", but referred to them as "the wells". This expresses the lack of ownership, leading to the lack of management and maintenance, forms of sabotage and rapid malfunctioning that has never been resolved.

The participatory model and its ambiguities
This more anthropocentric model that focusses on individuals also faces local resistance. As it entails taking into account cultures and socio-political aspects to manage territorial identities, it proposes an organizational pattern derived from Western thought and "'contracts' the individuals, handing out rights and obligations to each one, including sanction"(Winter, 2011), through a sort of universal governance, decreed instead of customary governance methods. This "democratization" embodied by ad hoc "user committees", is likely to generate conflicts in the villages, between clans, families, villagers and the authority's usual representatives.
Under the terms of the "Alizés électriques" decentralized wind power project in Mauritania, management committees duplicated the existing social and political organizations without taking into account the divides that transcend them, creating a second decision-making venue that was not always an exact match of the first that was generally narrower and above all organized along hierarchical lines (Caratini, 2005).

The "tragedy of commons"
This notion, used to describe the negative effects of making available for sharing a resource, capital good or equipment (water, air, land, etc.) to a group of people (district, village, community, etc.) is not alien to DRE. Even if originally, it referred to free goods, it applies to individualized uses in the case of a common energy production system. Once users have their own meter, even if they pay for what they use (prepaid card, bill, etc.), over-consumption by some of them can hit the system and damage it (breakdowns increase).
The experience of the Palikur Amerindians on the Oyapock resembles many others in Sub-Saharan Africa. Those who have an individual meter sometimes sell electricity to their neighbours who cannot afford to have their own electrical installation. Sometimes there are more than 15 "unauthorized" connections on a single meter, which regularly brings the power plants to a halt as they are stretched beyond their production capacities.
The reasons for these malfunctions are both the under-dimensioning of the electrical infrastructures, which may be for many reasons (financial constraints, too brief a needs analysis, inappropriate pricing) and general ignorance on how these technologies work. As soon as they have a functioning connection, some users behave like "freeriders" and indulge in logical but unsuitable practices (some resell, others steal), left out of the electrification developers' scenarios.

Marie-Christine Zélem is a Professor in Sociology at the Toulouse Jean Jaurès University co-director of the "Environmental Policies and Social Practices" at CERTOP-CNRS.
Find all the articles on the book's webpage: ***http://www.fondem.org/electrifier-lafrique-rurale/***

situation runs two risks:

- **regardless of whether or not they are low-consumption receivers, they are incorrectly used, and their inept use incurs energy over-consumptions:** refrigerator propped open with a piece of wood, vaccine storage units also used to store food, lights left on all night to protect the house from evil spirits, and so on. When diverted from their initial function, these uses show how the notions of energy management and rational use of energy, which are intimately linked with any recourse to renewable energies, require awareness-building and training even though the use of electricity is innovative.
- **even when used properly, the receivers are of mediocre quality and very energy-intensive.** Apart from LED bulbs, which are widespread, low energy-consumption electrical appliances are not necessarily available, while transport costs and potential customers' low purchasing power are inconducive to establishing a market for products of this type. These receivers are still expensive even within the scope of the national grid, whose social electricity rates from the grid do not penalize the use of entry-range appliances. Consumers often make do with second-hand equipment or equipment whose attractive price can be explained by design faults (badly-placed switches, broken wires, etc.).

Yet in decentralized mode, it is vital to insist on high energy efficiency receivers or foster their use. Much higher than forecast electricity bills and expressed user dissatisfaction result from misuse or inappropriate use of unsuitable receivers. The biggest consumers, the first to be affected, tend to be notables. They are listened to and respected, so their grievances become common knowledge and are repeated, sometimes to the point of conflict with the local operator (even if the pricing schedule was approved by the national electricity sector regulatory body). The regional and national public authorities that are too far away, cannot remind the stakeholders of their commitments.

Multiple connections

Thus, every project can and must concern itself with controlling the demand for electricity and proper understanding of its constraints on the part of the users. Several levers can be brought to bear:

- **supplying equipment that meets the populations' needs accompanied by user guides that can be understood by them.** The new electrification methods (e.g. PAYG; cf. chapter 3.2.2) often include receivers exclusive of any other equipment;
- **provide a price inducement for the use of low-consumption receivers.** Operators are free to set their tariffs as long as they are approved by the electricity sector's regulatory body;
- **provide an after-sales service,** i.e. a low-consumption receiver servicing/repair facility.

Over and above these incentive mechanisms, dialogue must be continued with all the users and their representatives:

- **regular meetings** that bring together user representatives, the operator, the mayor, traditional chiefs etc. provide opportunities to exchange and discuss.
- **the users' association** is the preferred channel for dispensing information, learning of dissatisfaction and dialogues.
- well-chosen **mediators** may be effective allies for settling certain conflicts about the quality of the electricity service that will arise sooner or later (primarily when the source is very weak), the pricing schedule and any changes to it, new connections, and so on.

"Every 'commons' resource tends to be over-exploited, because nobody has the power to limit its use and everyone tries to make the most of it".

Hardin, 1968, quoted by Marie-Christine Zélem.

A well-negotiated low-flow period in Madagascar

The 42-kW micro hydropower plant installed at Antetezambato, in the centre of Madagascar, has been running since December 2002. The low-flow period of the watercourse that supplies it lasts 2-3 weeks a year, interrupting electricity production.
This issue was planned for even before the plant was primed, **an agreement was negotiated between the operator, the users and the nearby farmers so that during the low-flow period all the water would be allocated to agriculture.**
For 17 years, the power plant users have reverted to their former energy habits, without generating any conflict during the low-flow periods.

© Fondation Energies pour le Monde

Micro hydropower plant at Antetezambato (Madagascar) – 42 kW

2.4.3. One of the main challenges entails providing a sustainable electricity service despite the fact that the local sector is still in its infancy

The infrastructures and equipment, regardless of which technologies are implemented must ideally meet the following four conditions if they are to guarantee users sustainable access to electricity:
- **be based on good quality long-lasting materials;**
- **have an efficient customer service and reliable spare parts reordering source;**
- **have provision for collecting and recycling its end-of-life components;**
- **really be owned by their operators and users.**

This last condition lies partly in the local actors' hands, under the auspices of the project owner and the team that informs and builds awareness locally. As for the other three conditions, that depend on how the regional or national market is structured, they rarely come together in practice despite some significant progress.

Equipment quality and service life are no longer an obstacle to the spread of DRE, but the lack of standards impedes market consolidation

In principle, the service life of the main renewable energy electricity system components is high... more than thirty years for hydropower production units, solar photovoltaic modules and their associated structures or cables.

However, the mediocre quality and short lifespan of some equipment available on the market poses recurrent problems especially in Sub-Saharan Africa, where standards and quality controls are either non-existent or below par.

This issue is particularly poignant in the field of small domestic equipment sold directly

Portable solar lamps and individual systems (from 30 to > 200 Wp) are available at markets or in electrical appliance stores. The components, sold with no attention paid to their assembly, often flout all standards and are not subject to inspection of any sort, neither by the Customs service or at their point of sale. Additionally, resellers have a dearth of qualified staff capable of any kind of self-checks.

As for portable solar lamps:
- dozens of types are available at a single market, for prices that can vary as much as five-fold. While the service provided is claimed to be the same, the price difference results from a difference in sturdiness, a luxury that rural families' budgets rarely stretch to;
- many of these mass-produced lamps, often in Asia, are "disposable" because they cannot be repaired, and form a major new source of pollution (plastic, electronic, dry cells and batteries).

As for individual solar systems:
- the module nameplates are often misleading about the manufacturer's name and the technical specifications (cf. inset), while no references are given on the regulators, inverters or batteries

- these systems have been cobbled together from unsuitable components that offer service lives of six months to three years, as opposed to five to ten years for similar, but better-designed, better-installed equipment;
- sometimes installer incompetence assembling these unbranded inefficient components adds insult to injury;
- expert estimates reckon that 80-90% of this type of installation are out of order in Africa.

So much for observations. The good news is that the above situation can be remedied.

Project or lease-sale rationales tend to drive up product quality

The capital-intensive nature of renewable energies, which is problematic for financing the installations by the users themselves, should eventually lead to improved product quality. This is because, financers and investors require hard-wearing, reliable products as the electricity service stems from an interventionist or liberal approach (cf. chapter 2.4.1):

- projects implemented as part of electrification programmes approved by public institutions must **comply with regulations and technical standards** designed to guarantee installation quality, performance, safety and sustainability;
- in order to **make a profit out of their own investments and satisfy their investors**, lease-sale service operators of the Pay-As-You-Go type (cf. chapter 3.3), who are aiming for widespread distribution of their solutions, have every interest in using reliable and sustainable components that meet current standards when they exist.

In both instances, the procurement of quality products is one of the pillars of the economic model and are backed by recent progress made by the manufacturers:

The untrustworthiness of values marked on PV modules

During a training session on photovoltaics in Benin in 2018 for energy professionals, the trainer asked the trainees who were all either resellers or PV equipment installers, to bring one or more modules for the practical sessions.

During the exercise the trainees performed measurements in field conditions on 8 new attractively-priced PV modules available on the local market.

The measures result was conclusive – actual performance levels were 15-30% lower than those marked on the product nameplates, while none of the modules complied with the minimum prescriptive requirement of products available in Europe.

Source: Étienne Sauvage, HACSE.

- routine controls and certifications associated with mass produced regulation and energy conversion equipment have removed the obstacles initially encountered;
- batteries, provided that they have been properly selected for the planned use, on the basis of today's technology now offer adequate guarantees for 2-10 years of service life.

While, within the framework of structured or lease-sale programmes, decentralized system component quality is no longer an obstacle to the sustainability of the electricity service, the same cannot yet be claimed for *in situ* repair capacity.

In the rural environment, customer service and supplies of spare parts still have many shortcomings

The first breakdowns, if they last more than a few hours, often result in signs of abandonment, if not downright refusal to pay for the electricity. Therefore, customer service efficiency and the availability of spare parts within reasonable times are two essential conditions of long-term electrification system operation and their economic viability.
In practical terms, it calls for regular preventive installation monitoring to check that they are operating properly and identify any breakdown risks, but also and above all for available, skilled customer service operators, as well as spare part supply and distribution chains.

Preventive monitoring requires trained contact people available close to the electrification systems to apply the right protocols to identify the malfunctions and breakdown risks. This preventive monitoring reduces the travelling of specialized technicians and spare parts needs, and thus running costs.
Identifying and training these specialists is not the main problem but their turnover rate once they have been trained, especially in out-of-the-way places. One method of overcoming this problem is to select a mature local person, who commands respect.
Incidentally, there are not enough customer service providers in the rural environment. There is shortage of qualified staff (specialist technicians) and they do not have networks deployed over all the rural electrified territories. The same hold true for the spare parts supply and distribution chains. Often, these shortages lead to failure to carry out preventive maintenance properly or respond quickly to troubleshoot electrification systems, which undermines user support and with it, service sustainability.
The upshot is that very special attention must be paid to the following two points if the project is to succeed:

- **facilitate spare parts imports and delivery to the site** in a proactive approach and at minimum procurement cost;
- **devise pooling mechanisms** that make the components prone to failure available to the operators from secured storage depots.

Similar questions need to be resolved for electrical receiver servicing and maintenance that retailers cannot currently provide.

The weak link in the logistics chain is the management of end-of-life equipment

Whatever precautions are taken to ensure that the electrification system components keep working (preventive monitoring, servicing and maintenance, spare parts availability), their service lives vary in length, but in any case, they are limited. They amount to a new source of pollution (plastic, electronics, dry cells and batteries) if nothing is done to manage them. This also goes for electrification equipment that can still be repaired but has been abandoned by their users.

This electricity system production components issue is compounded by that of electrical receivers, primarily household appliance waste. They raise special waste management issues owing to the effects caused by fluids (water and soil pollution, landscape eyesores, fly-tipping, jettisoning of powerful GHG gases, etc.).

Recovery and recycling chains are needed to manage end-of-life or dumped components and receivers, in addition to storage for hazardous waste. While these chains are taking their first steps in Sub-Saharan Africa, there is growing experience in the matter. The example of the Burkina Faso company BETA demonstrates this awareness (cf. inset).

Ownership of the infrastructures and equipment is the best guarantee of their sustainability

Proper user grasp (project owner, operators, users) of how the infrastructures and equipment work and their support for the service rendered is vital for the sustainability of the service. One of the most delicate phases of decentralized rural electrification is succeeding in giving rise to the feeling of responsibility with regard to the service and the tools that deliver it (cf. chapter 2.4.2).

"LAGAZEL solar products are manufactured locally in Africa by specially-trained technicians. The first workshop, which started operating in September 2016 in Burkina Faso, manufactured almost 60 000 solar lamps in 2 years. This innovative approach enables LAGAZEL to guarantee the social and environmental sustainability of the value chain, like a local customer service point in the countries where we have workshops. Firstly, that gives the customer investing in solar equipment confidence. Secondly, the possibility of having a lamp component repaired rather than exchanging the lamp lengthens the product service life and reduces the volume of waste.

LAGAZEL is backed by the Agence Française du Développement's Facility for Global Environment to expedite the replication of manufacturing workshops on the African continent. It aims to have five of them up and running by 2025, which will create about a hundred local jobs".

Arnaud Chabanne, renewable energies engineer who is aware of access to energy issues, has been working in Burkina Faso's solar sector since 2004. He co-founded LAGAZEL in 2015 with his brother Maxence, aiming to industrialize the manufacture of quality solar lamps on the African continent.

Find the whole interview in French on the book's webpage: ***http://www.fondem.org/electrifier-lafrique-rurale/***

This ownership is all the more necessary when there are different stakeholders and interdependencies between them. Thus, it is crucial in the interventionist approach, in the case of a mini-grid electrification project, for example (cf. chapter 3.5.3). Observations on the ground demonstrate the importance of commitment by actors seasoned in setting up access to electricity programmes, who combine skills in the methodology, knowledge of the field and capacity to talk with the various stakeholders, be they foreigners or local, financial or technical (cf. chapter 2.4.1.).

An example of a battery recycling initiative

Mr Kabré, Director of the company BETA, at Koupéla, east of Ouagadougou is committed to protecting the environment. He has made collecting photovoltaic components his main hobbyhorse. Every year, he sells around 5 000 lamps and individual solar systems through informal distribution channels.

The rechargeable storage batteries of solar lamps and non-spillable batteries that are replaced are collected and stored. As soon as the utility vehicle loading capacity is reached, they are delivered to the company Bedaya, based in the capital. BETA sells them to Bedaya for the sum of 8 000-12 000 FCFA (€ 12-18) per 100 Ah/12 V battery. The latter puts them into the car battery collection circuit and finally delivers them to Accra, in Ghana, for onward shipping of storage and other batteries to India for recycling.

2.4.4. To ensure that the service is viable and sustainable, pricing and payment for electricity must be thoroughly factored in

The viability of an electrification system's operation, the pricing policy adopted for selling the service and associated payment methods are the main basis for its sustainability.

Regardless of the underlying rationale – interventionist or liberal – setting a price for a service entails reconciling the feasibility between operating constraints and commercial opportunities. The pricing schedule and collection mechanism implemented must also face the twofold challenge of:

- **generating adequate revenues to produce operating results that match the need for economic viability**, if not profitability of the service, if possible, creating a surplus (the surplus can be invested in new connections or set aside for equipment replacement);
- **being compatible with users' willingness and real payment capacities**, which in the rural environment, is complicated given the low level and seasonal nature of their incomes.

Pricing fulfils three major functions.

For a mini-grid, this definition has three kinds of sometimes contradictory yet adjacent interests that create a conundrum that must be resolved:

- **the operating companies** seek to increase their revenues,
- **the public authorities**, primarily the state, seeks to extend the electricity service to the highest number of people at an acceptable price,
- **the users** seek to minimize their energy budgets.

The above interests, whose convergence is akin to squaring the circle, match the three major functions of pricing: covering costs, ensuring equitable redistribution and influencing the uses.

The cost covering function

Covering the costs engendered by the system set up to provide the particular service offer is decisive for the sustainable equilibrium of the system's trading accounts and thus, system viability.
In an ideal world, the service tariffs should cover all the operation-related costs:

- infrastructure depreciation;
- infrastructure maintenance (preventive maintenance and component replacement);
- running costs and service management overheads;
- operating risks (insurances);
- infrastructure development;
- investor compensation;
- the operator's profit margin.

Achieving this cost coverage goal tends to be compromised by economic and social choices that elude the designer if not the system operator who is next in line.

The redistributive function

The public authorities may decide to implement revenue transfer mechanisms between the various user categories, primarily in the interests of family accessibility to the service or developing specific economic activity sectors.
The introduction of "social" rates that ignore actual costs, is usually based on a rate equalizing scheme comprising a single rate applied to two users with the same consumption profile, regardless of where they are physically based. This solidarity between the urban and rural populations is implemented in practically all public services whose coverage is organised as a network. When that does not affect the feasibility of a DRE project, equalization fosters service accessibility to the highest numbers. In this sense it is desirable, provided that it is confined to a suitable catchment area (cf. the recommendations made in part 4).

The state may seek to favour specific sectors or economic activities to stimulate their development, by allowing them to benefit from particularly low tariffs, which boost the positive externalities created by using electricity but are too low to enable all the costs to be covered. Thus, service under-pricing has to go hand-in-hand with a subsidy mechanism (direct or indirect) to pay the operator. In most developing countries, the electricity utilities' pricing systems reveal this redistribution and generally breaking down the rates into "social", "cottage industry", "industry", "public lighting", "pumping", etc. categories. DRE projects also apply this type of segmentation whenever possible.
This contrasts with the freedom to set tariffs under the liberal approach. Developers can optimize their pricing policies in line with their business strategies. While the numbers policy is required to attract new investors, the security of regular payment is just as relevant to confirm business plan forecasts.

The signal function

Pricing is a mechanism that shapes the orientation of electricity service users' economic choice over and above the economic equilibrium and redistribution functions. Indeed, price is one of users' main criteria when deciding whether or not to adopt the service, or when choosing between various service levels.
Thus, the "price signal" is used to influence user behaviour, with a view to reconciling their choice with the economic optimum of the service. For example, night-time use, that draws on battery-stored electricity is distinguished from day-time use, that calls for solar production alone[1]. The variable rate will motivate users to use electricity outside evening hours whose production costs are higher.
What holds true for the users is symmetrically so for operators developing sales in a regulated price context. If the rate applied to a use (e.g. domestic) guarantees a lower margin than that of another type of use (e.g. productive), the operators will gear their promotion drives to the latter. Pricing also helps gear investment decisions to specific areas or sectors.

Challenges stemming from factoring in equity

The economic viability of rural electrification is penalized by the per-user investment and operating costs (primarily of personnel) that are higher than in urban areas. The outcome is that although the financial precarity of rural Sub-Saharan populations is greater, access to electricity costs them more.

1. Many uses can be concentrated during production periods (middle of the day for solar, high-water for hydropower): industrial and craft activities, thermal uses for highly storable cooling and heating, agricultural uses linked to harvest or processing dates.

In principle, pricing inequity should be the norm

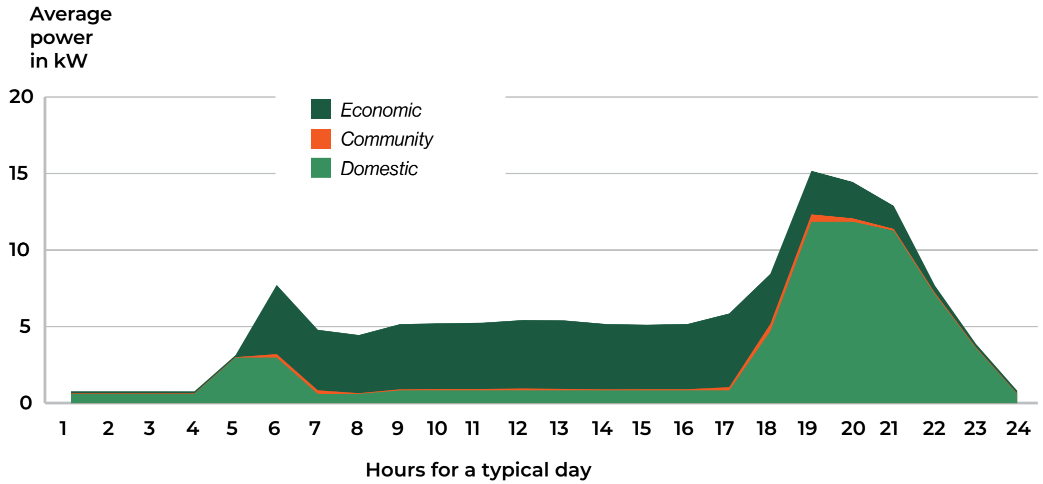
Three factors, already mentioned (cf. chapter 2.1.2.) combine to explain the difference in costs that discriminates against the rural environment: the lower user numbers, greater dispersal of the customer base, and a very much lower load factor*, of about 25-30% in the rural environment compared to 60-70% in the urban environment.

Two phenomena are to blame for this lower load factor (cf. graph):
- low domestic electricity use, concentrated on very limited uses (lighting, audio-visual) at peak times;
- the fact that this low use is not offset by economic, community or administrative activity use, concentrated outside these peak periods.

This is compounded by an additional rate variability factor for rural populations... the geographical context. The rate, for a single user category, differs from one rural area to another in line with the type of possible activities in the territory, the extent of its degree of isolation, etc., leading to the following unacceptable human development and ethical paradox that the more isolated and poor the territory is, the more expensive the supply of electricity is.

In the context of a rural mini-grid, making allowance for cost variability may lead to adopting two contrasting pricing approaches:
- ***ad hoc* pricing defined in line with the local context.** This applied for a long time to France and is the approach adopted by the electricity sector's regulatory bodies in the countries of Sub-Saharan Africa;

Demand – use is concentrated in the evening (projected curve for the village of Sambailo in Guinea).



Source: Fondation Énergies pour le Monde.

- **a rate equalization mechanism**, which guarantees users an electricity supply at regulated sales prices applying the same economic terms to all by virtue of being a "public energy service".

Local rate equalization is an interesting but complex solution to implement

The rate equalization principle means that **two consumers with the same consumption profile are invoiced at the same rate, irrespective of their geographical location within the territory**. It can work at national or local level, at the scale of part of the territory (such as a region).
Although national equalization was sought by the Senegal's rural populations, promised by its political leaders, and examined as part of the electricity price harmonization scheme, it faces obstacles that have forced it to be postponed.
This type of mechanism can only operate on two conditions:
- the percentage of urban users must be much higher than the rural users;
- the urban users' electricity use and financial resources resulting from their fees must be high.

Yet, in most of the Sub-Saharan countries, the population is still mainly rural, urban electricity consumption is low and the fee amounts are random.

Additionally, the introduction of an effective rate equalization mechanism has to contend with myriad projects and situations in the rural environment. This disparity accentuates the difficulty... how should we go about choosing a relevant territorial scale to devise a single appropriate mechanism?

Local equalization, founded on the solidarity between user classes, is one solution for easing access to electricity for the most destitute members of the population. Although it is easier to set up than national equalization, its introduction faces two obstacles:
- **the redistribution that it organizes for the most vulnerable may arouse great misgivings** in the territory's influential families;
- **the DRE companies' financial acumen and capacities are seldom compatible** with managing an equalization mechanism, even when it is simple and local.

So, at least two aspects of electricity pricing are inherently controversial – the price levels and the choice between single or differentiated pricing. It depends on the position adopted by the various participants (users, electrification companies and national and regional public players).

The choice of pricing – positions that are hard to reconcile

In the case of an individual electricity system distributed as part of a purely commercial venture (cf. chapter 3.2), the difficulty with pricing is in fact reduced. Many external factors come into play (consumer expectations, competing offers, market size, compliance with standards, and so on), but the service provider is free to set the service price, after adjudication essentially guided by the profitability goal. Furthermore, when there is no interdependence between users, failure by one of them to pay does not jeopardize the rest of the community's access to the service.

In contrast, whenever the project follows institutional and multiple player rationale (interventionist approach) and access to the service is dependent on users' collective discipline, it is vital that everybody accepts and upholds the introduction of fair pricing. Which is no small matter. In fact, mini-grid designers must make allowance for the stakeholders' often divergent points of view.

The users' stance – the right price

Urban users, well aware of their purchasing power, seek the most reasonable rates and any rise is taken badly and likely to trigger violent reactions (protests, demonstrations).
Rural dwellers who still have no access to electricity are generally ready to pay much more than the urban rate in the light of the savings made through electricity and its value in use (particularly telecommunications and lighting), which many surveys bear out (cf. inset).

Nonetheless, while rural households are ready to pay a lot for electricity (rather than not have access to it), they know how much families connected to the power grid pay elsewhere. If they have to pay much more for the same service than the others, then the reasons for it will have to be explained to them. In order to get them to accept the price and ensure the level of service, transparency on costs is the order of the day. It implies that the developer, with the support of the local authorities can come up with a well-substantiated argument that the users can understand.

High, yet under-priced rates

In urban areas...

Rates in many Sub-Saharan African countries are among the highest in the developing world. Price raising is politically unpopular, even where more households have a willingness to pay for electricity services with improved quality. For example, Twerefou (2014) finds that households were prepared to pay on average about $ 0.27 per kWh for improved quality of electricity service in Ghana, or about 150 percent of the rates at the time of the study. Similarly, Oseni (2017) finds that Nigerian households would be willing to pay up to 86 percent above the current rate for improved service quality. Yet, under-pricing persists in both countries.

Source: World Bank Group, "Africa's Pulse: An Analysis of Issues Shaping Africa's Economic Future" (Washington, D.C, 2018).

... as in rural areas.

The survey conducted in 2001 for the purpose of preparing the rural electrification master plan for the Cameroon for 1 450 potential users (each representing a family unit of about 10 people on average) shows that small and medium rural consumers are **ready to pay three times as much as urban users.**

Source: Rural electrification master plan in Cameroon, 2001.

Key figures

Depending on social category, € 5-15 are spent on purchasing candles, burning oil or electric dry cells, that equates to **10-15% of the monthly household budget.**

Sources : Noria Surveys, Fondation Énergies pour le Monde.

The operators' stance – profitability

For concessionary or lease operators, profitability guides their investments. Given the other investment opportunities these companies expect:

- a financial internal rate of return (FIRR) of about 15%;
- and/or a return on investment (ROI) for a period of less than 15 years, given the specific risks of the Sub-Saharan countries.

Companies are aware that the rates can neither exceed users' capacity or willingness to pay, and that a badly-adjusted or misunderstood rise increases the risk for their business. Optimizing pricing, together with obtaining possible investment grants (cf. following paragraph), are vital to this profitability.

Pricing is a political issue

The public authorities, who are eager to defend the users, affect the rates. They seek to promote private investment in DRE by setting up grants or tax cuts.
However, the diverseness of the grant mechanism, which is also expedient in driving up project quality (cf. inset) may create inter-project competition or even conflicts. This is because, grants may cover 30-80% of the initial investments, depending on the territory in question and its potential economic development.

The public authorities, wielding more or less authority depending on the country, ensure that certain pricing principles are upheld. Are different rates acceptable for electricity distributors and users in the rural environment? Is it acceptable for project developers to dictate their own tariffs? How can we judge whether or not they are appropriate? To answer these questions, the electricity

Grants are not indispensable but make for quality electrification

Services have been independently developed without any type of subsidy in some African localities. The electricity is sold to a tight nucleus of consumers at very high prices of around 2 500 FCFA (or 3.8 EUR) per lighting point per month and the users are satisfied.

But the installations are very basic, do not meet any safety standards and the system is just waiting for the first breakdowns to happen. Electrification with professional standards can hardly be envisaged in these financial conditions.

sector regulatory bodies draw on investors' and private operators' business plan analyses, that seem to satisfy them. Yet, it must be admitted that the population's response (few users, low consumption levels) seldom matches the simulations.

It should be stressed that some opinion leaders, who defend the generalization of the current pricing schedules in the urban context and do not make allowance for the financial situations of the national utilities or the lifelines sent to them by the state, pour scorn on the fairly recent involvement of private actors in what is a traditionally public sector. Consequently, most of the national policy makers support the setting of low tariffs and rate equalization between urban and rural areas. This stance is taken up by the regional and community peers (cf. inset).

However, the situation is changing direction towards decentralization which is slowly but surely making headway. The gradual transfer of skills, the emergence of the territory concept and access to a quality electricity service provide economic development opportunities for the territorial communities. Henceforth, there could be new close dialogue between project owners and operators, which could make for consensual pricing arrangements.

Pre-financing connection costs breaks down the access barrier

In DRE, the initial connection costs are a major barrier to access to electricity, regardless of the proposed service. Weighing in at € 20-50 per user[1] depending on the user contracts, they exclude a large segment of the population that cannot be precisely determined because of the variety of contexts.

Connection to a mini-grid or installation of an individual solar system inside the user's dwelling may be financed by the project developer's budget. These connection costs are then split to make them "painless" for the user and re-invoiced using a periodic rate component that makes allowance for:

- the distance from the grid or type of solar kit for the connection, for example,
- and the number of rooms, lighting points and sockets for indoor installations.

This works pre-financing option entails a cash advance and complicates pricing, but, for the operator, it offers a twofold economic and operational advantage:

- it widens the user base by removing the barrier raised by paying for the connection cost;
- it guarantees the compliance, safety and sustainability of the indoor installations, for work undertaken by users often leads to rough-and-ready electrical installations that endanger individuals and property and enforce inspections prior to powering up.

Digital solutions facilitate payment for electricity services

Post-payment has long dominated electricity service payment methods along the lines of existing mechanisms in Europe. Electricity use is calculated by the operators and the users settle their accounts every month against invoice. Post-payment is economically unsuitable for the African rural context, although it is relatively inexpensive because it is limited to a simple ordinary meter:

- **the collector must visit the users very often**, as overdue payment rates are high;
- **setting up a daily or weekly payment device is too expensive** compared to the sums collected.

But this is hardly the end of the world, because new remote metering and cell phone pre-payment technologies reduce the above risks and help the operators balance their books if not create a surplus. The proponents of PAYG, who apply pre-payment to individual solar systems. have shown the way. This solution is starting to spread rapidly to all patterns of electricity service provision (cf. chapter 2.3.1.) interventionist and liberal approaches alike.

1. Source: Fondation Énergies pour le Monde.

Regulating mini-grid service pricing – the examples of Nigeria and Rwanda

The Nigerian Electricity Regulatory Commission (NERC) regulates tariffs for mini-grids developed by independent companies with distribution capacity of more than 100 kilowatts (kW). The goal is to establish cost-based tariffs, given targets for technical and commercial losses. For mini-grids with distribution capacity of less than 100 kW, NERC will accept tariffs that have been negotiated with the community.

Like Nigeria, Rwanda requires cost-reflective mini-grid tariffs. However, a mini-grid developer need not obtain the regulator's approval of its cost calculations before its retail tariffs go into effect. The regulations indicate what is to be included in calculating allowed costs. The regulator reserves the right to review the developer's cost calculations at any time.

Sources : Bernard Tenenbaum, Chris Greacen, and Dipti Vaghela, "Mini-Grids and Arrival of the Main Grid: Lessons from Cambodia, Sri Lanka, and Indonesia" (Washington, D.C: World Bank Group, 2018).
World Bank Group, "Africa's Pulse: An Analysis of Issues Shaping Africa's Economic Future" (Washington, D.C, 2018).

Mali – national pricing that applies to everybody

During the first decade of the millennium, Mali backed the development of decentralized rural electrification projects awarded through tenders to private companies that set their own pricing schedules.

The country has reversed this approach by asking the public electricity utility, Electricité du Mali, to take over the operation of the electrical infrastructures of the main cities of their cercles, that were originally awarded to private concessionaires. Since then, the national utility's pricing schedule applies.

There are various reasons for this change in strategy. It is a political choice, first and foremost, that makes for equalization throughout the territory in the name of a public service, to which Malians made a strong social claim. It is also a technical choice – the national utility appears to be more effective at making the existing DRE systems operate smoothly and sustainably than the operators who created them and very often experience financial difficulties.

A professional has his say
Mamadou Saidou Diallo

In your view, which main difficulties do mini-grid developers encounter in the Guinean context ?

"First of all, we must remember that the mini-grid operator occupation is recent and still under-developed in Guinea. Only a few operators are currently working in the wake of the DRE projects completed between 2006 and 2013 backed by the Decentralized Rural Electrification Bureau, that has since become AGER. Mini-grid development encounters several difficulties.
The public grid's very low average electricity price*, that ranges from 0.03 to 0.14 dollars per kWh depending on the type of customer, penalizes the application of mini-grid tariffs (generally at least 0.5 dollars per kWh), as DRE users tend to compare the two system's tariffs;*
The lack of professionalism *has led to several operators, often villagers themselves, to prioritize the social over the business aspect of the service rather than finding the best equilibrium between them.*
The current very weak involvement on the part of the banking sector *often prevents operators from gaining access to the funds they need to finance DRE mini-grids".*

Mamadou Saidou Diallo, trained as an electrical energy engineer, has been working in the field of rural electrification in Guinea for 15 years. He is the Joint Director General of the Guinean Rural Electrification Agency (AGER).

Find the whole interview in French on the book's webpage: ***http://www.fondem.ong/electrifier-lafrique-rurale/***

A professional has his say
Olivier Oriol

The pre-paid metering market for rural mini-grids is booming. How does a company like Michaud position itself, given its undisputed experience as an energy manager?

"Very strong lobbying has been required to impose the Pay-as-you-go pre-payment model in Africa. The system is relevant in the city, but not necessarily to first-time energy users in rural areas. In their resolve to create equity for the country's populations, many developing countries impose this scheme whatever the users' resources, energy production modes, etc... But as we know, urban schemes cannot always be transposed to the rural world.

The Michaud philosophy is to position ourselves both on the user's and the operator's side to guarantee that the latter has a reliable and credible business plan. We devised the energy manager to develop payment by pre-paid price plan. The system is ideal for off-grid mini-grids because it guarantees constant energy use all year round and fixed, regular income for the operator. On the user side, the monthly electricity bill is drawn up when they sign up for the same amount every month. Thus, there are no nasty surprises or untimely disconnections. This type of invoicing is educational for new users and easy to manage for the operators".

Olivier Oriol, a developing country specialist for 10 years, currently works on the issues of access to energy in the rural environment in Africa. He is the Africa Market Manager for Michaud Exp

Find the whole interview in French on the book's webpage: ***http://www.fondem.ong/electrifier-lafrique-rurale/***

[Part 2]
Conclusion

Rural electrification will be achieved by making decentralized solutions widespread to back up grid extension. That is what happened in many industrialized countries during the 20th century and is the course history is taking in Sub-Saharan Africa.

Recent digital and photovoltaic breakthroughs, which are still on-going, combined with the need for environmental transition, suggest a glimpse of fast-tracked cheaper and inclusive energy decentralization.

But this prospect depends on a change in the way projects are financed, maintaining investment aid, coherent strategy between fund raisers, intelligent coordination between private and public actors, profit-making operators and development organizations and lastly, setting up real decentralization in every country.

Thus, to rise to the challenge, the actors cannot count on the technology accelerator alone. They must also learn from over 50 years' worth of experience gleaned by decentralized rural electrification pioneers, who are almost all agreed around one golden rule – do not overlook the human factor.

Managing an ecosystem with many stakeholders, involves a sociological approach, customized pricing, the headache of end-of-life equipment... These various constraints make technical standardisation very difficult, as long as we try to ensure that this service is accessible to all and covers all useful uses.

We also take stock of the wide variety of solutions on Sub-Saharan soil, which is a real-life access to off-grid electricity proving ground. The third part of this book makes a methodical presentation of the main decentralized solutions found out on the ground and assesses their capacity to contribute to effectively reducing the energy divide in Sub-Saharan Africa.

These solutions whose legal outlines are still vague, come somewhere between delivering a basic service and supplying capital goods. This leaves us up against an almost philosophical challenge that inevitably comes to mind when we consider the assets and limitations that each solution offers for reducing the energy divide. Part 3 of the book outlines this very view.

The different models of off-grid electrification by solar systems

Info

Feedback from the field

Definition

Key Dates

Key figures

[Part 3 - Technical specification]

Rural Sub-Saharan Africa has become a proving ground for decentralized solutions from portable lamps to mini-grids

Introduction

It has to be admitted that the technical and operational aspects of access to off-grid electricity are innovative and fast-moving, but also fragmented and disorganized. That is no doubt the very essence of evolving sectors.

Encouraged by promising technological, political, social and economic circumstances, increasing numbers of actors are investing in rural electrification in piecemeal fashion, primarily with solutions based on photovoltaic technology (3.1.).

There are many highly different economic rationales and social approaches that vary between developers hidden behind the many solutions.

The following paragraphs attempt to portray the diversity by grouping the various patterns that coexist divided into three areas: individual domestic electrification (3.2.), electrification of community infrastructures (3.3) and collective electrification (3.4 & 3.5).

The main electrification solutions mentioned in this part are illustrated in the panoramic centrefold plate. There is also a detailed block drawing of each solution at the beginning of the relevant section.

"The humanist legacy of the first rural electrification actors naturally leads to treating technologies as tools. However, technologies sometimes call the shots, which changes thinking processes and forces people to get a thorough grasp of the specific mechanisms".

Bernard Equer, former Research Director at the CNRS, Solar Energy Specialist.

3.1. In the absence of a sector-wide policy, many solutions coexist, and they are mainly based on photovoltaics

We have already mentioned that actors, mainly from the private sector, add new pieces to the off-grid electrification puzzle. So, in the space of a few years it has become considerably more complicated.

In countries where rural electrification policies are fairly ineffective and in the absence of any international or Pan African strategy, none of the interest groups present can develop an 'intelligent' holistic vision of all the operations carried out there.

All the electricity services rolled out enable part of the rural population to improve its living conditions, but their impact is obviously lower than if the project developers were to join forces to consider the electrification of a territory and combine their solutions in a coordinated and planned way (3.1.1).

Despite this motley collection of solutions, one common factor stands out and that is the ubiquity of solar technology. It has the edge by being simple and accessible. Some of the basic techniques are recalled in this section (3.1.2.).

In rural areas a motley collection of solutions can be found in a single village

3.1.1. The array of decentralized rural electrification solutions is very wide

They range from portable solar lamps to interconnected grids, while in the absence of regulation and coordination, the scope for action is almost totally wide open. Whether these solutions are available on the market or implemented within an institutional framework, they meet most of the populations' needs. But their random juxtaposition in the same region, devoid of vision or overall consistency sometimes has adverse effects.

All the conditions are ripe for promoting a multitude of solutions on the access to off-grid electricity "market".

Several factors that we have already mentioned, come together to explain the abundance of renewable decentralized solutions out on the ground, and primarily those developed by non-institutional actors.

- **the African continent's electricity demand is steadily rising**, and it will be very hard to satisfy it, for its demographic growth that far outstrips the speed at which electrical infrastructures are developing (cf. chapter 1.1.1) and its needs follow the exponential curve of the spread of mobile telephony and its associated digital solutions (cf. chapter 1.1.3). While some people are concerned about the growing social inequalities that this pent-up demand is prompting, others see it as a great market opportunity.
- **national electrification policies and their official bodies supported by international financial institutions, are unconvincing**, after so many broken promises (cf. chapter 1.2). Many actors, in the first instance the unserved populations, hold out little hope for anything from these institutions and are naturally turning to the offers they see around them.
- **recent technological developments have given birth to new technical and economic models** (cf. chapter 2.3.1) that enable electricity to reach rural areas that have so far been inaccessible by using simple, affordable systems. The supply is there, and it meets the demand.
- **the energy industry heavyweights and digital start-ups have grabbed the segment**, thereby turning decentralized rural electrification into a community opportunity (that some describe as a battlefield[1]). Their strengths are their economic clout, investment and innovation capacity, and their agility to attract investors whose attention they could not catch before. The mass spread of solutions is easier as a result.
- **international aid policies support access to "modern, sustainable and affordable" electricity**. They endorse renewable energies, paying increasingly generous attention and funding to "innovative" solutions, often developed by private actors, often backed by private investments. Development bankers are clearly receptive to the arguments of those who claim that subsidy-free rural electrification is viable.

1. Aurélien Bernier, "Batailles commerciales pour éclairer l'Afrique: un marché de l'électricité qui suscite bien des convoitises", *Le Monde diplomatique*, 2018.

The current drive is being rolled out widely outside any institutional framework

The increase in the number of private actors putting forward off-grid rural electrification schemes seems to have eluded institutional control. This is because, these new actors often act without consulting the public authorities in a context where regulatory frameworks are still in the making. Incidentally, some of these actors, primarily guided by profit expectations, are indifferent to the underlying principles that an access to electricity project should serve human development. So, new concepts, which, certainly satisfy part of the demand, are spreading like wildfire over rural Africa without any safeguards.

Some interpret the proliferation of access to electricity schemes as a useful combination of suitable responses to different contexts. But in actual fact, this complementarity is more often than not theoretical, in that the actors on the ground do not even share a single area assessment or coordinate in any way when carrying out their respective projects. As the example in the inset shows, a mixed bag of even contradicting electrification schemes may be side-by-side in the same zone[2].

The lack of harmonization, planning and failure to consult have another consequence... the users, who are seldom considered in all their dimensions (namely their expressed needs and also their environment), have difficulty finding their way. Therefore, the messages coming from some actors, especially the NGOs (about the notion of the electricity service, consumers' rights or the solution providers' obligations) may fall on deaf ears.

The solutions presented below are classified by the scope of usage of the electricity service

The following paragraphs describe the main off-grid electrification models seen on the ground. The selection is non-exhaustive given the number and plurality of the uses and is founded on a necessarily flawed choice of classification.

Having been analysed from different angles, the needs they cover, solution developers, underlying economic models, institutional framework, strengths and weaknesses..., the selected solutions are presented in three scheme categories that are all prone to having a number of variants or combinations of variants:

- **individual domestic electrification schemes:** standalone domestic photovoltaic systems, portable solar equipment, "*Pay-As-You-Go*" (PAYG) solar home systems
- **the special case of public infrastructure electrification:** public buildings and structures such as town halls, schools, health centres, community premises, etc., mainly electrified by standalone solar systems or micro-grids, with bigger capacity ranges than individual devices
- **collective electrification schemes:** electricity production and possibly distribution systems that totally or partially serve a set of users, such as multi-purpose platforms, energy kiosks, nano-grids and of course, mini-grids, that are so complex that a paragraph is dedicated to them.

This non-exhaustive presentation strives to be factual and devoid of analytical hierarchy.

2. Note that this situation of various solutions alongside each other is the same as the development of DRE in rural France. For example, in the department of the Lot, before 1940, there were more than a hundred electrification firms with different technical solutions and tariffs. This coexistence of technologies and tariffs is probably a compulsory step in the development of electrification... you learn on your feet.

Aerial view of Kouramangui, Guinea where we can see solar kits, solar lamp posts and a mini-grid

The exercise is illustrated by examples, feedback and interviews, and does not intend to highlight any specific solution or actor, but portray a lively description of a booming sector, piece together the patchwork of services with their often different philosophies and thus mirror a multifaceted reality.

Prior to that we provide a little technical background on the main orders of magnitude, terminologies and operating principles of standalone photovoltaic operating systems in the paragraph immediately below.

An example of a patchwork of solutions in a single region

There are three different electricity schemes on offer on a single rural zone in the south of Madagascar, in the Atsimo Andrefana region:
- a private operator distributes electricity by **solar mini-grid** at € 1 per kWh in a rural community of a few thousand inhabitants.
- a few kilometres away, several landlocked hamlets are gradually being equipped with solar home systems with PAYG distributed by a local company,
- nearby, another locality has had the benefit of a "**solar kiosk**" with the support of an international NGO, that offers very low-cost electricity services with a social vocation.

This patchwork situation is hardly an isolated case and is located about thirty kilometres from the Sub-prefecture, which is electrified by the national utility grid, which offers a poor service but at a "social" tariff (of about € 0.1 per kWh), which is far below its actual production cost. Consequently, none of the users are satisfied and the individual solutions are increasing to replace or top up the existing grids:
- The mini-grid users complain of paying 10 times more for their electricity than in the sub-prefecture.
- The PAYG solar home systems users demand to be able to use other appliances, like in the city or on the neighbouring mini-grid.
- The portable solar lamps on sale at a modest cost by the "kiosk" can be found all over the zone, including in the electrified areas.

How can a non-electrified household technically and economically build an energy culture and fair benchmarks? How can the rural electrification agency work to harmonize the rules? How can the electricity sector's regulatory body make the various actors uphold their rights and obligations?

Source: Fondation Énergies pour le Monde.

3.1.2. Standalone photovoltaic systems – basic technical concepts

The array of solutions identified out on the ground gives pride of place to photovoltaic as solar technology is the simplest to implement in the rural environment for the technical and economic reasons already described, for at least the last decade (cf. 1.1.2).

The following technical recap is made to give lay readers the keys they require to understand the technology that underlies the solutions presented further on in the book.

Recap of a few technical concepts on standalone solar photovoltaic generators

How a standalone solar photovoltaic generator operates

A solar photovoltaic generator is an electricity production system that works using one or more photovoltaic (PV) modules that convert solar radiation instantly into electricity. This electricity is stored in a set of electrochemical batteries to be restored to the user at night and when there is little sunshine.

A photovoltaic generator comprises four components: production, storage, regulation and distribution.

- **the photovoltaic (production) field,** comprising one of more modules that produce electricity "when the sun shines", is installed on roof- or ground-mounted stationary or mobile structures, and usually directed towards the equator.
- **the electrochemical storage battery bank**, comprising one or more batteries, restores the electricity stored during the day at night-time and when the sun is weak. Every day, the battery goes through a more or less thorough charging and discharging cycle. Its service life is governed by the number of cycles and cycle depths.

Nowadays, most individually sold batteries are based on lead-acid technology, although new alloys are entering the standalone electrification market (lithium, nickel-metal hydride, etc.).

Batteries are the solar generators' weak point and one of the main reasons for premature failure of PV generators (cf. 2.3.1). They require special attention at the sizing phase as their usage conditions (temperature, regulation quality, servicing, etc.) must be known to make the best of their service life.

- **the charge and/or discharge controller (regulation),** comprising electronic components, electricity flows inside the generator. Its main role is to protect the batteries from deep overloading and discharging, which are two phenomena that have a major effect on their service life. Incidentally, recent systems offer display and alarm features to improve system understanding and management by their own users.
- **the inverter (distribution)** if needs be, converts the electricity produced from direct current (generally 12, 24 or 48 V) into alternating current (generally 220 V/50 Hz). Electricity in its alternating current form is distributed by urban grids, as ordinary and/or high-capacity electrical receivers are designed to run on alternating current. Inverters, which are generally used in large photovoltaic generators (from a few kWp), thus supply receivers designed to be connected to traditional electricity grids.

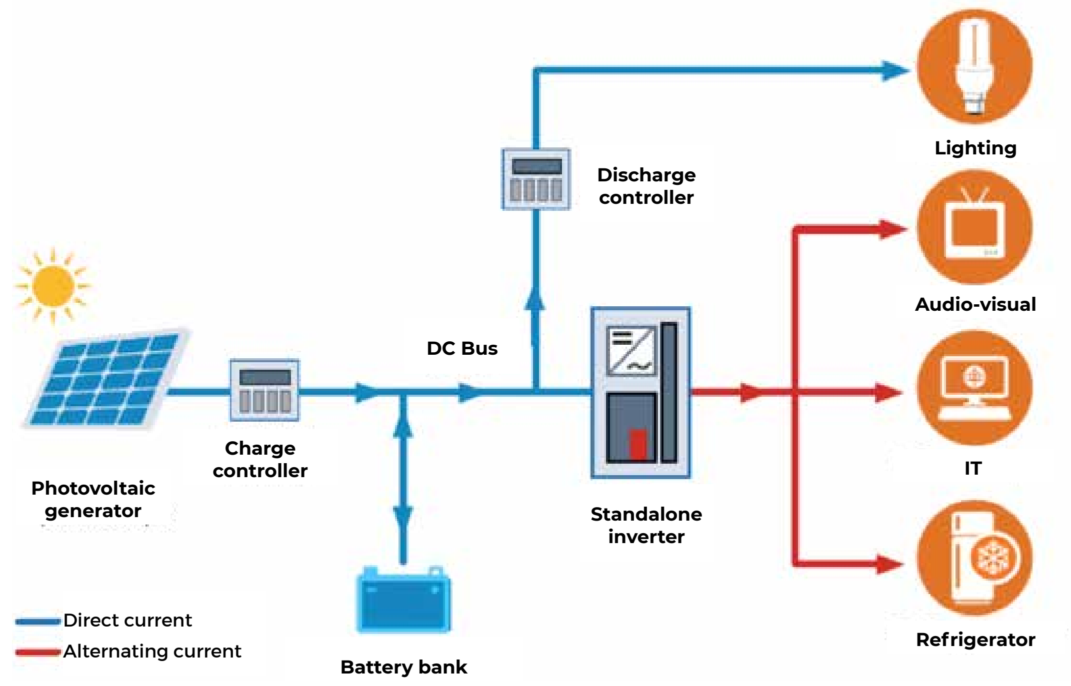
In the case of small systems, electricity is delivered as direct current (cf. inset), to avoid conversion losses on their way to the receivers, that are often designed for these types of PV systems, and thus optimize electricity consumption.

The different types of standalone solar generators

Now there is a wide array of solar generators ranging from a few Watts peak (Wp; cf. inset) for solar lamps – we sometime talk of "nano PV" – to several hundred kWp for some solar plants that supply mini-grids.

There are many fields of application for standalone solar generators that can meet all sorts of electricity needs.

Block diagram of a standalone PV system with storage



Source: Gérard Moine

The Watt-peak

The reference unit in the area of photovoltaic, is the Watt-peak (Wp). It is a sort of "nominal" electrical rating of a photovoltaic module. In practice, **this normalized value is used to compare the components and calculate energy sizing**. A 50-Wp module will restore half the amount of daily energy than a 100-Wp module in identical climate conditions.
The same goes for a 125 HP car engine that will be able to supply this power only if a set of theoretical conditions come together (engine temperature, oil quality, fuel quality, air temperature, etc.), a PV module can only deliver its peak power in specific optimum conditions. The notion of Wp is essential in the laboratory to characterize the photovoltaic cells and modules. It is the electrical power delivered by a PV module in the internationally normalized sunshine and temperature conditions:
*A solar radiation power value of 1 000 W/m²
*A cell temperature of 25°C.
*A solar emission spectrum corresponding to crossing one and a half atmosphere thickness without clouds (that is called the AM 1.5 spectrum).

Why are these values used to create a standard framework? The values used to build the peak power measurement standard are more appropriate to the climate environment of northern countries than the developing countries.
A 1 000-W/m² solar radiation power is the value commonly measured when observing the sun at solar noon at average latitudes, of 30-50°, in the summer. One could thus say that it is a "maximum" observable solar power. At these same latitudes, an AM 1.5 solar spectrum corresponds to the sun's position in the sky during the day and a cell temperature of 25°C can be observed in cold, sunny weather on a winter's day.

Exemple:
A 250-Wp photovoltaic module installed at high altitude will regularly receive radiation capacities of 1 200-1 300 W/m² and will be exposed to temperatures far below zero. Thus, it will frequently deliver electrical power levels in excess of 300 W, although its peak capacity is 250 Wp.
This same module installed in the Sahel and exposed to high radiation (1 000-1 100 W/m² at solar noon) will very frequently see its surface temperature surface rise to 70-80°C. It will restore electrical power often limited to 210-220 W, although its stated peak capacity is 250 Wp.

Examples of the various types of PV and hybrid generators

Type of use	Electrical receivers	Average daily requirements	PV/hybrid power	Battery storage	Inverter capacity
Family of six	Lighting, telephone, radio TV	0.2 kWh per day	50 Wp	70 Ah @ 12 Vdc	Only DC
Shop	Lighting, telephone, hifi, refrigeration	1 kWh per day	300 Wp	250 Ah @ 24 Vdc	Only DC
Internet café/ video	Video, media, hifi, Internet	0.7 kWh per day	200 Wp	200 Ah @ 24 Vdc	500 VA single phase
Dispensary	Lighting, refrigeration, telephone	0.9 kWh per day	400 Wp	500 Ah @ 24 Vdc	1000 VA single phase
Public lighting	Lighting	0.15 kWh per day	30 Wp	50 Ah @ 12 Vdc (or Li-ion/Nimh)	Only DC
Ten-bungalow ecolodge	Domestic, household appliances	35 kWh per day	7000 Wp / back-up 11-kVA genset	2500 AH @48 Vdc	9000 VA single phase
Telecoms link	BTS, securement lighting, communications	8 kWh per day	3000 Wp/11-kVA back-up genset	500 Ah @ 48 Vdc	Only DC
Mini-grid serving one hundred and fifty families	Miscellaneous domestic, community, IGA	100 kWh per day	30 Wp/50-kVA back-up genset	8500 Ah @ 48 Vdc	40 kVA three-phase
Urban hospital	Specific hospital equipment	300 kWh per day	100 Wp/120-kVA back-up genset	3750 Ah @ 240 Vdc	80 kVA three-phase

Source: Fondation Énergies pour le Monde.

3.2. Individual electrification schemes democratize access to electricity, but do not solve the equation of the diversity of needs

In contrast with conventional electricity sources, photovoltaic technology can sustainably produce small amounts of electricity in any geographic and climate context.
It is this specific feature that the individual electrification scheme harnesses when it aims at systems for family use.
In practice, we do not distinguish between “solar kit”, “individual solar system” or *Solar Home System* (SHS). We retain the term “*solar home system*”.

MINIDOSSIER

Some key elements about individual solar systems

Solar home system examples and magnitudes

Field observations suggest classifying the systems into three groups, by capacity, or the PV modules used.
Yet, we should bear in mind that the assemblies of PV modules and batteries enable customized systems of any rating to be designed. The more diverse and numerous the uses, the more “case-by-case” design is needed.

The table below suggests some (non-exhaustive) magnitudes of locally available photovoltaic equipment that can be acquired directly, using the local terms.

Examples of solar systems sold in non-specialized shops in Madagascar

	“Small panel”	“Medium panel”	“Big panel”
PV rating	5-10 Wp	50-130 Wp	220-280 Wp
Battery capacity	5-10 Ah (12 V)	50-130 Ah (12 V)	150-300 Ah (12 V)
Type of receivers and services	LED lighting, cell phone charging	LED lighting, cell phone charging, radio, small TV/ video player	LED lighting, cell phone charging, radio, TV/satellite decoder, multimedia
Average equivalent electricity service at 4-6 kWh/m²/day) of sunshine	12-25 Wh/day	200-350 Wh/day	600-800 Wh/day
Average acquisition price in West Africa (hardware from Asia)	€ 20-50	€ 70-150	€ 150-350

Source: Fondation Énergies pour le Monde.

Operating principle of an SHS

The electricity output from a correctly dimensioned, installed and used SHS is available 24/7. The amount of electricity that can be used every day is naturally correlated to how much electricity is produced by the photovoltaic field. The bigger it is, the sunnier the day, the greater the amount of "available" electricity will be, provided that the surplus has been correctly stored in the storage battery.
Therefore, a solar home system must be designed and dimensioned to integrate the following three parameters:

- the user's daily electricity needs (that are graphically expressed by a "daily load curve"),
- the site sunshine level, incorporating the seasonal factor,
- sufficient storage to cover night-time needs and prolonged bad weather periods.

Further reading

The book by Jean-Paul Louineau, *A practical guide to solar photovoltaic systems for technicians: Sizing, installation and maintenance,* takes a very educational and well-illustrated approach to the operating, installation and running principle of a solar home system.

Source: Edition Observ'ER, 2017.

SHS servicing and service life

As the SHS operates with no servicing, its mean weak point is the battery. Although the brands and models run into their hundreds, the quality of batteries sold on the African market is highly variable. In most cases, the purchaser cannot check the stated performance levels. Vendors do not offer guarantees and the regulator does not set standards.
Batteries of this type of system may last as little as a few months and very rarely extend beyond three years, as they not only depend on product manufacturing quality but also the storage and usage conditions.

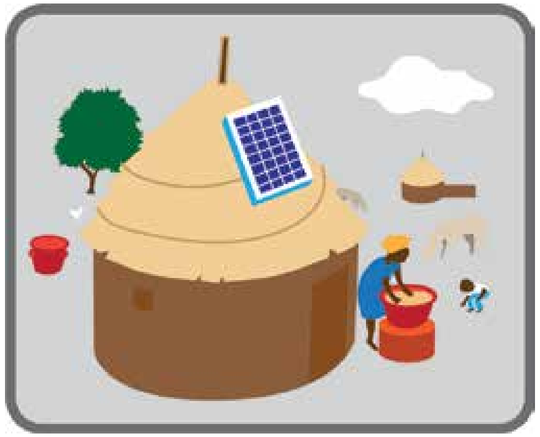
The World Bank reckons that 90 million SHS were in service worldwide in 2017[1]. Three main types of SHS electrification solutions coexist, that offer variable usage cover and employ different acquisition and distribution approaches:

- equipment directly acquired by users from a local reseller, and possibly installed by the latter (cf. 3.2.1);
- PAYG (Pay-As-You-Go) kits, through a more complex lease-sale or leasing business approach provided by private operators (cf. 3.2.2.);
- lastly electrification using solar kits as part of an integrated project (cf. 3.2.3).

1. Lighting Global et Global Off-Grid Lighting Association, "OffGrid Solar Market Trends Report" (Washington, D.C, 2018).

3.2.1. Direct acquisition of a solar home system

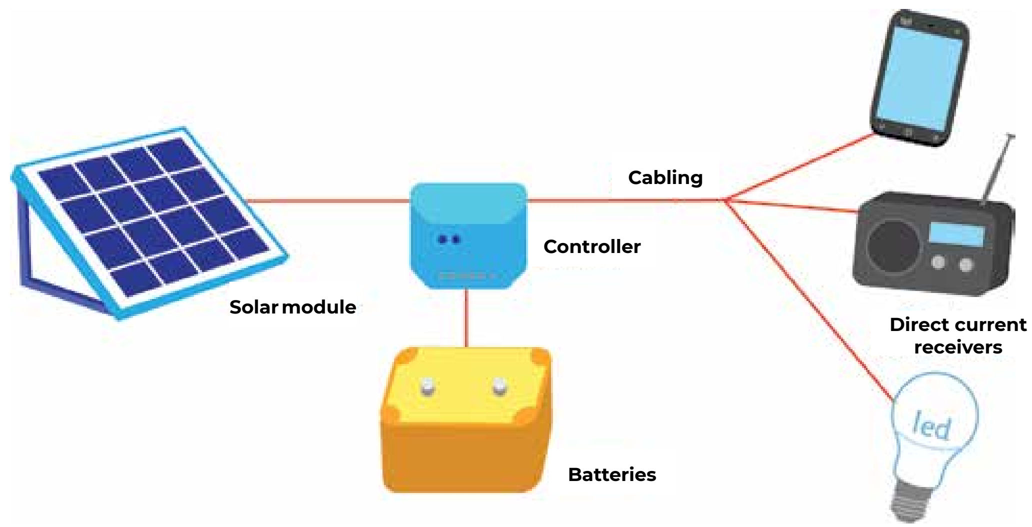
In Sub-Saharan Africa, no regulated electrification mechanism is tied to procuring a solar home system from a local retailer using own funds. Yet, this electrification pattern is one of the most widespread avenues to access to electricity in off-grid rural areas.



The solar home system (lamps, kits) market is very buoyant. In the space of just four years, between 2011 and 2015, global sales rose from 500 000 to 11.3 million units, dominated by the spread of portable solutions (cf. graph). Experts claim that the revenues from these sales will double every two years and rise from $ 700 million in 2015 to more than $ 3 billion in 2020[1].

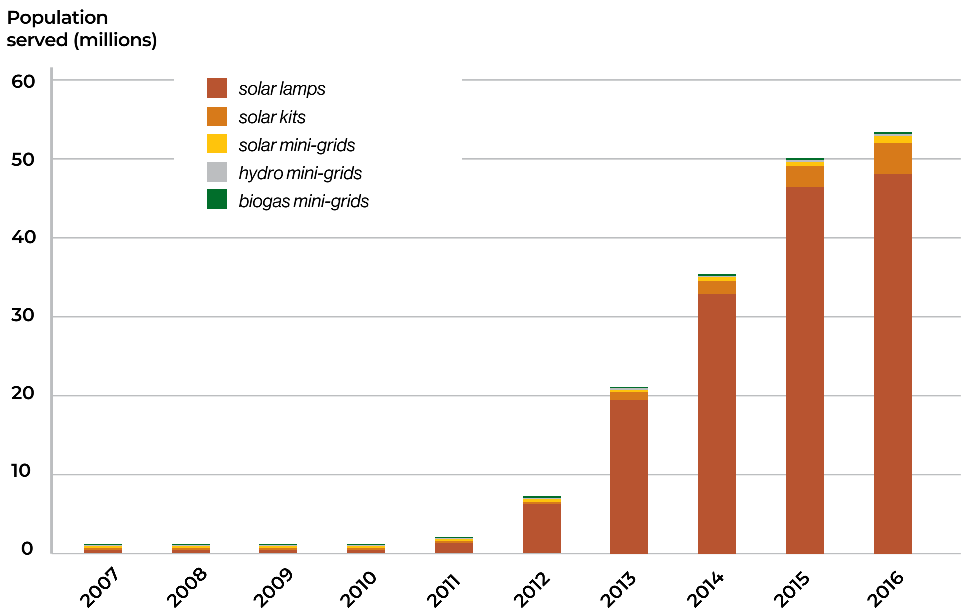
1. Lighting Global and Bloomberg New Energy Finance, "OffGrid Solar Market Trends Report" (Washington, D.C, 2016), quoted by Simon Lamy, "Solutions offgrid : quelles perspectives en Afrique ?" (Casablanca: PricewaterhouseCoopers, 2017).

How an individual PV solar system works



Source: Fondation Énergies pour le Monde.

Population benefiting from off-grid renewable solutions in Africa



Source: IRENA, "Off-Grid renewable energy solutions, Global and Regional Status and Trends" (Abu Dhabi, 2018).

It must be borne in mind that this solution is above all accessible to the members of rural population who are well off. Moreover, without supervision, a freewheeling boom tends to be made at the expense of equipment quality.

What are we talking about?

The principle of a solar home system is simple, and its spread is based on a purely commercial process... the direct sale of photovoltaic equipment and accessories by local economic actors to their end users.

At the end of the 1990s, a few tens of companies specializing in sales and installation of PV systems were identified in West Africa. They were often backed by international groups and targeted dedicated markets (telecoms, social and military applications, pumping).

The scene around these pioneers (some of whom are still trading with a reputation for their experience and know-how), has totally changed in under twenty years. There are now countless small SHS vendors on the African continent, that certainly run into the thousands. A full SHS can be purchased almost anywhere from a business claiming to be specialized or from an itinerant hardware trader at a weekly market.

In some out-of-the-way localities, these "local" systems may equip more than 50% of all dwellings (cf. inset about Kouramangui in section 1.3), although for the poorest households, so much capital is required to get equipped with a solar home system that the acquisition is hard to envisage. The reverse side of this commoditization of SHS devoid of any regulation, is that the market is flooded with products of very uneven quality, despite the many initiatives made to define technical standards and boost skills.

The PV modules and batteries sold often claim misleading performance levels and are mediocre in quality, at the expense of the service given and system service life.

Who are the main promotors?

SHS distribution is based on a *Business-to-Customer* circuit of distributed solutions along the lines of the liberal model (cf. 2.4.1.). The chain of actors is relatively short: manufacturers (mostly Asian), importers, distributors and local resellers.

In the main cities, specialist, experienced firms provide quality PV equipment, backed by suitable installation and maintenance services. But they seldom affect the rural domestic market, whose purchasers turn to local traders for cost and proximity reasons. These fairly unskilled traders sell often poor quality components (from the module to the receivers) and leave the customer to assemble and install them. They offer too little advice and after-sales service.

Expert advice

The sector professionals reckon that more than 9 out of every 10 solar domestic installations in Africa are not carried out properly.

A professional has his say Boubacar Sow

Generally speaking, would you say that the quality of PV installations in Senegal has improved in recent years?

"Yes, despite a few problems at the beginning of the decade, due to the influx of new actors attracted by a sector touted by all the politicians as being a miracle solution to meet the country's electricity needs.

Improvement came about through the many training programmes funded by international cooperation, and also the experience acquired when constructing several high-capacity power plants and conducting major rural electrification projects in the country".

Boubacar Sow, an electromechanical engineer, Director-General of the company SOLENE (Senegal) has been working in the off-grid solar for more than a decade.

On the book's website you can find the French-language interview with Boubacar Sow as well as that of Tanga Boureima Kabré, who trained as a socio-economist, a solidarity economy specialist, co-founder of BETA, who has built up more than 23 years' worth of expertise in the field of renewable access to energy.

Which services do users have access to[1]?

The SHS disseminated in Sub-Saharan Africa mainly power up low-power receivers: lighting, radio, TV, lamp and cell phone charging; which rules out for example small refrigeration appliances. Only a few economic activities can be envisaged, such as small grocery, sewing workshop, hairdressing, cybercafe and possibly computer services.

Electricity supplied by a solar home system has rating and daily electricity quantity limitations. Although it seems to be available freely every day, that limited amount of available electricity forces users to adopt energy consumption control measures. Also, awareness-raising is always required to get across the reasons and effects.

What is the economic model?

From the users' stance

The cost of the electricity produced by an SHS for the user, is subtracted from the initial investment amount and any expenditure arising from the replacement of faulty components. That amounts to purchasing, all at once, a finite quantity of kWh for several years, until the system becomes defective or requires renewal (the battery is usually the first to succumb).

1. Rather than talk of "users", we should use the term "customers" because individual solar systems are distributed based on a commercial model.

Component	Average service life observed
Batteries	2-10 years
Inverters and converters	3-10 years
Charge/discharge controller	5-15 years
Cabling and accessories	10-20 years
PV module	10-30 years

Source: Fondation Énergies pour le Monde.

The companies' stance

Equipment sellers are finding the sector increasingly competitive given the increase in the number of "solar" firms trading in Africa. The distribution chain is full, from importer to retailers, who today can be seen even in the most out-of-the-way area markets. Nonetheless, new distribution models providing better service quality are attacking this direct sales model and fend off competition from *Pay-As-You-Go* operators (cf. following paragraph). Solar home system vendors are making so little profit that in order to make volume sales they are conducting a race to drive prices down, often at the expense of quality.

What is the institutional framework?

Electrification by direct solar home system acquisition follows a commercial rationale and, so far, is not part of any institutional framework specific to the area of access to electricity in most Sub-Saharan countries. SHS users are strongly penalized by the absence of technical standards and controls on the equipment distributed.

A professional has his say
Arnaud Chabanne

Does the acquisition of a PV lamp enable households to make savings?

"A survey commissioned by LIGHTING AFRICA[1] in Burkina Faso in 2013 put monthly lighting expenditure at 3 100 FCFA (€ 4.7) – up to 10% of a household's budget. Therefore, LAGAZEL solar lamps sold in West Africa for € 15-45, pay for themselves within 4-8 months. Savings over the lifetime of the product are put at € 180, over and above the fact that LAGAZEL's after-sales service can double the lamp's service life simply by changing the battery. However, as households are accustomed to lower but more repeated expenses, ***the promotion of the lamps must be backed by awareness-building actions and financial services (such as microcredit) to enable households to overcome the initial investment hurdle"****.*

Arnaud Chabanne, renewable energies engineer who is aware of access to energy issues, has been working in Burkina Faso's solar sector since 2004, where he created the company CB ENERGIE. He co-founded LAGAZEL in 2015 with his brother Maxence, aiming to industrialize the manufacture of quality solar lamps on the African continent.

Find the whole interview in French on the book's webpage: *http://www.fondem.ong/electrifier-lafrique-rurale*

1. See section 1.1.1.

What are the model's strengths and weaknesses?

The rural and peri-urban populations naturally resort to this form of pre-electrification by teaching themselves, and often at their cost, how to use the implementation methods and tools for want of any electricity distribution grid extension programme or more effective solar home system sales model. The market for small photovoltaic equipment for domestic use is being weakened by the glut of manufacturers, misleading performance claims, unregulated distribution and lack of minimum technical standards. The positive corollary to this local loss of credibility in PV technology, is that the need for a minimum level of quality is recognized. In the medium term, the worst performing products will probably be eliminated, opening the way for more sustainable existing sales methods. But, in the short term, the populations will naturally resort to mediocre products to cover a few basic needs, by purchasing "whatever they find" for want of a structuring programme.

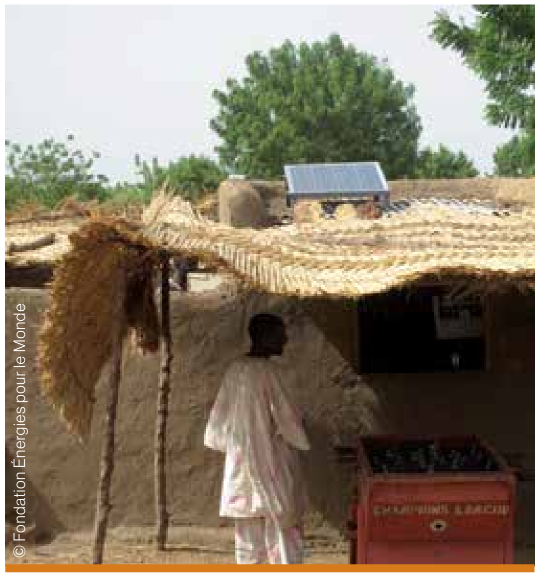
Additionally, while the presence of SHS can be thought of as pre-electrification in advance of the deployment of a grid, it may be a paradox. The mass presence of solar home systems in an area actually cuts both ways. On the one hand, it gets a population accustomed to using electricity and confirms the existence of payment capacity, which are both conducive to using the service if the grid is extended or of a mini-grid is installed.

A professional has his say
Olivier Rasoldier

Do you think that the profession needs a stricter regulatory framework for better quality deliverables, especially in Madagascar?

"I agree in theory, but it's harder to put into practice. The business environment is totally unsuitable. Especially as users do not express strong expectations on the subject. The profession is developing at various speeds:
*The **"zero standard"**: where equipment is supplied that does not meet any quality criteria. This exposes the country to major environmental dangers (because of industrial waste such as heavy metals).*
*The **"intermediate"**: offering an acceptable service life, with no guarantees.*
*The **"top-of-the-range"**: offering work backed by quality certificates and whose installations are conducted upholding professional safety and quality procedures".*

Olivier Rasoldier, has a doctorate in engineering in machine design and has specialized in RES since 1987. He has been the owner-manager of the ENERGIE TECHNOLOGIE since 1994.
Find the whole interview in French on the book's webpage: *http://www.fondem.org/electrifier-lafrique-rurale/*



A rural solar shop operating thanks to a solar kit

On the other hand, SHS owner-users who accept the principle of battery renewal (on average every 18 months) will not necessarily be keen on making regular payments for an electricity service that they neither control nor own in the eventuality of grid deployment.

One of the major risks that is only just emerging, is created by the mass spread of unrecycled polluting components – batteries (of all technologies). Thousands of "spent" batteries are dumped every day with environmental and health consequences that could reach disastrous proportions in the medium term. In spite of a few initiatives, the recycling sector is largely neglected. It will take considerable impetus to match the breadth of the distribution of standalone electrification systems.

To sum up, in the absence of a collective solution (which is often long and complicated to roll out) and notwithstanding their limitations of use, solar home systems can meet basic electricity needs in the long term. Yet, the booming business should be backed by strengthening the local actors' skills and minimum standard requirements on the quality of imported products. If the sector becomes more professional, it will then be relevant to extend the circle of SHS users beyond the better-off strata of the rural population through the aid mechanisms that cannot be avoided (cf. inset). Finally, the acquisition of an SHS through direct sales offers another advantage (also seen in the PAYG rationale): it leads to a direct relation between electricity production and use and encourages the immediate ownership of energy issues, in particular energy efficiency.

Solar home systems cannot be acquired by the lowest-income households without subsidies.

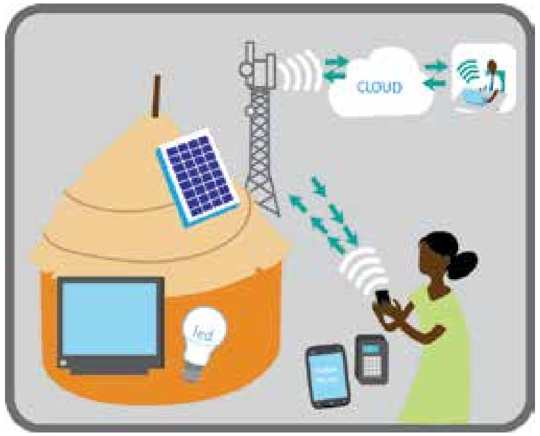
"Even these small-scale ways to increase electricity access may well require some form of subsidies to reach the lowest-income households ».

Grimm and Peters (2016) find that in several Sub-Saharan African countries, the level of expense that households would be willing to incur for off-grid solar tends to be less than the cost of the technology for households in lower income strata.

Source: World Bank Group, "Africa's Pulse: An Analysis of Issues Shaping Africa's Economic Future" (Washington, D.C, 2018).

3.2.2.
Pay-As-You-Go *solar home systems*

Since 2010, solar home systems have spread even faster through new sales methods that commonly feature supplying electricity services via an equipment rental mechanism (with or without a purchase option). These devices usually go under the generic Pay-As-You-Go (PAYG) term, which applies to pre-payment, one of their basic aspects.



This recent phenomenon is high on the checklist of off-grid electrification discussions and their associated financing mechanisms, for two reasons:
- firstly, PAYG incorporates digital innovation that focuses most observers' and financiers' attentions,
- secondly, the PAYG operating model should remove two barriers that typify the solar home system direct sales offer: its technical shortcomings and its lack of affordability (cost restricts it to the well-off).

Pay as you go (PAYG)

'Pay-As-You-Go' denotes the advance payment system for a service, based on a fixed sum geared to the forecast service use, which was initially introduced by mobile telephone operators (pre-paid cards). This method of accessing a service has gradually migrated to other sectors such as energy and insurance (e.g. *'Pay-As-You-Drive'*).

This paragraph proffers a simple explanation of this solution and a first approach to its strengths and weaknesses, as they emerge on the start of their deployment. Because, despite its success, caution is of the essence... we have no hindsight on which to draw sound conclusions as to the impact and sustainability of existing PAYG devices.

What are we talking about?

The service offered by PAYG systems is similar to the service offered by classic solar home systems in that they meet high user value electricity needs with a simple, small (5-100 Wp) photovoltaic system. But there are clear differences between the direct sales and PAYG sectors.

Commercially speaking, PAYG is based on a fixed-term contract system that is often part of a lease-purchase agreement.

Various systems coexist, that are based on a pre-payment system for the electricity service, with or without the option for the user to acquire the equipment.

In most cases, after making a down-payment of 10-20% of the equipment price, the customer reimburses the service for the equipment over a 12-36-month period, at the end of which (s)he usually becomes the system owner. Thus, the mechanism is tantamount to a simplified "microcredit-lease", although with a microcredit, the formalities are streamlined. For example, M-Kopa, one of the historical proponents of PAYG (250 000 sales made in Kenya in 2017), waives the need for any guarantees. All it takes to sign up for the offer is for the person to produce ID and have a valid *Mobile Money* account[1].

Reimbursement is de facto "guaranteed" by the pre-payment mechanism. The connected SHS are activated for a fixed period (1 day, 1 week, 1 month), once a fixed sum has been paid. If the customer defaults, the operator automatically cuts off the service remotely. The two parties are thus committed – one is to pay for the service while the other must provide service availability.

1. Séverine Leboucher, "Le pay-as-you-go sur les terres du microcrédit", *Revue Banque*, n°811 (2017).

Operating scheme of a PAYG PV kit

Source: Fondation Énergies pour le Monde.

MINI FILE

Connected PAYG kit, telecoms, *Mobile Money* and pre-payment meter... how do they work?

PAYG solutions, like mini-grids, practically all use a pre-payment system backed by *Mobile Money* technology.
PAYG kits are fitted with a simple microprocessor and a communicating GSM chip (GPRS, 2-5 G) or via data sent by SMS from the most remote areas (simple dataless GSM network). Data transmission costs are paid by the PAYG operator, who provides service continuity.

Users connect to the PAYG operator's platform using either an DSCD interface or a dedicated smartphone application.
Step 1: the users apply to purchase energy credit (a time credit of a few days, or electricity credit in the case of mini-grids)
Step 2: they pay with their *Mobile Money* account: the money is directly paid into the operator's *Mobile Money* account by electronic transfer.
Step 3: after the payment has been confirmed, a digital signal is sent over the telecom network to the chip on the kit or connected meter that is automatically activated for the period and/or amount of energy purchased.
Step 4: the users receive a confirmation message.

The system continues to communicate with the operator and user while the electricity credit is being used
The technical data (precise consumption profile, state of the batteries), are analysed and archived in the operator's cloud, which improves knowledge of electricity use in rural areas and insight into changes in behaviour.
The operator can thus send relevant information to users, so helping them improve their control of consumption, and warn them of the remaining electricity credit (when it runs out, the system is automatically cut off).
Users are also sent promotional offers by the operator that encourage them to:

- use electricity during the day at a reduced rate in the case of SHS, to avoid the electricity being shunted into the batteries;
- use electricity during the weekend on solar mini-grids, when the economic actors' inactivity leads to surplus electricity in the plant;
- reduce consumption during the winter, rainy season or cyclone periods, whatever device they use (SHS or mini-grid).

Users and operators can change a number of limiting factors. In the case of mini-grids (where several packages can be proposed at different rates (cf. 3.4), connected meters can be used to change a subscription remotely. Thus, a user can upscale from a basic plan (for example, limited to 100 W and 0.5 kWh/day) to a higher plan (500 W and 2 kWh/day). The power limiter and energy settings can be remotely controlled.

The combination of digital technology with telecoms and big data applications offer scope for almost unlimited opportunities for upgrading to totally paperless technical and commercial management models. The future will tell us whether a device that leaves so little room for the human factor and is founded on the reliability of very widespread electronic components is really suitable for rural Sub-Saharan Africa.

A rural PAYG shop

How PAYG works




1. The customer signs a contract

2. A technician installs the solar system

3. The customer makes the prepayment for the amount of daily energy via Mobile Money

4. The customer receives a single-use code by SMS

5. The customer enters the code, the product is released for the prepaid time

6. The customer uses prepaid, reliable services

Source: Fondation Énergies pour le Monde

From a technical point of view, PAYG is based on SHS component quality and the use of digital technology

Operators take care with the product design and choice to supply reliable equipment and good quality service, that vouchsafe customer satisfaction and regular payments.

Li-ion batteries have thus replaced lead-acid batteries, endorsing the relevance of this new technology for rural electrification, at least for low-capacity systems.
Digital technology is also a strong feature. The first PAYG kits were pre-programmed with a set of codes that the user purchased from the operator to activate the system for a given period. This method that is robust but not particularly scalable has made way for "connected SHS" via the telephone networks. The systems are remotely activated or deactivated by the operator on the basis of received payments.

The paperless drive has been pursued by using *Mobile Money*, which is almost ubiquitous with East Africa's operators and fast-growing in West Africa (see section 1.3.2). The presence of a physical operator providing codes and top-ups has been replaced by an interactive trading and payment platform that can be accessed by cell phone.

Connected SHS offer customers new services while operators have new capacities in addition to facilitating payment: they can send users information on their consumption, the possibility of changing power and energy thresholds to adapt to those of the customers, collect information on energy behaviour and how the systems are operating (cf. mini-file).

An example of a French PAYG kit – the UpOwa kit

FLASH	LUCIOLE	LION
3 LAMPS + PHONE CHARGERS	4 LAMPS + PHONE CHARGERS + RECHARGEABLE TORCH + RECHARGEABLE USB RADIO	1 TV + DECODER + 4 LAMPS + PHONE CHARGERS + 2 USB PORTS
18 months credit : 130 000 CFA francs	18 months credit : 180 000 CFA francs	24 months credit : 560 000 CFA francs
advanced : 130 000 CFA francs	advanced : 180 000 CFA francs	advanced : 80 000 CFA francs
per month : 6 500 CFA francs	per month : 9 000 CFA francs	per month : 20 000 CFA francs

Source: UpOwa (*https://www.upowa.energy*)

PAYG does not sell kWh, but energy services

PAYG solar home systems are supplied with very low-consumption receivers – LED bulb(s) of a few Watts, a television set of about fifteen Watts, a dedicated cell phone charging socket, in order to control electricity consumption and the quality of the service provided. Users cannot employ other receivers of the same type or other types of receivers than those supplied.

Thus, users purchase high usage value services "on credit" (very good quality lighting, cell phone charging, television) by acquiring a full, pre-cabled SHS, equipped with receivers whose number and kind depend on the chosen plan.

This electrification model is really taking off

It entered Africa via the east coast in Tanzania and Kenya around 2010, supporting the liberalization of the energy, finance and telecommunications sectors. M-KOPA and MOBISOL, who pioneered this sector each claimed to have electrified more than 600 000 homes by the end of 2017.
French-speaking Africa has only recently discovered PAYG. It accounted for 12% of accumulated sales of PAYG systems from 2013-2017 (as opposed to 86% for East Africa). It still has a lot of ground to make up, but offers significant market potential, because of the buoyancy of the mobile telephone sector and the development of *Mobile Money* across the region.

Comparison of 3 French offers (QOTTO/UPOWA/ONIRIQ)

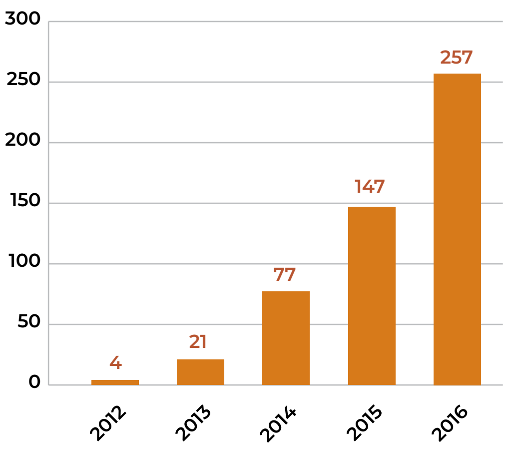
Company	Services	Tarifs
QOTTO	The most popular kit: • connected charge controller • 150 Wp of solar panel, 60 Ah of battery • 4 LEDs • 22" LED TV • cables • light sockets • switches • free maintenance for 3 years	1 euro per day for 3 years
UPOWA	5-10 W kit: • lamps and chargers • installation • maintenance • torch • radio • guarantee • ownership after 18 months - 3 years	Down-payment of 19-22 euros then 8-10 euros per month
ONIRIQ	• 50-Wp polycrystalline solar panel • router with digital screen (4 USB ports, 4 sockets 12V DC lead battery) • 3 x 200-lumen pendant lamps • compatible with Orange Money PAYG • HD TV • Wi-Fi hotspot • 15h of lighting per day • 6h of TV • 5 cell phone charges • 1-year guarantee	Sales price 250 euros excl. of taxes (min. order 1 000 units)
ORANGE	Véenem Basic solar kit: • 1 battery • 3 LED bulbs • 1 solar panel • cables	Sign-up fee: 30 euros Monthly cost: 4.50 euros *Prices for Burkina Faso*

In 10 years, PAYG has spread to almost half the countries in the world

Source: "The symbiotic relationship between PAYG Solar and Mobile Money ecosystems". Climatescope, *http://2017.global-climatescope.org/en/blog/2017/06/26/GSMA/*

A QOTTO solar kit being installed in a private home

Investments in PAYG solar firms are increasing (in millions of dollars)



Source: Bloomberg New Energy Finance, "New Energy Outlook 2017" (Washington, D.C, 2017).

Who are the main promotors?

The numbers of PAYG promotors, based on a capital-intensive model aiming for mass sales, are swelling. Energy manufacturers, start-ups and local firms share a playing field that attracts many financial partners (cf. 2.3.2).
However, the model's viability is not a given. It is based on many trades and a delicate balance... strong commercial presence out on the ground, a suitable, modular offer, attractive marketing, good-quality equipment, sound partnerships with telecoms operators, powerful paperless management, mass distribution strategy and constant capital injections to carry out the investments required for growth.

This range of competencies leads to motley, globalized mapping of PAYG system proponents: R&D teams in the USA, Europe and China for continuous innovation, mainly Asian integrated solution manufacturers, vendors-installers on the ground, a paperless management team, investors in financial centres.

What kind of electricity do customers have access to?

Electricity produced by a PAYG SHS has the same limitations as a traditional SHS, namely low available power and a limited quantity of daily energy. As it stands, this arrangement seldom meets the needs of productive activities[1].

Nonetheless PAYG system user perception is different. For payment of a regular sum, users acquire less of an electricity generator that "energy services" that take the form of one or more receivers (LED lamps, TV, chargers) that enjoy guaranteed working time (a few hours a day).

What is the economic model?

The users' stance

PAYG solar home system customers see a simple and fast way of accessing a good quality basic electricity service in this new solution. The fairly low initial expense makes the product accessible to more rural homes than it would through direct acquisition. As theoretically, the amount payable equates to the household energy expenditure prior to acquiring the system (purchases of candles, batteries and/or kerosene).

These arguments often highlighted by PAYG operators should be put into perspective. The tariffs charged (cf. comparative table of French offers above) are still inaccessible for the most destitute households and only part of the population, that is relatively stable in economic terms, can contemplate committing to a regular payment mechanism. Calculation of the "equivalent cost per kWh" sold on this type of system gives results that may raise questions: € 5-15 per kWh (compared to € 0.1-0.5 per kWh for urban grids, € 0.5-1 per kWh for mini-grids).

The operators' stance

The amount pre-paid by the customers covers the equipment cost (generator and receivers), system maintenance and operator costs and profit margins.

While PAYG actors keep their business plans to themselves, their main strategy lines are common knowledge today, including their ambition to reduce poverty, which seems to be a secondary consideration even if it is emphasized in their communications. Profitability is the PAYG operators' main aim, whose model seeks viability eschewing subsidies but demands commitment from investors. The latter, who are often far-removed from the societal issues of rural African populations, insist on relatively fast return on investment.

Despite the growth prospects and figures announced by the PAYG actors, only a few of them have reached the critical volume required to attain breakeven point and satisfy their investors. PAYG operators are "subsidized" in a way as they are always on the lookout for working capital or investment capital and sometime receive donations through access to energy projects (as institutional donors are increasingly opening their mechanisms to the private sector).

Accordingly, PAYG operators strategically target peri-urban or high-potential rural areas with stable or growing economic resources that are easy to get to and have high population densities. In fact, as some impact investors ruefully note, they are sometimes prompted to turn their backs on the rural segment and back out of their initial social promise, in order to stay profitable[2].

What is PAYG's contribution towards the universal access to electricity goal?

While this new electrification method appears to offer an effective response to the demand of a large proportion of the population that is not or only badly served by the national grid, it nonetheless suffers from three major limitations:

- **it is not as rural as planned:** although it was targeted at access to electricity for vulnerable rural areas, today it mainly meets the demand expressed in the outlying areas of big cities, where population density and payment capacities meet the requirement for profitability,
- **only domestic high usage value needs are covered:** meeting other applications, primarily giving economic activity needs better coverage entails the development of specific, low-consumption receivers and more complex solar kits. Some operators are working on this[3],
- **it is likely to suffer from the absence of interpersonal relations between customers and the operators' agents:** while it appears easy to gain new customers, keeping them demands more effort than expected. Today, depersonalized sales appear to damage the sustainability of the model.

The investors, who know how to attract PAYG developers, should give them the means to remove some of these barriers. But it is likely that this electrification method will leave a few essential societal issues unanswered:

1. Lighting enables work to be continued after sundown. The most powerful SHS on offer (up to 200 Wp) such as those supplied by QOTTO, open up the possibility of offering a service activity (e.g.: video clubs, cell phone charging, hairdressing).
2. Diane Isenberg, Greg Neichin and Mary Roach, "An Impact Investor Urges Caution on the 'Energy Access Hype Cycle'", Next Billion Blog, 2017, *https://nextbillion.net/an-impact-investor-urges-caution-on-the-energy-access-hype-cycle/*
3. Cf. Full interview of Jean-Baptiste Lenoir in French on the book's webpage: *http://www.fondem.ong/electrifierlafriquerurale/.*

"Today, by proposing a leasing system, PAYG firms effectively play the role of financial institutions, yet it is not their vocation no are they subjected to the sector's rules (except for M-KOPA, which has chosen to declare itself as a financial institution). Yet, they are losing money with this "credit" function. Most of the PAYG actors do not have enough working capital to finance equipment stocks and have under-assessed the credit risk. I believe the current models will be short-lived.

Therefore, the logical way forward would seem to be an alliance with the microfinance institutions (MFIs) capable of delivering digital services. They know how to assess credit and have the necessary funds to purchase equipment through their savings inflow activity.

However, a partnership of this sort is quite another matter. MFIs often view PAYG operators as competitors. Experience tells us that a lot of work has to go into developing the right sales lines and motivate sales. It is essential to equip MFI staff (the first customer is the vendor) and make demonstration kits available to them".

Renée Chao-Beroff, General Manager, PAMIGA and PAMIGA Finance SA, an impact investment vehicle for rural microfinance in Sub-Saharan Africa.

- What about access to electricity for the most underprivileged sections of the population, especially in rural areas?
- How can public buildings, schools, health centres be electrified, and public lighting be developed in these rural areas?
- What kind of economic development is possible with PAYG alone for as long as this solution is unsuitable for productive uses?
- How can PAYG solutions be linked with mini-grids, which can satisfy more uses and segments of the population?

As one of the PAYG professional points out (cf. account given below), *"PAYG is not the single solution to all electrification problems"*.

Is an institutional framework lacking?

As it stands, PAYG entails individual electrification through direct acquisition of photovoltaic equipment, so it falls outside any specific institutional framework and is rolled out in a disorderly competitive environment. Although some international observers include its users in their statistics and macroscopic electrification scenarios, hardly any technical or pricing regulations apply to PAYG.

Zones with service, service quality level, pricing, rights and obligations of the parties... access to the service is governed by a private contract between an operator and a user, and guided, asymmetrically, more by the former's strategy than by the latter's interests.

A professional has his say
Caroline Frontigny

In your experience, what are the most expressed electricity needs made by the rural populations of Cameroon? *Television! It's undoubtedly the most widespread demand when we meet families and traders in the rural areas. The desire for entertainment (particularly to watch football matches!) and have access to the world is very strong. The possibility of charging one's cell phone comes second, as almost all rural populations have cell phones. Charging them regularly in zones without electricity is complicated and is an expensive daily constraint. Domestic needs come next – lighting for quality of life and the children's homework, a fridge to keep food fresh, an iron, etc..*

What are the main difficulties you encounter when rolling out your offer on the ground? *There are many of them. Firstly, you need to realize that access to rural areas is challenging... the roads are poor and often blocked during the rainy season, customers are hard to contact by telephone because they work in the fields in areas with little telephone coverage. Moreover, using a solar kit and paying via Mobile Money tends to be new for our customers. On top of that, managing a network of agents is a real organizational feat. We invest a lot in their training so that they can guide our customers and offer them a quality, neighbourhood service.*

PAYG kit operators are criticized for not targeting poor, out-of-the-way areas. What is your view on this? *The development of PAYG has enabled a considerable number of people to have access to electricity in record time. But it is right to say that PAYG is not the one-stop solution to all electrification problems. As it happens, people living in sparsely populated, out-of-the-way areas cannot be served at prices that are affordable to them. I think that PAYG driven by companies is a tremendous tool, but cooperation is needed between companies, states, institutions and NGOs to achieve the electrification of all the areas that are still left out in the dark.*

What kind of professional relationships do you enjoy with the institutional energy bodies in Cameroon? *We regularly report on the deployment of our activities to the Cameroon institutions, primarily the Ministry of Water Resources and Energy and the Electricity Sector Regulatory Agency. Generally speaking, our activity has been well accepted by the Cameroon institutions. Indeed, all solutions that can bring access to electricity solutions to the Cameroon populations rapidly and sustainably are welcome.*

Caroline Frontigny trained as an engineer and worked at the World Bank for five years on access to electricity issues. She is a co-founder of the Cameroon-based company UPOWA.

Find the whole interview in French on the book's webpage: *http://www.fondem.org/electrifier-lafrique-rurale/*

User awareness

A professional has his say
Jean-Baptiste Lenoir

How important are user awareness-building and training?

"Absolutely crucial. We spend a lot of time presenting our systems to our future customers so that they will adopt the technology and accept the products. Our teams demonstrate the systems in the villages, in the squares, at junctions. The prospects have the whole evening to look at the equipment, touch it, use it, ask questions... When the system is installed, our technicians explain how it works. We also provide after-sales service and our call centre is open 7/7 to answer customers' questions and help them if necessary »

Jean-Baptiste Lenoir, trained as an engineer and after working for 15 years in telecommunications, devoted 2 years to the NGO, Action Contre la Faim. His vision of industry serving as many people as possible and his knowledge of new technologies prompted him to create QOTTO to design, distribute and operate PAYG SHS systems in West Africa.

Find the whole interview in French on the book's webpage: *http://www.fondem.org/electrifier-lafrique-rurale/*

Admittedly, LIGHTING AFRICA[1] has been established as a qualitative approval authority. But in the area of SHS, the market is relatively free and hardly regulated as the customer base is all end users. As the contract is not for the sale of electricity but for the sale of equipment, the applicable regulation covers capital goods. The main constraint is the regulation on imported goods.

Given the scale of the boom in PAYG systems, it would be in the regulator's interest to bind some of the actors to a more consistent approach that benefits the whole population. The "missing legal link" should be created between capital goods sales and the sale of electricity or the supply of a public service.
See the recommendations in Part 4 for the actions to be implemented.

In conclusion, while some consider domestic electrification by PAYG solar home systems as THE solution, its current limits make it only ONE of the effective electrification methods for a rural area. As it has so far evolved outside of any regulation on the quality of service, social equity or pricing, basically affecting the areas close to towns or more densely populated housing areas, the spread of this new model in its current form is likely to exclude the most fragile populations from access to electricity over time.

Hence, this emphasizes the need for initiatives that seek broader democratization of SHS.

1. See section 1.1.1.

ELECTRIFYING RURAL AFRICA: AN ECONOMIC CHALLENGE, A HUMAN NECESSITY

3.2.3.
Electrification by solar home system as part of an integrated project

As previously mentioned, most solar home systems are installed in a deregulated equipment sale setting directly acquired from an equipment supplier or a company with a PAYG offer. Some occasional but not so ineffectual concerted electrification schemes rolled out within an institutional framework and run by not-for-profit organizations and or private operators through concessions, contribute to developing rural electrification via solar home systems.

The example of Decentralized Service Companies (DSC)

Many Southern African territories (South Africa, Namibia, Botswana), and also some West African regions, use private decentralized service companies or "DSCs" that they entrust with the management of a solar home system base.

The territories are awarded to these operators as 10-20-year concessions. The operator takes up investment subsidies, to deploy a solar home system base (from hundreds to thousands) aiming to serve the maximum number of beneficiaries and uses (domestic, community and economic). The SHS are sized to meet the specific needs of the area, including potential economic activities and social uses.

The equipment remains the property of the operator who provides maintenance and renews components, while the user pays a fee (usually at monthly intervals). Contractual obligations tie the DSC to the user and the parent ministry, mainly the ministry with the energy portfolio.

The electricity sector's national regulatory agencies ensure compliance with the specifications – technical quality of the service, suitable pricing, coverage rate for the most destitute households. Special attention is paid to the quality of equipment and user awareness-raising.

In theory, this scheme meets the goals of concerted, appropriate and equitable electrification. However, in practice, the need for investment subsidies (if not operating subsidies when batteries or other major components are replaced simultaneously) limits their deployment and complicates their roll-out.

This scheme that is side-lined by the arrival of PAYG operators, who are positioned as staging posts, shows that electrification by SHS accessible to the greatest numbers and covering all uses is foreseeable on two conditions:

- financial support
- and the presence of a minimal regulatory framework that sets each stakeholder's rights and obligations.

In that case, decentralized electricity is considered to be a service managed by a private operator who is meant to make a profit, and not as a commercial commodity, thereby approaching the public service delegation method.

The Yelen Koura DSC team based in Mali

A project can bring together a private operator and microfinance institution

It has already been stated that only the better-off segments of rural populations can self-finance the direct acquisition of an SHS. Acquisition can also be financed by using microcredit, but the microfinance institution (MFI) interest rates are high. Microcredit is not necessarily accessible to all.

Some projects, especially those run by NGOs, bet on a different involvement by the finance sector by organizing the distribution of an offer of a "turn-key" SHS via an MFI.

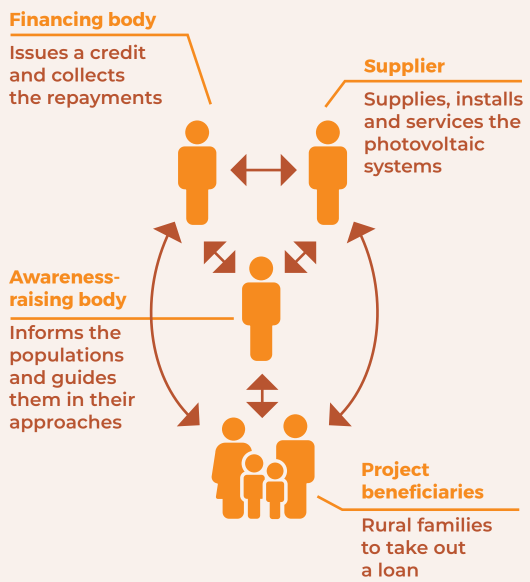
The backing of a development financier, in the form of a subsidy, covers the technical support expenses (MFI guidance) and subsidizes part of the equipment and ultimately safeguards the quality of the equipment acquired through the microcredit over a territory and expand the base of users eligible for microcredit.

This financing circuit is particularly useful for covering productive needs. The use of microcredit enables micro-entrepreneurs to acquire the right system to develop their businesses (such as mechanization or refrigeration).

Admittedly the change of scale of this type of operation cannot be taken for granted, for the existence of a subsidy mechanism, that is needed to be able to combine equipment quality and accessibility to the highest numbers, is a constraint. But the Micresol project (see inset) demonstrates that ambitious electrification programmes by SHS can be rolled out in cooperation with the local financial sector putting aside purely commercial considerations.

The MICRESOL project

Energy credit mechanism block diagram



Source: Fondation Énergies pour le Monde.

This project was rolled out between 2008 and 2012 by Fondation Énergies pour le Monde. The original solar home system acquisition mechanism benefited 1 000 homes in Burkina Faso. Its principle of bringing together local private operators (systems suppliers, installers), the public authorities, a local microfinance fund and the Fondation was simple but it turned out to be quite complicated to implement. The Fondation's wide brief included defining a range of solar home systems, ensuring component quality and providing service... installation and customer service.

The microfinance institution offered its members the possibility of acquiring the equipment on the basis of methods and tools to design an offer geared to the various categories of the population and to assess the risks for each borrower. Once the credit was awarded, the system was installed, and the local technical partner serviced it for 3 years (which equated to the microcredit repayment term).

Equipment purchase and supply were partly subsidized, while the monthly instalment payments covered the installation, maintenance, finance and other management costs.

A strong bond was formed between the user and the technical partner who offered maintenance services for uninterrupted service once repayment was completed. The operation was really successful, primarily thanks to the offer of several kits to economic players, including a 300-Wp system supplied with a 140-litre refrigerator.

© Fondation Énergies pour le Monde

Microcredit fund in Burkina Faso (MICRESOL project)

A professional has her say
Sarah Holt

Is the equipment still running four years after the end of the Micresol project?

"A local operator, BETA (based in the heart of the intervention zone), was involved from the project design phase, and installed and maintained the solar equipment. As this service was fully financed for its 3-year term by the microcredit, some users are still benefiting from it (as the last microcredits were awarded at the end of 2016 and early 2017). Once beneficiaries have finished paying for their solar kit and it has passed into their ownership, they are free to continue working with BETA to have it serviced.

Unfortunately, monitoring the equipment is difficult despite this arrangement, once the credit has been repaid and the main players relieved of their contractual undertakings. I think this lack of support over time is one of the major challenges of decentralized electrification projects in Africa.»

Sarah Holt, an energy socio-economist, has worked with ADEME, GIZ, Fondation Énergies pour le Monde and today with IED. She has been working for about twelve years in the access to electricity field in several countries of Africa.

Find the whole interview in French on the book's webpage: *http://www.fondem.org/electrifier-lafrique-rurale/*

Women's association pose with their savings in Malawi

PAMIGA: Access to energy via participatory microfinance

PAMIGA (Participatory microfinance group for Africa), an international NGO created in 2005, develops microfinance institution (MFI) networks in 10 countries of Sub-Saharan Africa, to contribute to unlocking the continent's economic development potential.

Furthermore, since 2013, **it has helped rural financial institutions (RFIs) develop suitable financial products to encourage access to energy to rural populations.** The PAMIGA model is based on a partnership approach (*two-hand model*) between a financing institution and one or more solar solution suppliers, who make available access to financial investment and quality solar solutions to rural populations.

Solar Credit, the specific financial product intended to fund access to energy, and adapted to existing MFI procedures, was co-developed to lower energy credit-related risks. Besides, through this partnership rationale, MFIs can release the money directly to the supplier, who then delivers the solar solution to the customers who thus receive the Solar Credit "in kind".

Since the end of 2015, this model has been tested in Cameroon (1 993 solar kits), Ethiopia (1 124 kits) and Kenya (446 kits). Although roll-out has been below initial expectations, the first impacts mentioned by customers (easier access to quality solar solutions, lower energy expenditure, reduction in health problems related to kerosene use) are positive.

PAMIGA is currently supports its RFI partners with the change of scale as they deploy Solar Credits in all three countries' rural agency networks and diversify their solar solutions offer. Incidentally, this model has been taken up in West Africa, specifically in Benin and Senegal.

Source: Nicolas Renard, David Ojcius, Dinah Louda, and Monique Fourdrignier, "Decentralized Electrification and Development" Veolia Institute FACTS Report, (2016): 128-137.

3.3. The electrification of public infrastructures is still a challenging issue

In the less-developed Sub-Saharan countries often bereft of sufficient, stable tax resources, public services have insufficient funds to conduct their missions with minimum equipment conditions. In the rural context, the educational, health, religious or cultural infrastructures, all essential places where social cohesion and development take place, are no exception. That explains why their electrification was first of the ventures undertaken by access to electricity players.

Here again as most of these players worked haphazardly, they did not plan for the constraints that would arise from operating and managing the structures, which has led to the unsustainable nature of the service.

© Fondation Énergies pour le Monde

Electrified health centre in Burkina Faso

3.3.1. Electrifying public infrastructures – social certainty foiled by reality

Infrastructures described as "public" include all the buildings and structures for use by the public members of a rural locality:

- **teaching/education:** primary schools, middle and high schools, that may be privately (often affiliated to a religion) or publicly managed
- **healthcare:** all the healthcare infrastructures, from dispensary to secondary hospital, most of which have maternity capacity
- **institutions:** town halls and connected administrative buildings, in main community towns, not far from public places or spaces used for markets and local events
- **buildings for social and cultural:** youth centres or women's centres, covered markets, cooperative premises, centres for associations, cultural centres, often built on NGO initiatives
- **religious buildings:** places of worship maintained and run by religious representatives, active spaces for the life and balance of the communities

All of these are spaces that provide a minimum of public service, places for important meetings in traditional societies where oral transmission is essential. Depending on the cultures, social hierarchy is made or broken there.

These places that are vital for the rural community cohesion, have little contributory capacity

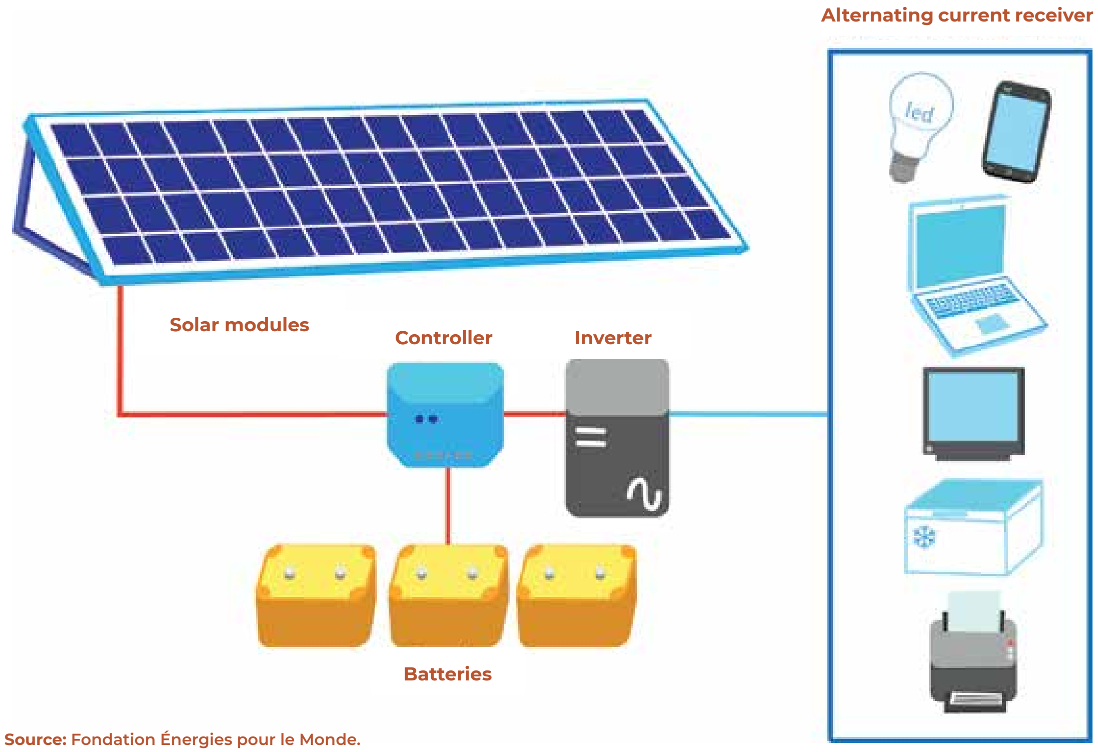
In Sub-Saharan, and particularly French-speaking Africa, management of these infrastructures is theoretically provided at a local level along the lines of the "French" decentralization model. In practice, experience shows that this local management is poor, because of the lack of funds allocated by the supervisory bodies (ministries of decentralization, health, education) or by the users' associations (school parents' committees, dispensary management committees, etc.).

Before embarking on an electrification programme, it must be made clear whether provisions are made for the maintenance and replacement expenses. The relevant institutions must be involved from the preparatory phase, and the obstacles that could affect operation and thus sustainability must be forestalled.

Their electricity needs are often limited

Generally, the electricity needs of these structures tend to be low and easily quantified. Apart from the health centres, that, depending on their size, may be equipped with vaccine chillers or other specific

Electrification of community buildings



Source: Fondation Énergies pour le Monde.

equipment (surgical lights, sterilizers, etc.), public buildings are fairly-energy efficient: lighting, computer equipment, telephone charging, sound system and possibly refrigeration.

Their electrification usually calls for fairly simple photovoltaic systems, ranging from a few hundred Wp to several kWp. This simplicity, combined with the strong social impact of the investment, is why the very first decentralized rural electrification projects focused on this type of infrastructure.

As they are generally open during the day, they are fully compatible with solar home systems as very little power will be drawn thus, the storage battery can be small.

3.3.2. Is the problem of electrifying public infrastructures that of method?

The problem has already been brought up... the absence of a holistic approach by the various development aid actors, their fragmented interventions that mar the effectiveness of their efforts. This observation is particularly poignant in the area of access to electricity.
The example of public infrastructures – whose electrification no doubt leads to many educational, health and social benefits in a zone – illustrate it quite clearly... many installations are out of service. The best guarantee of proper use and sustainable service are the attention paid to the real needs of the equipment users and the wise arbitration of investments to meet their primary expectations.

The many, but uncoordinated electrification initiatives promoted by the industrialized nations seldom last long

Many Northern Hemisphere organizations – associations, twinned communities, diaspora groupings – contribute to equipping public infrastructures with solar photovoltaic systems. While generosity is what drives them and the will to make a social impact, these initiatives are often left to newcomers with little experience of the specific technical and organizational issues of the region.

Only nationwide schemes conducted by organizations with the means to set up a framework, can achieve suitable results when electrifying public buildings.

A professional has his say
Hervé Gouyet

Hundreds of schools have been electrified by your NGO. Have you really been able to quantify the impact for the beneficiaries? *The absence of access to electricity seriously impairs the teaching quality received by 180 million schoolchildren in the world[1]. We have in-house monitoring and assessment tools (impact indicators, self-assessment framework) and a database that covers all our projects to enable us to make an aggregated impact estimate of our actions. The follow-up elements are regularly gathered, remotely or on the ground. Additionally, we routinely commission external assessments that demonstrate the improvement in school results.*

PV community electrification systems are frequently found to be out of order. How do you address this issue of sustainability given the thousands of operations that your NGO carries out every year? *The NGOs bear their share of responsibility. However, you must be aware that more than 700 million inhabitants still live below the poverty line. It is quite understandable that these populations are more concerned with meeting their immediate needs (food, safety, health) than saving to replace electrical equipment. Should they be excluded from access to electricity on that basis although they really do need it? Comparative feedback from the sector's NGOs shows that isolated rural communities seldom maintain community equipment without subsidies. Our NGO prefers to set up Café Lumière type projects... the collective services equipment servicing is funded by generating economic activities and an innovative public-private management mechanism involving a delegate. It conducts a pro-active policy of long-term project monitoring that aims to guarantee that the installations will operate for a 10-year term. It has established a sustainability fund to do so, that contributes from own funds to fund the necessary repairs when the need arises. It has published a Guide[2] to share the experience it has gained.*

What sort of links do you have with the local energy sector institutions when you are setting up and carrying out your projects? *In the identification phase, the local institutions are involved as a matter of course... the community, region/province and, for large-scale programmes, the parent ministries. The national electrification companies and regulatory authorities are also consulted to ensure that the planned actions in the area match the existing schemes. Furthermore, we take part in decentralized cooperation actions involving local authorities here and there, to conduct long-term, secure projects.*

Find the whole interview in French on the book's webpage: *http://www.fondem.ong/electrifier-lafrique-rurale/*.

Hervé Gouyet, trained as an engineer, is an electricity sector employee and has led Electriciens Sans Frontières for 10 years.

1. Benjamin Sovacool, and Ivan Vera, "Electricity and education: The benefits, barriers, and recommendations for achieving the electrification of primary and secondary schools" (Department of Economic and Social Affairs at the United Nations, 2014).
2. Julien Carlier, and Véronique de Geoffroy, "Guide de bonnes pratiques" (Electricians Without Borders and the URD Group, 2015).

Many installations are derelict, for lack of preparation for usage and servicing issues.

It is common to come across non-working solar equipment in Sub-Saharan Africa. Idle solar pumps, photovoltaic systems trashed... decentralized rural electrification has its slab in the development white elephant graveyard.

Although it would be unfair to make this a generalization about all projects, the technical aspects of schemes are improving. Yet the reasons, that usually stem from lack of experience of the association leading the operation, are well identified:

- inadequate needs analysis;
- installation design defects;
- but above all, lack of equipment servicing and/or suitable user training.

Whose idea was it in the first place when a remote primary school or a youth centre gets a stand-alone solar system with associated receivers (lighting, multimedia) as a gift without the means for the beneficiaries to service or renew them? Is it really a demand that meets a collective priority need?

This observation highlights the importance of the socio-cultural aspect for the stability of an electrification project, (cf. 2.4.2.). An installation's sustainability or lack of sustainability depends on integrating the human factor.
Bilateral cooperation actors, the main funders of public infrastructure electrification, are ramping up their efforts to achieve "the involvement of the beneficiaries". An operational need is hidden

Derelict solar system

Electrified school in Madagascar, Resouth project

behind this generic terminology, without any real methodological uniformity. Time must be taken to develop detailed insight into the local socio-cultural challenges.
We need to go beyond an initial approach (cf. 2.4.2.) as the verdict of the "involver" is generally influenced by what the "involved" wants to show the latter (whose aim is for the project to go ahead).
In the case of public infrastructure electrification, it has to be said that the exercise is fettered by the rural institutions' dearth of resources. The long-term results are seldom positive, however much effort to involve is made.

Yet, public infrastructure electrification can have very positive outcomes

For the institution, the direct beneficial impacts of the advent of electricity are clear. Electrification of a primary school leads to improved school results, and often leads to the construction of a general teaching establishment. That of a health centre encourages women to have their babies there, which reduces perinatal mortality.

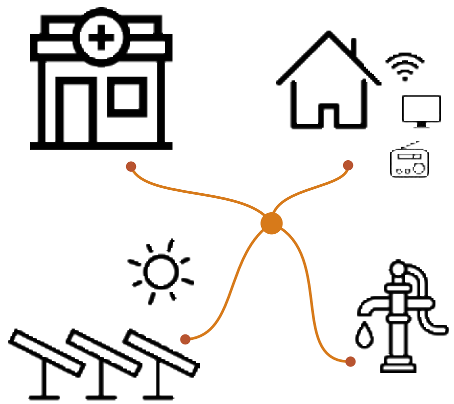
It also contributes to removing one of the public service limitations of land-locked communities, that of the effective presence of personnel on the ground... schools without teachers, health centres occasionally attended by a nurse from the nearest town, absent councillors... Electrification of staff accommodation gives a feeling of being valued and encourages them to live in the workplace.

All these precautions, that complicate project set-up, contribute to increasing the short- and long-term impacts. Feedback from the field confirms this (cf. inset): the electrification operation makes full sense and increases the longevity of the equipment.

"Many things changed when electricity arrived in the community of Ambondro. Socially, the children had direct benefits. We noted a clear improvement in their school results, in particular the First Cycle Certificate (BEPC) success rate".

Fitahia Tatanambina, Mayor of the community of Ambondro, Madagascar.

Grouped electrification of a dispensary, personnel accommodation and a pump



Source: Fondation Énergies pour le Monde.

An electrified classroom

A professional has his say Jean-Pierre Bresson

How do you involve the local beneficiaries?

"This is a thorny issue for the sustainability of installations. The turnover of nurses and teachers is fast (every 2-3 years). The solution to counter this is to plan for an annual PV system inspection by a skilled local electrician who arrives with a stock of spare parts".

Jean-Pierre Bresson, a retired electrician, has 30 years' experience in installing small PV systems on isolated sites or connected to the grid. For 10 years, he has been installing PV systems on schools and dispensaries for African and European associations with local electricians (artisans).

Find the whole interview in French on the book's webpage: *http://www.fondem.ong/electrifier-lafrique-rurale/.*

Electrification of public officials' homes

At Belo-sur-mer, a fishing village on the west coast of Madagascar, the NAMANA (Friends of Belo) association has been gathering funds to support the health centre since 2005. The centre has received equipment, medication and occasional visits from European doctors, and the building has been renovated and reconstructed a few times after cyclones. As a result of this aid, the regional authorities responsible for managing the hospital have turned their backs on it. In spite of the fact that it has a regularly renovated and improved working instrument, the problem of the lack of any permanent local medical team on the spot has not be resolved. When the association conducted an electrification project using solar systems in 2014, **special attention was paid to the needs of the staff accommodation, adjoining the hospital.** Discussions established that a minimum of domestic comfort would be an essential argument for hiring a doctor. Today, almost 50% of the electricity produced by the 800-Wp generator supplies the staff accommodation: TV, decoder, refrigerators, lighting, computer, sound system. The average number of days per week a doctor is now on call in the locality has risen from **2 to 5.**

Source: Fondation Énergies pour le Monde.

3.3.3.
Solar pumping and public lighting – other public infrastructure electrification examples

Solar pumping and public lighting should not be excluded from the scope of electrifying a rural locality. Equipping a public well with a solar pump or installing lampposts along a through road are part of the community structure electrification processes by providing the community with a specific service.

Solar pumping... water and electricity can mix

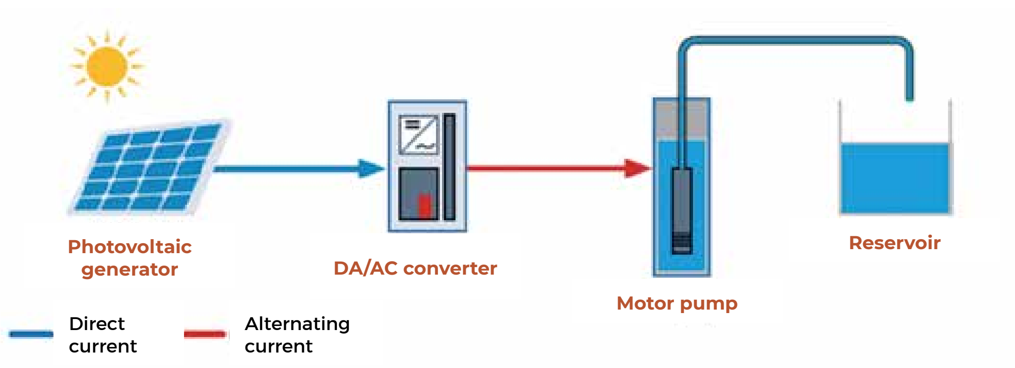
Photovoltaic energy first appeared in Africa during the 70's through its application to pumping. Today, tens of thousands of solar pumps have been installed on the continent, long before the first structured rural electrification initiatives using standalone photovoltaic systems.

While solar pumps of a few kWp can provide drinking water to several thousand people, they also offer productivity gains in the farming sector through crop irrigation and cattle watering.

Without going into detail, you should remember the advantages of this technology, which has been steadily making progress in performance, reliability, availability and accessibility for almost 40 years:

- its main asset is its reliability. This electricity production is static: without moving parts or wear. It does not need fuel.
- moreover, thanks to the modularity and simplicity of solar generators, a solar pump can be installed anywhere, furthest away in a desert whatever its rating.

Principle of solar pumping



Source: Gérard Moine

Drip irrigation system installed in Senegal as part of the Panenca project (Lower Casamance, 2018)

- added to that, their standalone operation "as the sun shines", with water storage in a reservoir, enables solar pumps to do without batteries, the weak link of PV systems.
- lastly the technology is sufficiently mature for retailers to have the skill and spare parts required to replace motors, pumps or converters. Thus, it is common to come across solar pumps that are still working more than 20 years after being commissioned.

The main shortcomings of solar pumping installations do not lie in technical weaknesses specific to the equipment. They often lie in poor analysis of their conditions of use, the water resource, the state of the boreholes or wells, inadequate servicing of the water distribution network. Thus, the problems are either hydraulic and hydrogeological upstream of the installation or downstream by water distribution. But, as with any other solar installation, payment for the service, water in this case, must be organized to cover regular minor maintenance visits and component renewal expenses.

Public lighting... is relevant pre-electrification

Standalone solar lampposts simplify public lighting and have developed like a flash in just a few years on the back of the technical progress made in the lighting sector (LED technology), photovoltaic and storage (cf. 2.3.1.).
They have been installed in their droves along Africa's capital city thoroughfares. Now they are spreading to rural Africa, using technical solutions adapted to new context, i.e., modular, maintenance-free lighting specifically adapted to

public spaces, with a guaranteed service life of 5-10 years. Several French manufacturers are trying to make their mark with high qualitative value in this increasingly competitive environment.

The International Solar Alliance in conjunction with the French National Solar Energy Institute (INES) has produced a practical guide for developers to help them roll out public lighting programmes using standalone solar lampposts[1].

Standalone public lighting meets various rural area needs:

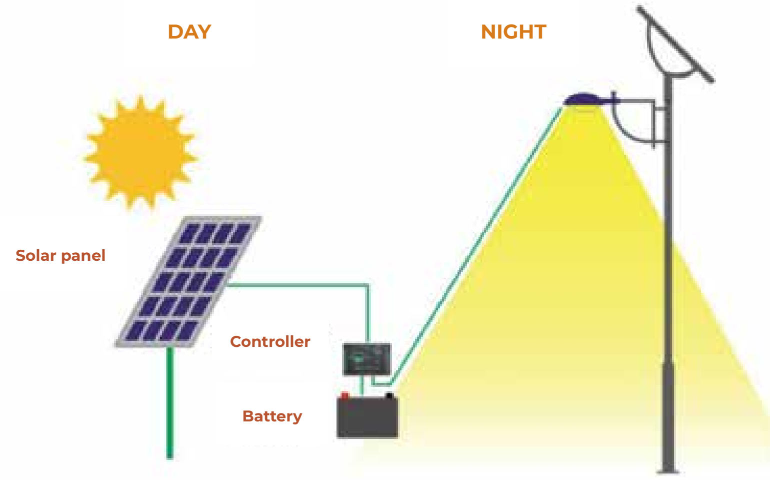
- **it significantly improves the security of property and individuals** along through roads but also in certain areas prone to insecurity
- **it broadens the scope for social activities** by facilitating evening discussions between villagers and shopping opportunities with the presence of traders.
- **it offers the most destitute families the opportunity to benefit from free quality lighting sources**. Children are often seen studying by the light of the village square lamppost.

Several solutions have been developed apart from these 'classic' patterns, to cover collective needs, and economic activities in particular.

1. National Solar Energy Institute, "Practical Guide Bo Solar streetlights" (Le Bourget-du-Lac, 2019). The guide can be downloaded from the INES site, in French at *http://www.ines-solaire.org/wp-content/uploads/2019/02/guideisa_lampadaires-v-web.pdf. and in English at http://www.ines-solaire.org/* wp-content/uploads/2019/02/guideisa_streetlights-feb2019.pdf.

Solar pump in a market garden in Senegal, ESSEN 2 project

Schematic diagram of a public lighting site with a solar lamppost



Source: Epsolar, *https://www.epsolarpv.com/*

A professional has his say
Stéphane Redon

Solar public lighting is deployed on a massive scale on all 5 continents. How can you distinguish a quality product in the glut on offer?

"From a purely technical point of view, a quality public lighting product is recognized first of all by its right sizing. You can guarantee users the service that matches their needs (lighting level) and sustainability (availability rate) with sound lighting and solar technology knowledge. Then, the intrinsic components must offer a minimum service life of 10 years, bearing in mind the environmental conditions of use (e.g.: temperature for the batteries, which are the most sensitive and expensive components)".

Stéphane Redon, trained as an engineer and has been giving guidance to photovoltaic sector manufacturers for more than 20 years in their many projects in emerging countries (Africa, Middle-East, Asia).

Find the whole interview in French on the book's webpage: *http://www.fondem.org/electrifier-lafrique-rurale/.*

© Fondation Énergies pour le Monde

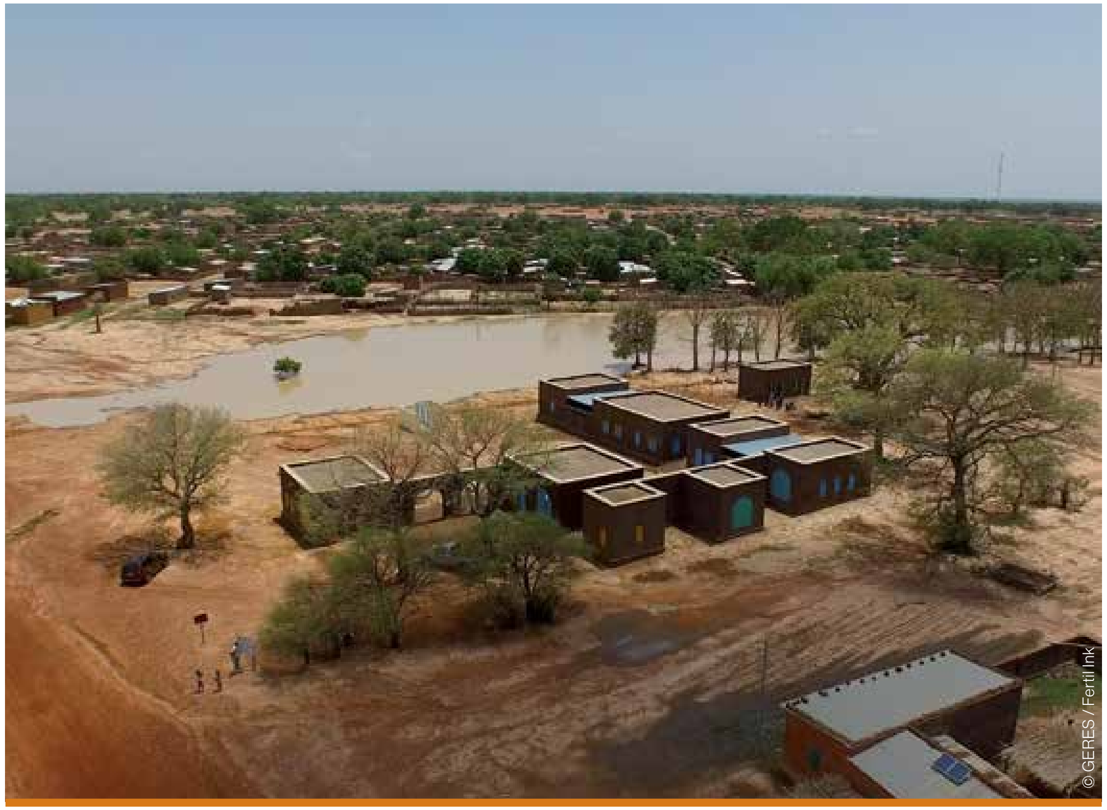
Living area with the benefit of public lighting in Madagascar, Androy and Anosy regions

3.4. New collective electrification schemes have recently emerged

Several schemes can cover a range of domestic and/or productive uses in a rural off-grid territory.

Some recent solutions are geared to productive uses: multipurpose platforms, Green Business Areas (GERES), energy kiosks while others provide a 'universal' service closer to the conventional grid: nano- or mini-grids.

Mini-grid schemes have the benefit of the most feedback and lie at the centre of today's electrification strategies, so they are covered in their own paragraph (3.5).



Aerial view of the Konséguala Green Business Area

3.4.1. Are collective solutions devoted to productive uses a relevant model or just a flash-in-the-pan novelty?

Analysing the economic fabric is central to the rural area electrification planning exercise. It would seem logical that if the needs relating to productive uses are properly factored in, the chances of seeing the advent of electricity contributing to the area's economic development will be maximized, provided that adequate measures are made to support the local actors.

On the basis of this assumption, several rural electrification concepts are geared to the productive uses and propose access to electricity by a more or less integrated collective system for the economic actors of a zone. Thus, they complement individual solutions (lamps, PV kits) and the installations that only cover the public infrastructures, to meet the territory's agricultural, craft trade, commercial or service activity needs.

The multipurpose platform – a pioneering model of energy services shared by economic actors

The UNDP initiated the multipurpose platform concept in 2006, based on sharing a single electricity services site for use by the economic actors of a village community.

The multipurpose platform can be thought of as the ancestor of current collective solutions devoted to productive uses that are beginning to shape the rural energy landscape of Africa. The lessons learned from this experience and the wide spread of PV technology have effectively revised the concept and given birth to that of the "energy kiosk".

The principle of multipurpose platforms

The idea is to centralize energy and/or electricity production in a locality to offer "productive" services for the zone's economic actors (farmers, tradespeople) to use. Mechanical workshop, food-processing machine... there is vast potential scope and in theory, grouping them together makes sense on all levels – financially, economically and socially.

Turning to the technical aspects, the first multipurpose platforms were fitted with a ≈15-kW diesel engine to drive various rotary machines (crusher, husker), but also an alternator to generate electricity for various types of receivers: portable electric tools, soldering unit, chiller, battery charging, etc.

Platform management is provided by the users grouped as committees, associations or cooperatives. Each use has to be paid for pro rata to the energy drawn, calculated on the basis of actual use (meter reading) or by charging a lump sum (pre-set equivalent). The fuel purchase, servicing and overall management of the platform are self-financed through the revenues generated by the sale of "energy services".

Initial feedback reveals a complex link between electricity and economic activities

The original multipurpose platform model proves that pooling activities is not enough to guarantee the sustainability of a shared installation.

A few platforms were quickly plagued by technical and financial difficulties relating to operating a thermal machine, (primarily fuel purchases), and have been deserted while others have lasted several years. For instance, some platforms sited in areas with little economic momentum failed to spawn new activities and soon floundered through lack of managing and servicing funds.

Another lesson to learn from this experience is that the social cohesion of the area where the platform is sited is a key factor of success. The "natural" presence of professional, and especially women's groups ahead of the project, smooths the way for this new collective mechanism to be adopted.

The model has changed to cater for new needs

Although the UNDP still deploys solar and hybrid platforms in various African nations, platforms now tend to be run by private actors rather than community organizations. Also, solar energy has quickly replaced generator sets and other combustion engines. Lastly, the services (which were originally mechanical and agricultural) have naturally branched out and adjusted to societal changes to become commercial "intangible" services... cell phone charging, sales and charging of portable lamps, computing services, PAYG operator outpost, etc.

UNDP multifunctional platform in Burkina Faso

Energy kiosks – collective electrification geared to providing services

Various project developers (NGOs, private and institutional operators) have developed a new type of shared platform over the past few years that we can describe as "energy kiosks".
This label covers various formats (that we will only skim over), that all share a common concept: **installing, in the centre of a rural locality (electrified or otherwise), a significant source of electricity production combined with the sale of services, all of which are managed by a local operator.**

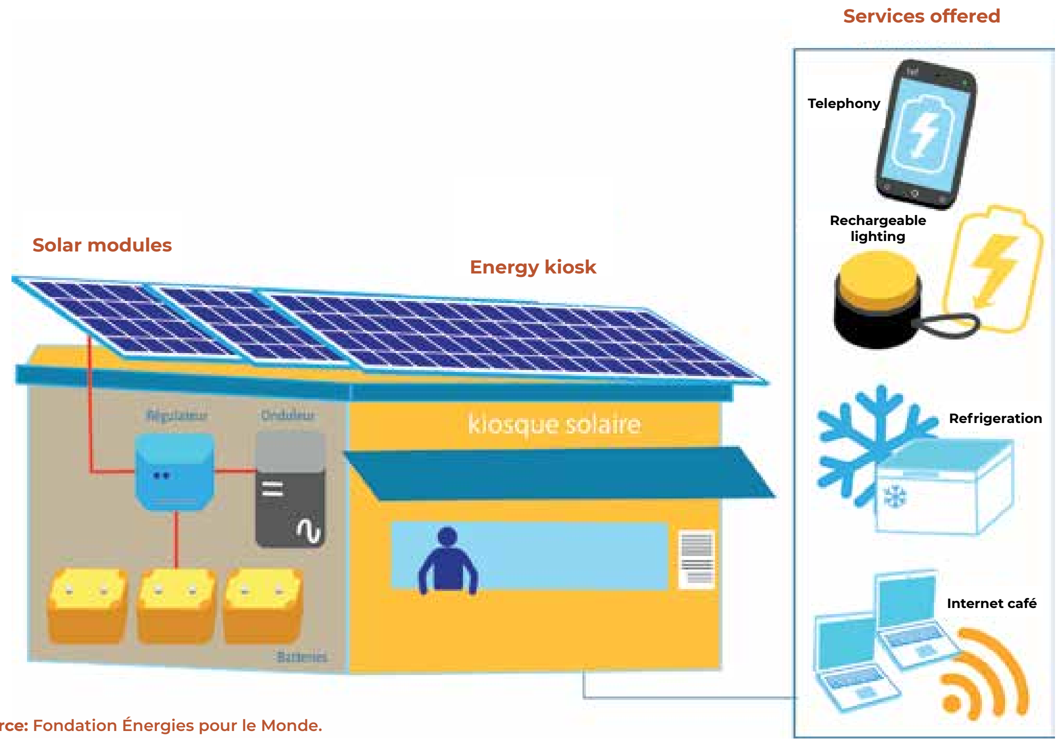
What are we talking about?

The source of electricity production is essentially solar, with possibly a back-up generator set. The several kWp-rated generators supply a significant amount of electricity and supply a wide range of equipment that far exceeds the limited capacities of domestic solar home systems.

As stated, the concept is primarily based on the supply of services. Users do not come to plug in a receiver and use the available electricity, but to buy a service powered by the electricity available at the kiosk (charging cell phones, multi-media services, refrigeration, charging portable lamps, etc.). The dozens of operators today in the African continent differ by their designs and economic models, but what they supply is generally much of a muchness.

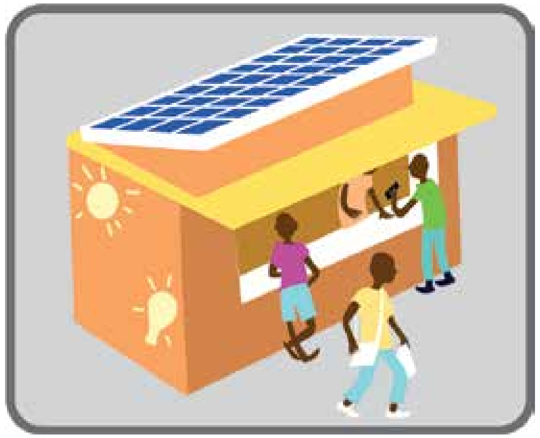
The profitability of the kiosk is often provided by services that were not originally envisaged by the developers but follow the logical asymptote of the needs expressed by the people: cell phone

Schematic diagram of how an energy kiosk works



Source: Fondation Énergies pour le Monde.

Examples of two types of solar kiosks – HERI in Madagascar and BENOO in Togo



charging, audio-visual and lighting. In electrified zones, kiosks can also meet various needs: minimum service for unconnected households, electricity service continuity during grid outages.

Who are the actors?

While there are different models, the current trend is for private operators, often start-ups and local SMEs to run these electrification schemes, with powerful, inexpensive and attractively, well thought-out designed solar kiosks installed in methodically selected localities.

Most of the systems are connected for remote technical monitoring, but their management is delegated to a local operator chosen for its commercial and entrepreneurial profile and are well-established in the locality. While the local manager is mainly responsible for the sale of services and everyday servicing of the system, some of them with fertile imaginations drive up their sales by developing the kiosks to meet needs: bar, cybercafé, video club, food shop, etc.

Some NGOs are also setting up multiservice energy platforms. A case in point is GRET in Mauritania, which has deployed more than 40 solar platforms, and Electriciens Sans Frontières which is experimenting with the "Café Lumière" concept managed by a private entrepreneur in Madagascar. *The "Café Lumière" programme has been covered in a case study that can be found in French on the book's webpage: http://fondem.ong/electrifier-lafrique-rurale/.*

Green Business Areas based on a similar principle but on a much larger scale, devised and deployed in Mali by GERES, bring together several economic actors around a single electricity production (standalone solar power plant). One of its strong and original points is its grounding in local financing mechanisms. *The Green Business Area has been covered in a case study that can be found*

Self-service refrigeration for cold drinks

One of the services offered by a Cameroon solar kiosk was a paying refrigeration service. The kiosk had several refrigerators. Users could pay to keep their farm produce there. The amount payable depended on the weight of the stored products and length of storage. On paper, the concept was attractive and meets the coding and impact measurements as devised by the international development organizations.

After a few months, the refrigeration service to the population was curtailed and the operator developed a cold drinks retail shop that provides 75% of his sales turnover.

A professional has his say
Samy Chalier

How do you choose where you will site your energy kiosks?

*"We pre-select the sites using the socio-economic database of the National Statistics Office then we go on site to confirm the data and meet the local authorities and populations. We have several criteria: minimum of 2000 households in the kiosk's catchment area, accessibility during the rainy season, telephone network coverage, the project must be adopted by the local actors, security, the presence of economic actors (microfinance institution, grocery, cooperative). **Sites that are already electrified offer good potential** because they are often on the main trunk roads, which feature high population density and higher purchasing power than the isolated areas".*

Samy Chalier, has an MBA and has worked internationally for more than 10 years. He has been living in Madagascar for a few years where he manages the company, HERI MADAGASCAR.

Find the whole interview in French on the book's webpage: *http://fondem.ong/electrifier-lafrique-rurale/*

A professional has his say
Vincent Renaud

Which techno-economic model is set up for maintenance, and more specifically for renewing critical components?

"We train the agency managers to first-level maintenance. The agencies are set up by service providers who carry out second-level maintenance. We have a technical sales officer who liaises between the agency managers and the service providers using a telephone number in the agency management application to provide effective support. This support is part of the service offer that we give to the entrepreneurs".

Vincent Renaud has 25 years' experience in rural project management in Africa. He co-founded BENOO ENERGIES, where he is primarily responsible for developing partnerships with rural development entrepreneurs and measuring social impact.

Find the whole interview in French on the book's webpage: *http://fondem.ong/electrifier-lafrique-rurale/*

in French on the book's webpage: http://fondem.ong/electrifier-lafrique-rurale/.

What is the economic model?

There seems to be no single economic model for these new concepts, that are still in the exploratory phase. Nonetheless, the main operators' approaches come together on various points: the search for a minimum of investment subsidy and incomes generated by the sale of services at the kiosk.

The individual who is locally in charge of the kiosk may be an employee, delegate, franchisee or self-employed taxed on sales. Ownership of the kiosk usually remains in the private operator's hands, so it is in the latter's interest to make available to the field operators the maximum number of tools, skills and flexibility to spawn initiatives, for the kiosk is not a "hermetic" concept.

A professional has his say
Grégoire Gailly

Today decentralized electricity service centre concepts come in various forms – Green Business Areas, platforms, kiosks… Do you think that this model is sufficiently economically viable to attract the private sector to invest extensively?

The model hasn't fully matured and if they are to win over investors, the new Green Business Areas must innovate, confirm the soundness of the economic model, partly standardize the organizational device and be able to provide more data.

Several factors can lure the private sector… a client base of solvent, very small companies, their grouping on a single site and the setting up of a support mechanism for them. A business plan is currently under study to allow an Green Business Area managing company to emerge, that would group the small, isolated sites into a bigger project, with lower transaction costs. Investors have already expressed their interest in this.

Community acceptance and fine understanding of the needs are essential for a successful project. Are the NGOs playing an indispensable role?

The NGO can play several roles: the R&D role for setting up pilot projects and producing techno-economic data; the role of intermediary and leader to get the actors of a territory to concert to identify suitable solutions; the support-advisory role to build a management capacity strengthening mechanism for the entrepreneurs in the activity zone.

What are the main flaws of the Green Business Area model trialled by GERES in Mali?

The main soft spot of the first Green Business Area is the site manager. Although he created a limited liability company to draw up a contract with the local development association delegated by the community to manage the Green Business Area, he did not invest any of his own funds in the infrastructure. If he leaves his job or is incapacitated, it will be hard to replace him within a reasonable timescale. That may jeopardize service continuity and the infrastructure's sustainability. In the event of a harsh blow on a site, an Green Business Area management company would safeguard this continuity.

While PAYG kit operators are criticized for only targeting domestic electrification, the Green Business Area model targets economic actors. Are these two electrification schemes complementary in a single area?

Indeed. We envisage setting up an SHS and SPS device distribution circuit backed by Green Business Areas (scalable "bespoke" solutions), with the idea of adding value to the permanent presence of sales engineering ability in the isolated rural area, that of the Green Business Area manager, propose customized sizing and an affordable quality installation solution by trained technicians. This activity would make the Green Business Area's economic model even more viable.

Grégoire Gailly is an agronomist, specializing in local development. He has worked for local development NGOs since 2001 and has been the director of GERES for West Africa since 2014.

Find the whole interview in French on the book's webpage: *http://www.fondem.ong/electrifier-lafrique-rurale/.*

However, this support does not negate the inherent risks of local management, for even if connected kiosks can remotely monitor electricity use, the informal economy and its lapses create stumbling blocks that must be kept in check.

What is the institutional framework?

Installing an energy kiosk in a village is more intrusive than distributing individual systems, as they require the intervention of the local authorities (mayors, dignitaries) to obtain a dedicated plot of land and pay any communal taxes that may be levied on the operator, in the same way as a right to acquire the land dedicated to installing the system. On a national level, selling services alone, rather than electricity, relieves the operator from compliance with regulation by the competent authorities for electricity sales. Supply and demand are shared trade-offs between the operators and the populations.

The model's strengths and weaknesses

The energy kiosk model meets domestic and economic needs through a pooled approach that appears to make more financial sense than distributing individual systems for cash-strapped households. Renting a portable, rechargeable solar lamp at the kiosk, including charging one or more cell phones, is less expensive for the user, who can turn to a kiosk rather than have a solar home system installed.

Moreover, there is no doubt about kiosks' social usefulness through the services users can obtain. They create a new social venue, bring innovation and distraction, develop connectivity, offer different levels of service without excluding the poorest households.

The multi-service concept, the attractive design of these projects and the modest "admission fee" (€ 10 000-20 000 to acquire and commission the whole kiosk on site) have little difficulty attracting subsidies that often cover the investment cost.

Case Study – Green Business Areas in Southern Mali

After realizing that only 18% of Mali's rural areas had access to electricity and that the primary source of energy was increasingly expensive diesel, the solution devised was to create a Green Business Area that would be totally powered by RES: solar photovoltaic panels and pure jatropha vegetable oil (PVO).

This solution was worked out by the inhabitants, in partnership with GERES and the community of Konséguéla. It aimed to concentrate firms together on a single site, firstly to overcome the technical constraints encountered with mini-grids (increased loads, voltage drops), and secondly to provide optimum coverage of their electricity needs affordably, with the right amounts and quality of electricity required for their activities. This Green Business Area, which operates like a rural business incubator, offers individual guidance for the first two years on site, as well as training and brokers contacts between very small local enterprises (VSE) and microfinance institutions.

So, the Green Business Area supplies electricity to VSEs (bakeries, joineries, community radio stations, etc.) in bioclimatic buildings. A jatropha PVO extraction service has also been installed to supply the Green Business Area's generator set and the firms of nearby localities. Solar photovoltaic panels generate electricity for the whole Green Business Area.

The project has produced many positive outcomes. Farming losses have been reduced, food preservation is enhanced and has better nutritional qualities. The community radio increases local public awareness and keeps the population informed, thus developing new social activities. The entrepreneurs, who are more productive, are more likely to generate profits, which has boosted employment… 50 direct jobs have been created and 150 indirect jobs consolidated. Furthermore, the territory has gained in attractiveness, which encourages new enterprises to set up there.

This success has paved the way for similar projects to be developed in other areas of Mali and further afield. The challenge set by ramping up to a significant number of Green Business Areas to meet the needs of non-electrified areas will be that of strengthening their governance and economic model.

Source : Summary based on the GERES' website: https://www.geres.eu/fr/actions/zone-dactivites-electrifiee-au-mali-zae/.
Find the full case study in French on the book's web page: *http://fondem.org/electrifier-lafrique-rurale/.*

Café Lumière… a repeatable solution for decentralized rural electrification

Context

The Café Lumière project (2016-2019) attempts to resolve the poor access to electricity in rural areas with an electrification facility that can assist the communal services, micro-enterprises and homes at the same time. It has been installed in six rural communities of the Vakinankaratra region, Madagascar, a country where 60% of the inhabitants live without access to electricity. There are several disadvantages to the generator sets and individual solar solutions that have so far been installed to alleviate this problem. The former can only be afforded by wealthy households, while the latter do not satisfy the significant electrical power needs required to develop economic activities.

Solution

Accordingly, the Electriciens Sans Frontières (ESF) NGO came up with a solution that lies somewhere between a grid and an individual kit… six **hybrid multi-service energy platforms** primarily supplied by solar energy. It is founded on the basis of a public-private partnership involving the local authorities and the State, and the participation of EOSOL, a private operator.
The project sets out to:
- supply 21 000 beneficiaries with a package of energy services after ascertaining their agreement to pay for them;
- develop economic activities in these villages;
- improve the availability of priority public services (schools, health centres, town hall) thanks to electricity.

The project sets out to be reproduced in a variety of local contexts, has already spread to Benin, where four Cafés Lumière will be installed by 2022.

Project monitoring

A **monitoring scheme** has been deployed since the project began to verify the results achieved and its impact on the population. The audit is based on 1) the definition of the **key monitoring indicators** in the project's conceptual phase in conjunction with AFD, 2) **prior** quantitative and qualitative **investigations**, to analyse the populations' living conditions and the market for each service, 3) two intermediate and final **assessments** performed to gauge the project's results and its impact the populations.

Source : Summary based on the Electricians Without Borders' website: *https://www.electriciens-sans-frontieres.org/projet/district-dantsirabe-cafe-lumiere-plateformes-energetiques-multiservices-dans-la-region-du-vakinankaratra/.*
Find the full case study in French on the book's web page: XXX

The operators also emphasize the positive result of the first operations.

Yet, there is still too little feedback to analyse the robustness of the model with regard to the technical problems that will inevitably arise... ordinary facility servicing, managing serious breakdowns, battery renewal, changes and volatility of the demand.

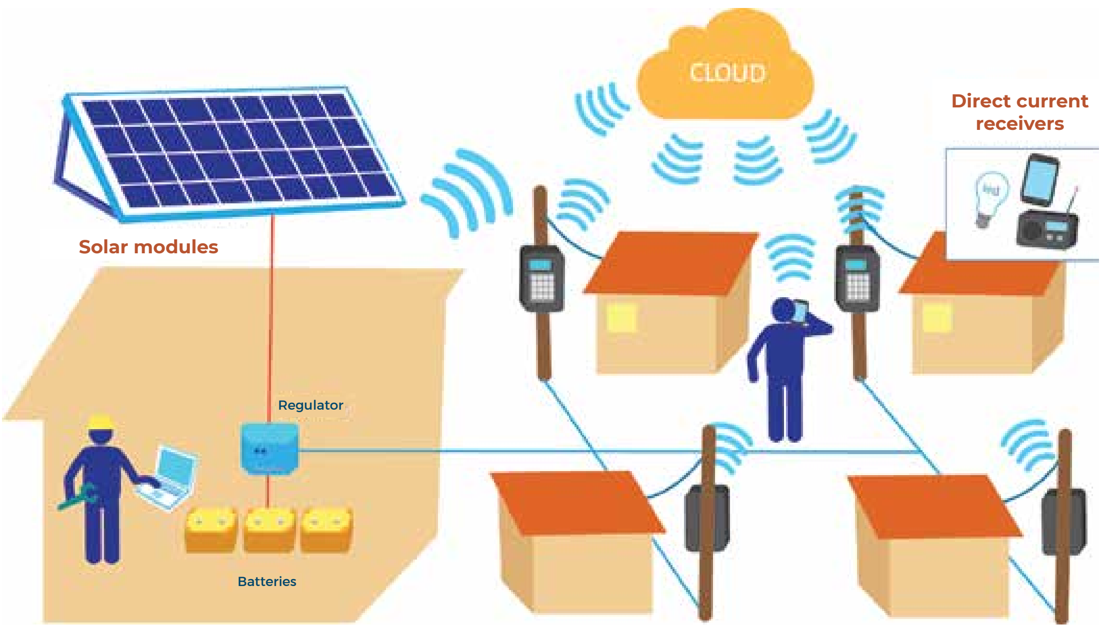
The risk of abandoning kiosks, as with other installations, is by no means insignificant because of the complex undertakings resulting from the franchise and support system which may turn out to be wanting when operators are more interested in multiplying the number of franchisees than their individual success. There is also the risk that the investors' and donors' current proclivity that is angling access to off-grid electrification towards the innovation race and fragmenting actions, will lead them to choose to invest in new trials instead of securing the future of existing installations.

The fact remains that kiosks usefully round out the range of services delivered by SHS by broadening the scope to economic activities. Without excluding the development of more concerted initiatives, they have their place in the decentralized rural electrification solution patchwork.

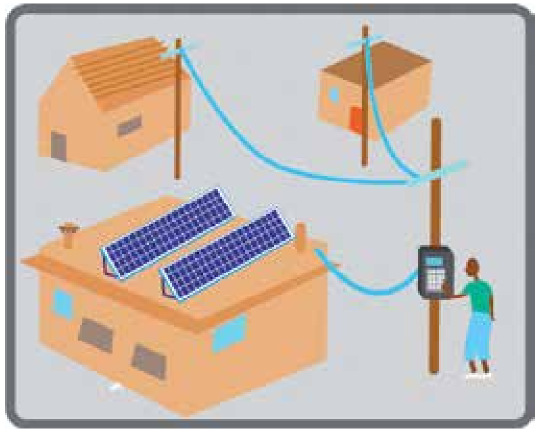
3.4.2.
Nano-grids... the concept is still finding its way

As it stands, there are too few initiatives setting up "nano-grids". They are founded on a scalable concept, in the gap between two schemes – the relatively rigid mini-grid scheme (cf. 3.5) and the plural scheme of SHS (cf. 3.2).
This hybrid solution entails physically connecting a group of users to a collective solar production source for essentially domestic use through an electricity grid measuring tens of metres in length.
The analysis of this new collective electrification scheme will be brief, for want of any comparative model or significant feedback.

Block diagram of a nano-grid



Source: Fondation Énergies pour le Monde.



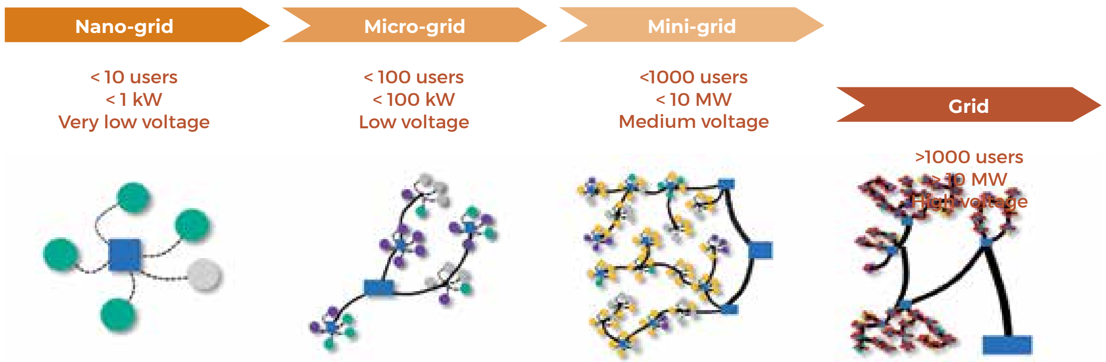
What are we talking about?

In practice, a standalone photovoltaic system ranging from 50 to 200 Wp is installed in a dwelling, to which 3-5 neighbouring dwellings can be connected by a cable and post system to form a nano-grid.

The services offered to this small user group are similar to those delivered by solar home systems, but the pooling of the production and storage source and abundance of uses enables a technical and economic optimum to be reached. For instance, a nano-grid serving 5 households with equivalent service will cost less than 5 individual solar home systems.

Above all, the model does not aim to stop at this simple pooling, as its originality and added value lie in its scalability. Several nano-grids can be interconnected to form a micro-grid, which in turn could be added to others to work towards mini-grids to reach the scale of a peri-urban grid... all of which could eventually be connected to the national grid.

The densification rationale of nano-grids



Source: Nanoé, *https://www.nanoe.net*

A professional has his say
Nicolas Saincy

How do you defend the nano-grid concept's position between Solar Home Systems and mini-grids? *The concept of gradual electrification through interconnectable nano-grids may meet both short- and long-term needs more effectively than the two other solutions currently deployed in rural Africa. Despite its significant impact on development, the electrification model by constructing and operating classic mini-grids, has had difficulty getting off the ground for several decades because of high investment costs and their development potential limited to fairly densely populated areas. The electrification model of manufacturing and distributing individual systems (SHS), that are geared to basic domestic needs, has spread like wildfire over the past decade, yet cannot mask its inability to support local development over time. The nano-grid's strength is based on the combination of technical solutions, on the borderline between SHS and grids, and on its novel approach, on the borderline between commercial and public service rationales. With small-scale customer clusters, it makes for a faster, more flexible, more modern and affordable electrification model than individual systems or classic grids to meet the territories' growing needs and support their development.*

What are the model's priority improvement lines that you envisage with the hindsight of initial feedback in Madagascar? *Having trialled our model for 18 months in Madagascar, it is now in the industrialization phase. Even if the trial has ratified its technical, social and economic essentials, there are many operational challenges to overcome before it can be considered as a totally credible alternative to the two mainstream models. In particular, we need to make major efforts in the area of training, organization and operational development to set up decentralized nano-grid construction and operating sectors on a large scale.*

How do you cater for the electricity demands of the economic actors, whose capacity and energy needs are greater? *By providing an electricity service that covers lighting (public or private), cell phone charging, multi-media and refrigeration, nano-grids actually cater for the energy needs of more than 90% of rural economic actors. This service can be gradually and economically extended to pumping and driving power needs by interconnecting several nano-grids (within a micro-grid). Ultimately, we envisage being able to meet all the industrial energy needs of an area through an additional clustering step (by interconnecting several micro-grids).*

Nicolas Saincy, is the co-founder of Nanoe, a firm based in Madagascar.

Find the whole interview in French on the book's webpage: *http://www.fondem.org/electrifier-lafrique-rurale/*

Electricity production is spread but is gradually pooled as new interconnections are made. This densification ensures that the system can supply high-demand productive services or public services such as those already mentioned.

Digital technology makes for high flexibility in use for this model as in the others, thanks to remote control of the nano-grids and pre-payment of consumption through a Mobile Money application.

Who are the main developers?

Nano-grids are still minor players in the rural electrification landscape, for there are just a handful of private promotors, linked to local partners, telecommunications operators and Mobile Money solution providers.
The French start-up NANOE, that has been operating in Madagascar since early 2017, is one of its pioneers. Its model, claimed to be in the throes of industrialization (cf. the next interview), encourages local entrepreneurs become nano-grid developers and operators. The hybrid model developed harks back to both the PAYG model and franchised energy kiosks.

What electricity for the users?

Electricity services for domestic users, are paid for at a fixed sum applicable to 2-3 limited and similar service levels to SHS, depending on the authorized number of bulbs and receivers. The number and type of receivers are limited (lighting points, cell phone charging, possibly a television set).
When a few nano-grids and any additional production sources are connected, a combined service can be considered that caters for both domestic users and economic actors for the heavier demands (refrigeration, simple electric tooling).

Gradual networking into tens of interconnected nano-grids would offer the electrical capacities of a traditional grid that meets all kinds of uses, but this possibility has still to be demonstrated on the ground.

What is the economic model?

There are still too few proponents and the data is too restricted to talk of a standardized economic model. Recurring own funds needs will probably be required for production investments: standalone photovoltaic systems, grid accessories, management and monitoring equipment. The sale of electricity in different forms (fixed-sum, kWh purchases) should cover the operating expenses, investment payback, and ideally, will finance the following nano-grid installations.

While the trials appear to be positive, the current model, like all the other models described, requires subsidies.

What is the institutional framework?

As they resemble the activities of electricity companies, those of nano-grid operators are theoretically subject to electricity sector regulations.
Also, as the nano-grids are rolled out in a concerted fashion with the local authorities and in line with any electricity grid extension plans, they must comply with a technical baseline on the safety of individuals and property, while the pricing of their services is subject to approval by the regulatory bodies. Yet in practice, the regulatory bodies' and rural electrification agencies' lack of resources combined with the model's novelty may lead to dispensation.

Strengths and weaknesses

The model's main strength is its scalable nature and capacity to be deployed fairly fast and flexibly. The electricity services it proposes, that are basically domestic, seem to be extendable to meet the economic actors' demands by adding several units together.

Although its underlying technical complexity is considerable, the gradual construction of one or more high-capacity nano-grids is a novel, appealing idea. In contrast to a mini-grid that is supplied by a single source, a nano-grid can call on several interdependent production sources at the same time (cf. above nano-grid diagram). But this complexity factor is also a pledge of security as the production sites can take over from one another.
Thus, careful attention must be paid to this unusual model that is likely to take advantage of the research into smart grids and also have to tackle the limitations of the traditional models.

3.5. The mini-grid – an historical collective electrification scheme undergoing a sea change

As it stands, the mini-grid appears to be the most satisfactory solution for providing all the members of a rural community with electricity simultaneously and covering the diversity of the domestic, productive or public needs.

As the scheme is designed to be global and versatile, the equation it attempts to solve is nonetheless complex. It is rolled out along various organizational, technical and economic lines, subjected to many factors and calls on various types of actors, none of which is universally accepted. This essential sub-sector of DRE, which tends to be developed by searching for rural electricity model that mimics its urban counterpart as closely as possible, is in turmoil.

After a brief historical and contextual synopsis, this section presents the various methods and technical fundamentals of mini-grids, their strengths and weaknesses, before it recounts the key points of the lessons learned of 20 years of rolling out rural mini-grids on Sub-Saharan soil.

The book deliberately focuses on mini-grids powered by photovoltaic and/or hybrid plants, that comprises most of the mini-grids in service and are at the heart of myriad on-going and future discussions and technological transformations.

Focus on the solar mini-grid

3.5.1. Despite many failures and complex economic assumptions, rural mini-grids are winning over new actors

The replication of the electrification model experienced in the industrialized countries since the end of the 1980s in Africa, has spawned the installation of thousands of rural mini-grids designed to deliver electricity "as they do in town". The first generation of thermal generator-based rural mini-grids ran into many operating difficulties. Micro-hydropower has proved its relevance for high capacities (100 kW-1 MW) when the source is plentiful and near the points of use. But the massive spread of photovoltaic solutions, new storage technologies and digital technology are reinventing the genre.

Perusal of most national electrification strategies and policies confirms mini-grids' leading role in the rural electrification goals and plans, particularly in West Africa.

The Club ER census shows that almost 1 900 rural mini-grids have been installed in the Sub-Saharan region (which does not mean that they are working), for about 35 MW, with wide territorial divergences (cf. mini-file).

Mini-grids... the example of Senegal

In the last 20 years, 984 villages have been electrified by SHS (1270 kWp) and mini-grids (900 kWp)

Planned by 2030, 760 new villages by solar power, with 19 900 kWp of projected peak capacity.

Source: Malick Gaye from the Senegalese Rural Electrification Agency (Club ER General Meeting, December 2018).

Transindo project... a 100% French smart hybrid mini-grid installed 20 years ago

Almost 20 years ago, the Transindo project was one of the first hybrid solar mini-grid electrification schemes. It aimed to set up reliable, inexpensive and clean-energy electricity grids in the Indonesian island villages of Celebes and Borneo.

These sparsely populated islands were mooted when the Indonesian government decided to reduce overcrowding on Sumatra and Java. But the newcomers used unreliable and expensive polluting generator sets, which prompted the government to seek a sustainable access to electricity solution in these faraway areas (more than 18 hrs away by boat).

The initiative changed into a project in partnership with the PHOTOWATT group and the Indonesian Transmigration Ministry with funding through a Franco-Indonesian protocol. **A 24-kWp hybrid power plant coupled to a battery bank and a generator set** was installed with hardware designed and developed in France, and project management provided by TRANSENERGIE. A mini-grid was installed to supply some 500 homes with electricity.

Already 20 years ago, user connections were made using current intensity, energy limiters and a pre-payment system. Given the high level of innovation, the strong resolve was marked in supporting the actors involved, including the users with regular awareness-raising campaigns on the rational use of electricity.

MINI-FILE

Mini-grids in Sub-Saharan Africa... the Club ER census findings

Club ER is an initiative of the French Environment & Energy Management Agency (ADEME) that groups the national agencies and national bodies responsible for rural electrification. In 2019, it piloted a vast census campaign of the mini-grids installed in its member countries.

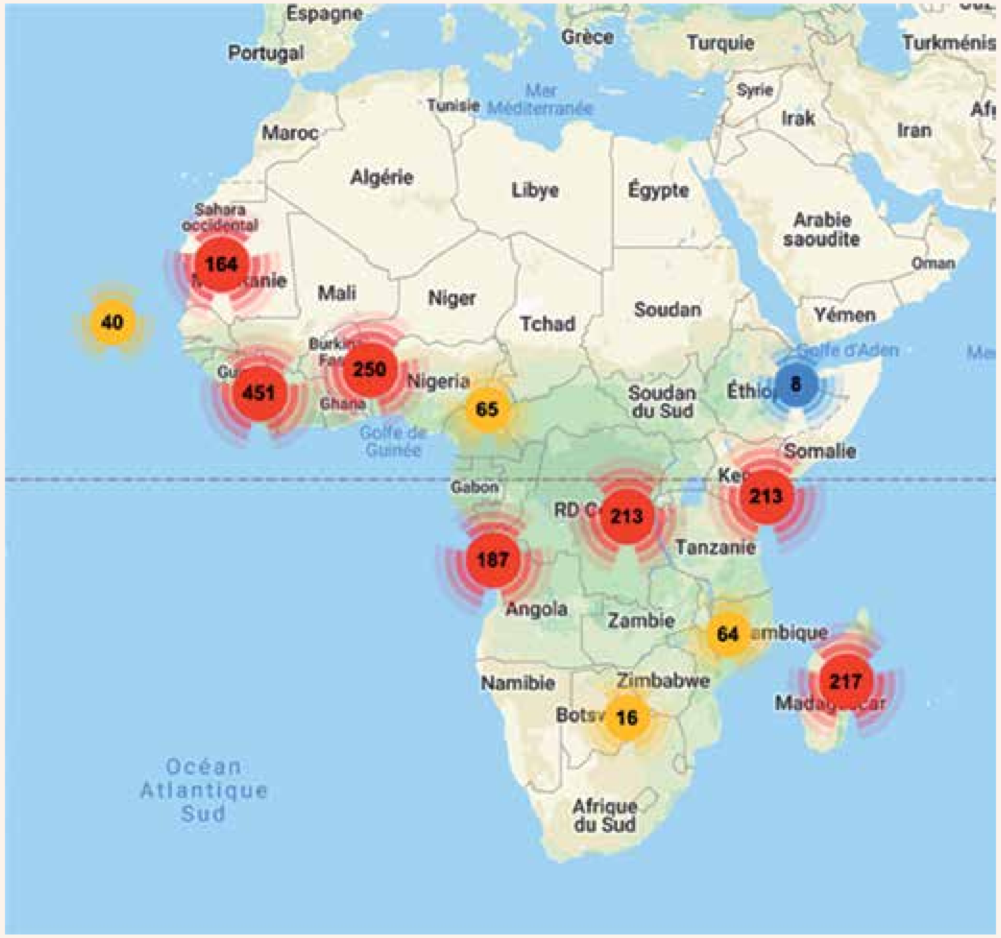
Analysis of the data, sometimes with a limited degree of accuracy, reveals some trends that apply to the last 20 years' achievements:

- **a few countries (Mali, Senegal, Burkina Faso, Mauritania, Kenya) hold a clear lead in terms of feedback on mini-grids**, diesel, solar and solar/diesel hybrid with storage in the main. The average mini-grid ratings run to the few tens of kWp.
- **photovoltaic technology (hybridized or otherwise) accounted for more than 70% of the identified mini-grids, over the entire study area, but less than 40% of the combined installed capacity.** There were a few hybrid solar/diesel grids with no storage for a few MW, mainly in Mali. They consist of connecting solar "to the grid" that is permanently supplied by a thermal power plant. These systems are found in secondary localities that have long been electrified by a thermal plant, whose fuel costs the operator would like to reduce (in practice 10-30% depending on the solar penetration rate). These schemes are not covered by the book.
- **hydropower has a very high presence in Central Africa**, with more than 400 mini-grids counted, for average capacities of several hundred kW.
- **the project counts about sixty biomass-fed mini-grids essentially in East Africa** (Jatropha, biogas digester, various biofuels), with similar capacity ranges to solar/hybrid mini-grids.

Major map display work has been performed on the basis of the data collected, that shows the distribution by zone and offers classification by technology.

Source: Find all informations map on: *https://thexs-mapping.firebaseapp.com/mapping.*

Mapping of Africa's mini-grids, all technologies taken together (2019, Club ER)



Source: Club ER, 2019, *https://www.club-er.org.*

Urban grids vs. diesel-powered mini-grids – significant differences

On the production side

> **Producing electricity via a fossil fuel thermal "power station" of several megawatts is a mature industrial discipline.** Several machines work in parallel, coordinated to operate at specific speeds and adjusted by optimized slope of reaction curves, designed and serviced for known, controlled lifecycles (30 000-50 000 hours) that guarantee service through extended maintenance periods. The scale effect enables permanent, dedicated, skilled technical staff to be hired, managed by the national utility, that has easier access to international donor support.

> **A rural diesel-powered mini-grid is a small thermal unit with capacity 50-1000 times lower than an urban power plant (50-300 kW).** The power plant often consists of a single machine (generator set) that alone withstands variable load curves (low demand during the day, significant peak in the evening) and all the peaks in demand. It thus operates in adverse technical conditions. The slightest breakdown can thus plunge a village into darkness for several days. So, while these low-power generator sets are designed for intermittent use (the service sector uses this type of equipment as a back-up during urban power cutbacks), they are thus not as sturdy as the national grid power plant machinery, and their specific litre/kWh consumption is higher than that of urban power plants.

On the transmission and distribution side

Whereas medium voltage (20 kV, 33 kV, 63 kV) is always found on urban grid transmission lines (that are of a more complex design), rural mini-grids are essentially low-voltage (0.4 kV) distribution, possibly backed up by a few MV (15-20 kV) lines because of the shorter distances and lower power capacity in transit. The difference stems partly from the power density (a function of the density of connected users and the type of users), and also from the amount of energy flowing per grid unit length:

> **In the urban zone,** 1 km of low voltage line can serve up to 500 users and carry up to 1 000 kWh per day.

> **In the rural zone,** we observe an average of about 50 users per km of line, hardly conveying 10 kWh flows per day.

On the operating and pricing side

> **In town, users pay for electricity that is both technically less expensive and more highly subsidized than in rural areas.** Urban grids, most of which are operated by the national utilities (cf. 1.2.) benefit from purchase and management pooling. Furthermore, even if they aspire to being standalone, profitable economic models, financial backers continue to support governments that are mindful to maintain social peace. This environment sometimes leads to pricing equalization mechanisms between the country's main towns, or even the introduction of social pricing (below a certain monthly consumption threshold, the cost per kWh is reduced).

> **In the rural area, recouping the real production cost of a kWh results to a per kWh sales price that is 2-3 times higher than the price paid in town.** While most diesel-powered rural mini-grids have taken up significant investment subsidies, they soon found themselves without any financial support during the operating phase, with unsubsidized pricing, unsuited to the rural populations' financial means. Moreover, management is often entrusted to an operator, whose integrity and motivation have a strong influence on the installation's sustainability, which is the weak point of this type of scheme.

Is the construction of a mini-grid a step towards a national grid?

The implementation of universal access to electricity projects are historically based on a premise inherited from the electrification of industrialized countries. "It is by clustering many mini-grids that you can construct the interconnected grid that the populations need". But as it stands, it is hard to imagine that at least in the medium term urban grids can be extended, then interconnected to rural areas (cf. s 1.2.1 and 2.1.2).

In addition, nor is it by international grid interconnection programmes that pool high-capacity production resources (such as hydropower plants

Mini low voltage grid in Guinea

Urban grid

running into their GW) that rural areas will gradually be electrified. Rolling out a national grid involves routing the electricity right to the user and selling it. Taking the electricity of a very high 400-000 volt voltage line down to a community living in scattered settlements with low incomes calls for the combination of two rare commodities: strong political resolve and a good subsidy mechanism.

A mini-grid is not simply a lower capacity grid
At first glance, there are similarities between the "national" grid and a diesel-powered rural mini-grid (the technology initially used by isolated mini-grid developers):
• production by a generator set;
• transmission and distribution by a set of posts and cables;
• connecting the users;
• metering and invoicing the kWh sold.

Yet, a rural diesel-powered mini-grid has significant differences stemming from the rural African context, at production, distribution and operating levels, with one crucial effect... t**he production cost of a kWh of electricity is considerably higher on a "diesel-powered mini-grid" than on an urban grid** (cf. inset).

When we give a few orders of magnitude of consumption, it is easier to grasp the difference in economic weight between an urban grid and a rural mini-grid:

Electricity consumption in urban and rural areas: some orders of magnitude

URBAN		RURAL
350 kWh p.a. Average consumption of an electrified home in a town	x 3	**100 kWh p.a.** Average consumption of a rural home[1]
100 000 kWh p.a. Consumption of an average luxury hotel in the town centre of an African capital city	=	**Consumption of 1 000 rural homes p.a.**
1 textile factory on the outskirts of an African capital city	=	**Consumption of 500 rural villages**

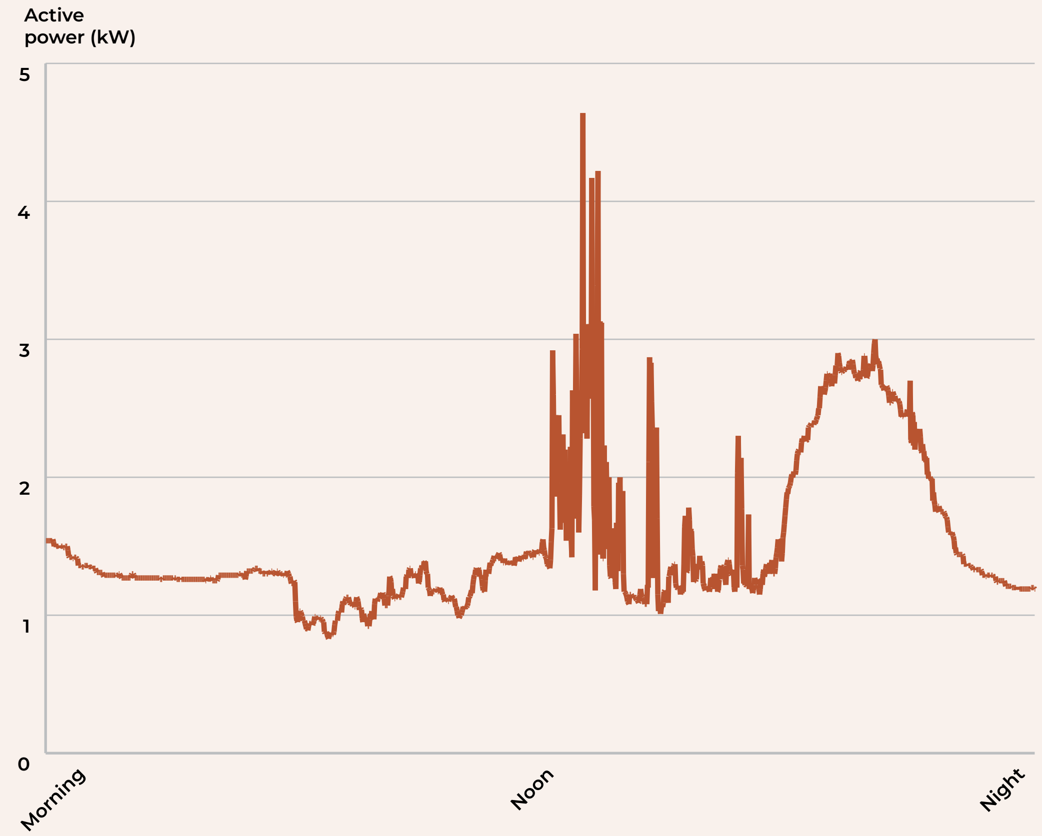
Source: Fondation Énergies pour le Monde.

1. NB: it is about 4 000 kWh in France, and double that figure in the United States

Load curves

Graph depicting the average electrical capacity drawn by a site (locality), where each time unit is at the scale of one day. The integral of the load curve indicates the daily electrical energy consumption.

Example of a load curve expressed as active power (kW): i.e., the power actually used by electrical appliances used on the mini-grid.

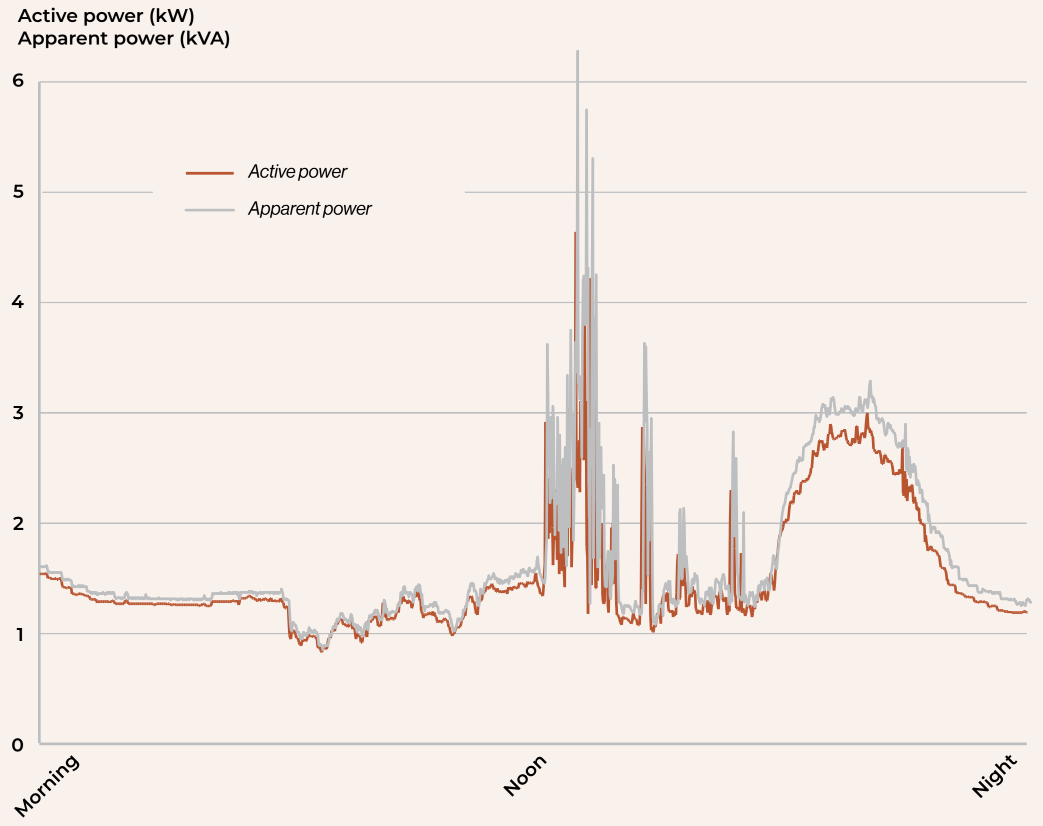


Source: Fondation Énergies pour le Monde.

Peaks in demand

Starting an electric motor generates intensity peaks up to 10 times the nominal operating intensity value, at a very degraded load factor for a few seconds

Example of a load curve expressed as active power (kW) and apparent power (kVA) illustrating the current surges and power factors of the electrical appliances used on the mini-grid.



Source: Fondation Énergies pour le Monde.

Accessibility of renewable energies and the digital revolution are changing the mini-grid model

Since the 2010s, these two technological developments (cf. 2.3.1.) have led to the design and implementation of renewable electricity production systems to replace thermal generator sets.

While adopting these technologies has revamped the genre, not all the obstacles have been removed. It highlights the importance of taking proper account of the human factor for the success of a project.

The rush to enlist renewable energies... a technological shift that raises the issue of local skills

The designers have made a beeline for renewable resources to develop mini-grids, mainly solar or hydropower and often "hybrid", as if the difficulties primarily stemmed from the production source.
However, this production change raises two new issues:

- **financing:** when these installations are well manufactured, the investment amounts needed are 5-10 times more than the cost of an ordinary generator set, although costs are steadily tumbling;
- **maintenance:** while a generator set can be repaired almost anywhere in Africa, repairing a solar inverter is quite another matter...

In the case of solar mini-grids and with hindsight, it seems as though the concentration on production has led to major investments of public funds in works that have often been oversized and too complex for the requested service and local ownership capacities. This strictly technical vision (RES system vs. thermal system) has obfuscated steps that are crucial to the survival of a rural mini-grid over time... namely, identifying the demand, ownership by the beneficiaries, choosing and supporting the operator, the institutional framework and long-lasting monitoring.
All these points will be discussed in section 3.5.3, that looks at feedback.

Gradual dematerialization of management also raises the issue of local ownership

Digital technology is another shift that is having an impact on how mini-grids are technically operated, with its range of solutions that are not the sole preserve of SHS. Communicating pre-payment meters are rapidly spreading to mini-grids, as they offer the same functional logic as the dematerialized management of PAYG kits mentioned above. They reduce manpower requirements, power plant operating is made easier through remote monitoring, and learning electricity usage habits is fast to take root.

An obvious corollary to this dematerialization is that the human factor fades away, damaging project set-up and management. Making users aware and involving the local authorities – who having built a track record, occupy a central position in NGO projects (cf. 2.4.2) – tend to be sacrificed to the business plan constraints and short term vision, at some risk.

The models initiated by the pioneers, especially the NGOs, are making way for those introduced by an ambitious private sector

The technical revolution blowing through the DRE sector comes with a change of models and actors (cf. 2.3) and has not left the mini-grid world unscathed.
It is leading to some erasure of the humanist goals borne by its pioneers. Despite their experience-based plea, the NGOs and their supporters who are now involved in just a small proportion of ongoing programmes, are having to struggle to

A professional has his say
Yann Chauvelin

Do you see a risk in rolling out 100% digital and connected solutions that minimize the presence of a team of operators out on the ground?

"Digital and connected solutions improve the management of production, distribution and user payments. They enhance and secure operations and maintenance, through pooled centres that offer better expertise as occurs with telecoms operators.

They do not eliminate the need for on-the-ground presence in every village, to deal with the commercial aspects, guide the villagers in how to use electricity and broaden its use".

Yann Chauvelin, trained as an engineer and has been running projects for more than 20 years in Africa for telecommunications and energy. He is the rural electrification business development manager for the company SAGEMCOM ENERGIE ET TELECOM.

Find the whole interview in French on the book's webpage: *http://www.fondem.org/electrifier-lafrique-rurale/*

justify their socially ambitious projects, in the face of an innovative private sector that is better prepared in terms of marketing and financing.

The original model, founded on strong institutional anchoring, is based on the joint action of public and voluntary actors

For a long time, mini-grids, like other DRE schemes were designed on the initiative of public institutions with the support of international cooperation and the technical backing of the local NGO or engineering office. Specific examples of this are the UNDP's multifunctional platforms (a sort of mini-grid for productive use (cf. 3.4.1.) and the EU's Energy Facilities. Thus, the historical model of the mini-grid is based on:

- public fund investments (international fund raisers);
- a structured institutional framework (national, regional and local public authorities);
- a call for projects mechanism and public/private partnerships;
- strong NGO presence plying the role of trailblazers and safety net.

"Pilot" mini-grid projects flourished, and several operational schemes were tested (cf. 2.4.2) thanks to this, not always cordial, assortment of public, institutional, voluntary and private actors working under the access to electricity umbrella. Even with the objectively weak long-term sustainability rate, these projects created several good practices, that today's current mini-grid project developers often adopt. The rural electrification NGOs, who had to shoulder several setbacks, have taken the time to reveal the technical, sociological and institutional invariables of a mini-grid electrification programme by experience (cf. 3.5.4).

But these complex collaborative projects deter many people

A number of private operators and local entrepreneurs, who are well-established and mindful of local development, have given up developing or perpetuating a mini-grid project because of broken national policy promises or administrative delays that undermine a fragile business plan.

An additional problem… the rural electrification agency subsidy awarding mechanism to these actors is petering out. As part of a framework akin to "delegating public service", they spare the operator from being forced to follow a profitability rationale that is often at odds with the reality out on the ground by simply helping them balance costs and expenses.

For their part, NGOs are finding it increasingly hard to raise the finance they need to roll out projects mindful of local ownership and skills transfer. On balance, it is hard to contest the financial fragile state of their operations. The support measures introduced cannot do everything. They are powerless meet the change of scale illusions. That also begs the question of the relevance of overly-rigid operating plans drawn up by some NGOs, whose modelling is sometimes derailed by reality.

The fund raisers and ministries, wearied by the differences in stance between DRE practitioners and the additional delays created by the social and institutional approaches of projects developed by civil society, are now readily turning to the private sector that proffers faster and apparently just as efficient solutions.

Technological breakthroughs and changes to institutional frameworks are opening up wide scope for action to the private sector

Private international mini-grid operators entered the rural Sub-Saharan market with private investor backing in 2015 without waiting for the cyclic subsidy campaigns prompted by the call for projects system, and today account for most of the investors.

These operators usually work independently, sometimes outside of any reference to plans or national policies:

- they conduct their own surveys in the areas they identify as strategic;
- their projects are devised with little, yet rapid concertation with the local authorities, and essentially aim to obtain the necessary permits on the basis of usually cursory energy and sociological situation analysis;
- the pricing schedule and services proposed to the "customers" are based on confidential plans, or plans that are formulated in such a way that the regulatory agencies have difficulty challenging them;
- the technical solutions rolled out are often too innovative to allow the competent authorities to appreciate their long-term implications.

User are no longer assured of the sustainability of the service and even less of its equity

While mini-grid projects borne by the relevant public authorities, backed by civil society actors will ensure that the service is equitable, and that electrification is universal, private operators will naturally focus on the areas with the highest economic development potential. Their electricity networks will be rolled out around the main consumption centres, selecting users likely to pay for

A professional has her say
Camille André-Bataille

What are the main steps and average lead times for rolling out a mini-grid, from identifying the site to commissioning the structures?

"Setting up a mini-grid is long and tedious, interspersed with key steps that partly depend on action by the administrative services. We start with field surveys with the local stakeholders (households, productive users, public services, local authorities, etc.) to gauge the energy demand and socio-economic development potential.

This is followed by the land tenure issue, which can take several months depending on the local actors' willingness to commit and the time taken for the technical (boundary marking, plans) and administrative stages (legal situation certificates, community convention of provision of land). In practice, these steps, which should be performed by the local beneficiaries backed by ADER, are often taken on by the project developer. (…)

Once the application has been finalized, it is submitted to ADER to be signed off technically, then to the Regulator, followed by the Ministry to sign the permits and concessions (which can take 2-8 months)".

Camille Andre-Bataille, is an engineer and energy and low-carbon project economist. She has worked for 5 years in DRE and the emergence of strong rural communities in Madagascar and Africa.
Find the whole interview in French on the book's webpage: *http://www.fondem.org/electrifier-lafrique-rurale/*

the service at a rate that covers the investors' expected returns.

The new 100% private electrification models will not directly benefit the most destitute without the political determination to establish a regulated public electricity service and tariff equalization at least across the territory. The future will give its verdict on these projects, but the first observations on the ground give a glimpse of methods and impacts fairly far removed from the humanist concept of the right to electricity.

The electrification of a rural area, regardless of the method, sometimes heightens the existing social inequalities (see 2.4.1), but that is not the end of the world. The electrification of the industrialized countries and some developing countries was carried out equitably, sometimes belatedly (in France, after nationalization in 1947 for example.), through price equalizing.

How can this equalizing be achieved in Sub-Saharan Africa, at least at the scale of a region? Perhaps by exploiting the complementarity between the interventionist and liberal rationales. That will call for an appropriate institutional and financial setting, real political and social vision, as well as resources that rural electrification does not have today (see the recommendations made in Part 4). The NGOs, on the strength of their presence and work concerned with the local context, need to change to enter into constructive dialogue with the private operators whose constraints also stem from practice. This complementarity must make itself felt, for the benefit of all, starting with the local populations.

The economic equation is complex, and no model really appears to demonstrate its relevance

The new private initiatives legitimately return the economic issue to its rightful place at the project centre… while its coverage by the pioneering MGOs tended to be underplayed.

Regardless of the operating scheme, renewable mini-grids are very capital-intensive, which is why the economic model gets all the attention.
The number of business plan software tools is increasing, and some grants are awarded provided that the cash flow forecasts are positive for 20 years (which in practice is tantamount to crystal ball gazing…). The arbitrage between CAPEX (investment expenses) and OPEX (operating expenses) occupies the centre of the discussions, for defining issues such as the hybridization rate per generator set, and allowance made for equipment renewals.

The economic model may seem simple. It entails investing in electricity production and distribution equipment with minimal operating costs (hence the RES boom) and offsetting the investment by selling electricity to users. However, in practice, several models coexist, with and without subsidies, along the lines of economic rationales that

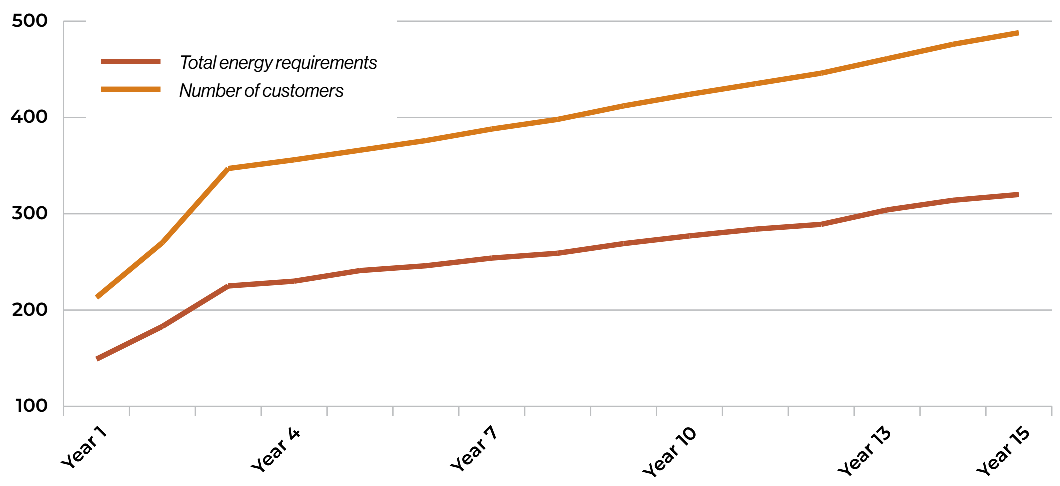
A professional has his say
Yann Chauvelin

Do you think that joint work between the private and voluntary sector can be of benefit to all the stakeholders?

"The NGOs are well aware of the decentralized rural electrification issues, not only in identifying and quantifying demand but also in guiding the populations to develop the use of electricity. Collaboration with the private sector developers could be complementary and beneficial to all the stakeholders, and especially the populations on these points.

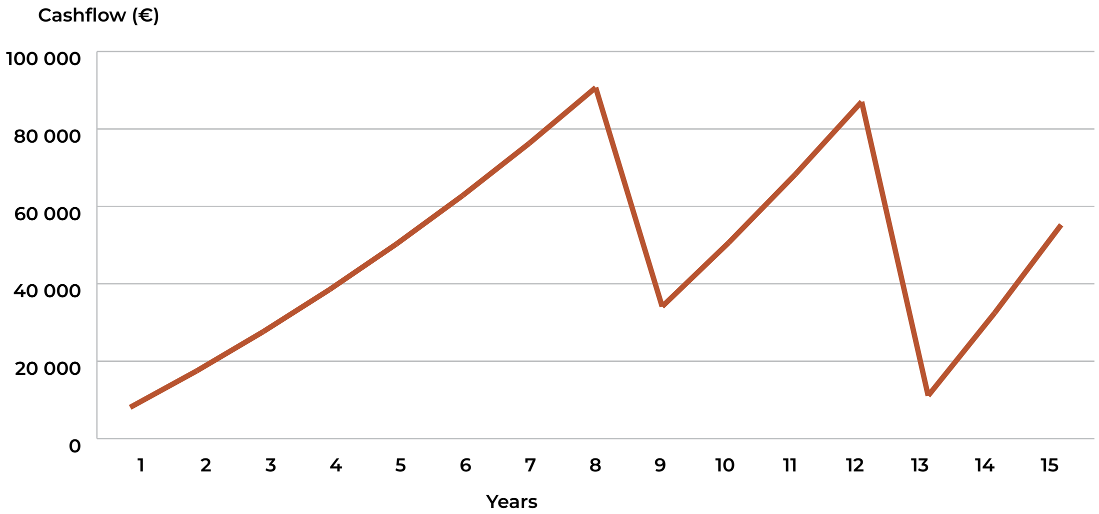
Yann Chauvelin, trained as an engineer and has been running projects for more than 20 years in Africa for telecommunications and energy. He is the rural electrification business development manager for the company SAGEMCOM ENERGIE ET TELECOM.
Find the whole interview in French on the book's webpage: *http://www.fondem.org/electrifier-lafrique-rurale/*

Trends in the number of customers and electricity consumption over time



Source: Fondation Énergies pour le Monde.

Cashflow trend during the operation



Source: Fondation Énergies pour le Monde.

convey a variety of operational schemes and sometimes contrasting intervention philosophies:

- some small local and independent operators that have been out on the ground for years and close to their customers post minimal but sufficient profitability thanks to a few investment subsidies[1];
- other energy actors, sometimes international in scale[2], set up as operators aiming at several hundred high potential villages to pool costs. They generally opt for "containerized" and/or "connected" solutions so that they can be remotely managed or managed by minimal local presence;
- for their part, the NGOs continue to make the case for the right to electricity for all (especially if it is renewably and locally sourced), to promote local private management in the flesh, and to demonstrate the need to subsidize at least investment, and sometimes also operations (such as renewals and extensions).

The question raised by developers looking for a viable, subsidy-free economic model is simple and essential. Does investing in a mini-grid today offer a coherent short-term return on investment (ideally 5 years in the African context) and significant medium-term gains (economic models are drawn up with 15-25-year timelines)?

Obviously, the answer is more complex than the question, because projects are subject to several uncertainty factors. Section 3.5.3 summarizes the elements that are the basis of the brittle cement of the rural electrification by mini-grid model and its operational deployment in the current context.

Prior to that, the technical bases are taken up in a section that the energy sector players will no doubt be able to skip but will give the other readers more insight into some underlying operational aspects.

1. As in the case of EOSOL, that works in Madagascar - (See the interview of Camille Bataille on the web page of the book: *http://www.fondem.ong/electrifier-lafrique-rurale/*).
2. As for example the French groups ORANGE, EDF, ENGIE, SCHNEIDER ELECTRIC and SAGEMCOM.

3.5.2.
Mini-grids – recap of the technical fundamentals

When designing an electricity power plant to supply a mini-grid, various complementary engineering trades need to intervene – geology and civil engineering, power electronics and PLCs, electromechanical, electricity transmission and distribution – while hydropower has its own additional specific needs.

This paragraph is deliberately geared to solar and/or hybrid power plant fed mini-grids. The extremely interesting area of hydropower calls for a specific initial context. The subject is covered in a knowledge management document published in French in January 2019 by GRET, "Des Turbines et des Hommes"[1], that presents excellent feedback on the deployment of hydroelectric mini-grids in Madagascar.
Technically speaking a mini-grid is thus classically based on three pillars:

- a production system through one or more combined electricity sources, and includes the regulation and storage
- an electricity distribution infrastructure,
- a connection that creates an interface with the end user, including the electricity meter.

The following paragraphs aim to describe how a mini-grid works in these various technical aspects and mention the main problems encountered.

Production is currently dominated by solar power

Solar photovoltaic is the main source at least for the time being, even though other renewable energy sources can be envisaged for electricity production for mini-grids. Apart from plummeting costs, which explain its fast spread, photovoltaic

Low voltage mini-grid, Madagascar

has relatively constant and abundant potential all over the year and especially in West Africa (cf. 1.1.2). It is sometimes combined with a top-up generator set when needed, so turning it into a hybrid system.

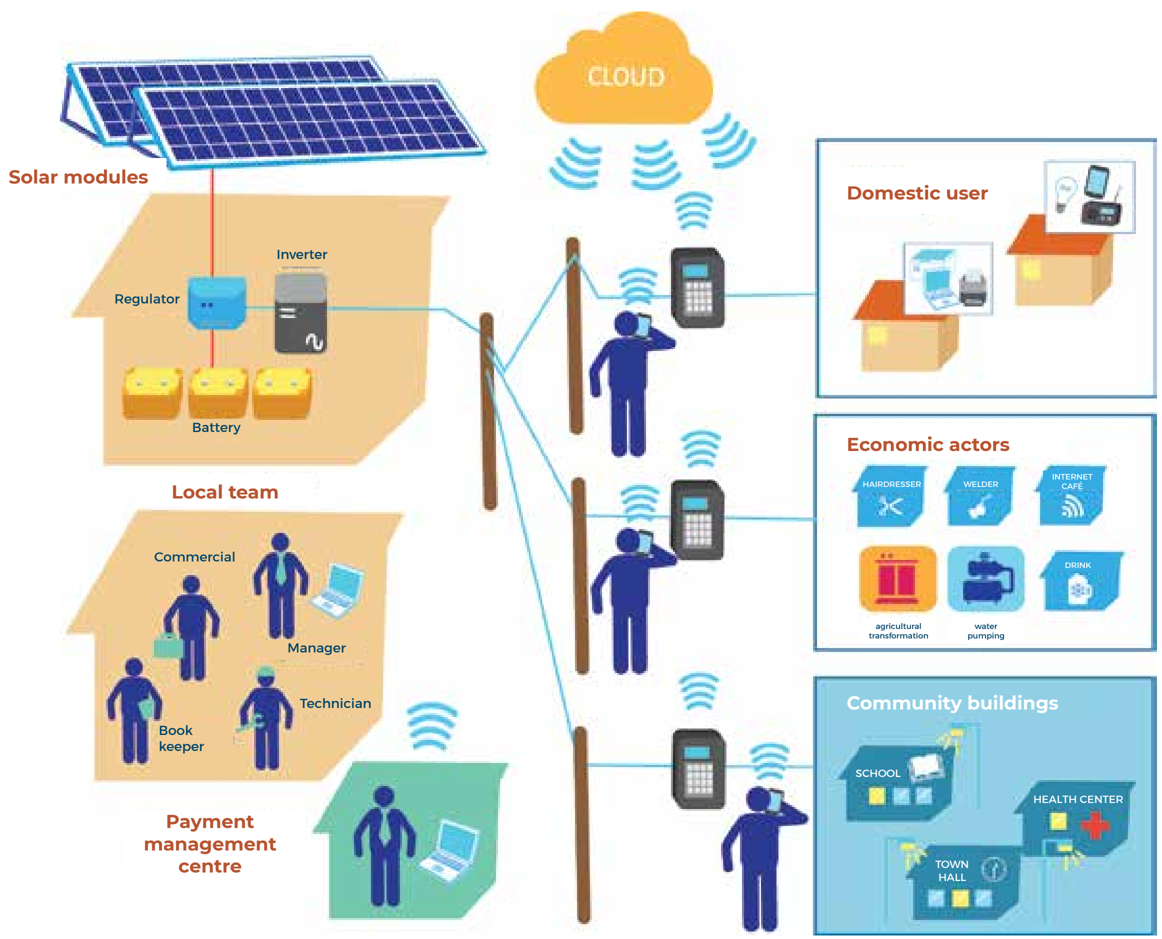
Production by solar energy

While the operating principle of a solar generator is the same as in small systems (cf. 3.1), two mini-grid specific points need to be emphasized:

- the regulation and conversion electronics is more complex, because it needs to deal with different problems resulting from the diversity of the electrical receivers connected to the mini-grid;
- lead accumulator batteries are still the most commonly found but lithium, along with other innovative technologies, is gradually making inroads and should be widespread in time, especially for containerized solutions.

1. Julien Cerqueira, Juliette Darlu, Rija Randrianarivony and Théo Grondin, "Des turbines et des hommes, quelles coalitions d'acteurs pour l'électrification rurale à Madagascar ? Retour d'expériences du projet Rhyviere" (Paris: Gret's Editions, 2019). Find the whole study case in French on the book's webpage: *http://www.fondem.ong/electrifier-lafrique-rurale/.*

Principle of a solar mini-grid



Source: Fondation Énergies pour le Monde

Preparing interfaces for user connection

To find out more about hybrid systems

There are about ten different type of electrical power coupling and management architecture for hybrid systems. Gérard Moine has written a book in French, *Electrification solaire photovoltaïque* that gives a very good overview of the various technical design and operating methods of hybrid power plants and is also the standard technical reference book on all aspects of standalone photovoltaic system design and operation.

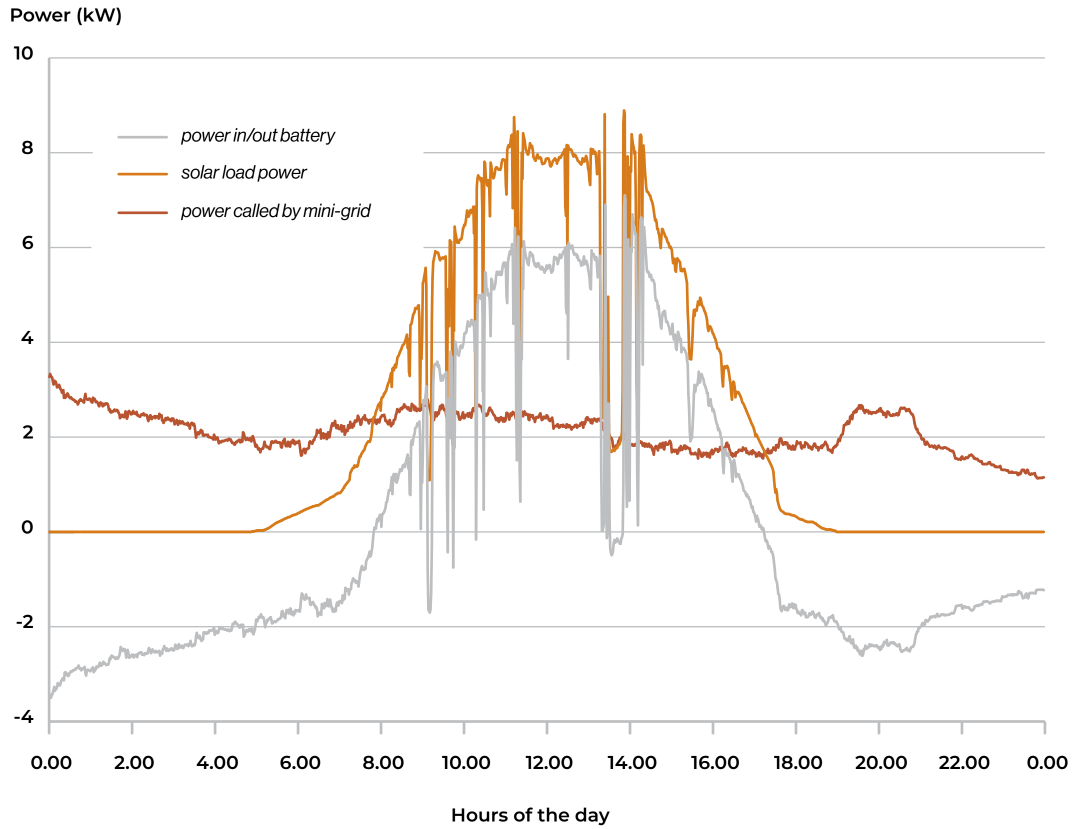
Find all the useful documents in the bibliography at the end of the book.

Hybrid systems – the narrow path that is somewhat flexible

While it is fairly easy to estimate a household's electricity needs to size a domestic SHS, it is quite another matter to model the electricity demand of a rural community and build in its growth factor.

How many households will be connected to the mini-grid? Will new economic activities appear that use electricity? How will demand grow over time? It is vital that these questions are asked before designing a mini-grid. Correct sizing of a solar power plant to supply a mini-grid is actually based on the assessment of forecast current and future demand, are all highly dependent on several elements, over which project designers have more or less control:

Example of power flows on a 10-kWP mini-grid, typical 24-hour day



Source: Fondation Énergies pour le Monde.

- the envisaged pricing policy;
- the technical limitations imposed on the users is limited by the quantity of electricity available to the users (the quality of the local source and the capacity of the installed production system cf. inset);
- the area's economic development potential.

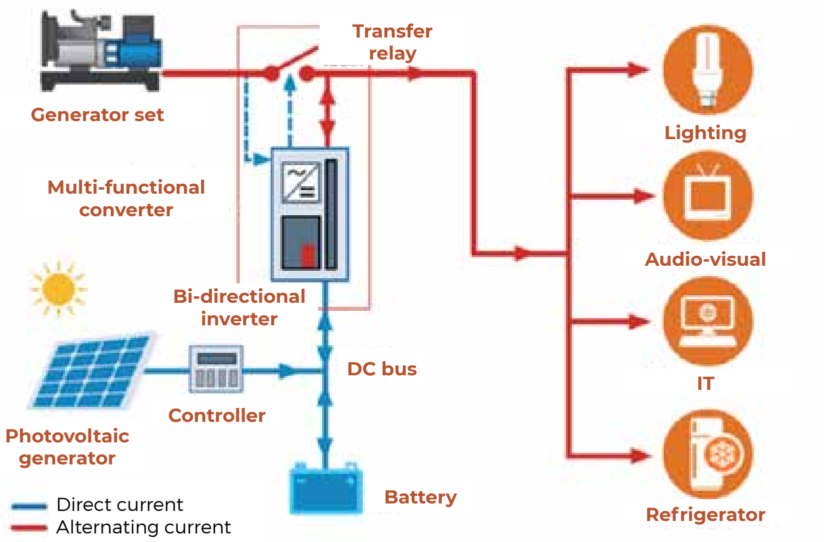
Yet, some technical, climate, sociological and political factors are more short-lived. In a rural context, where reliable statistics are only rarely available, it is hard to rule out uncertainty from the sizing equation.

Hybridization, which associates a generator set with a standalone solar power plant, compensates for part of the variation in electricity demand as the generator set will take over from the solar power plant:

- in the case of occasional, or even more regular high demand if demand has outstripped forecasts;
- during an extended period without sun;
- if the photovoltaic equipment is faulty.

Its presence also means that the battery bank to be scaled down, whose cost is a significant burden on the initial investment and operating costs

Hybrid system with multi-functional single-phase converter



Source: Gérard Moine

Fully understanding the energy limitations of a solar (or wind) energy plant compared to a thermal power plant (genset-powered).

In theory, a 100 kVA (80 kW) **generator set** installed to supply a mini-grid has instant power capacity of 100 kVA, all day long, i.e. a quantity of releasable electrical energy in the region of 2 000 kWh per day. In practice, the generator set will run at 30-70% of its maximum capacity following the village load curve, and thus has available a sizeable energy reserve. If the daytime electricity needs double, the generator set will keep up with demand and use twice as much fuel.

A 100-kWp **solar power plant** can also, if the inverters allow it to, have instant power capacity of 100 kVA available, but will only be able to release 300-400 kWh on a sunny day, and 10 times less when it rains. As the system has no reserve, the site's daytime supply of electricity to cover needs must remain below the daily production capacities, which are fixed. If the system is called on for more energy, it will switch to safety mode and automatically stop.

(renewal) (as the generator set can be activated in the evening to save the batteries).

But this flexibility comes at a price: each additional kWh produced by the generator set costs the more than its solar equivalent to the operator... and emits greenhouse gases, which damage the unit's environmental performance.

Other hybridizations, combining several different sources, wind/solar, hydro/solar are possible. While engineers and design software developers are enthusiastic about these systems, their costliness and operating complexity are hurdles that need to be prepared for.

Electricity distribution relies on the same fundamental techniques as an ordinary grid

Physically, a mini-grid comprises a set of supports (poles), and conductors (cables), used to distribute electricity from the production source to the consumer points. A low-voltage (LV) rural mini-grid averages 1-10 km in length and is not significantly different from an LV branch of an urban grid.

Yet, the technical and financial constraints of the rural context make some choices harder, such as having to arbitrate between longevity and cost for the supports:

Wooden poles, the most commonly found in rural Sub-Sahara, must be given rot prevention treatment for the below-ground part, which may shorten their service life. The origin of the poles must be checked (responsibly managed forest) and also the quality of the treatment, which is often difficult when they are locally made. To limit the risks, designers increasingly resort to procuring standardized poles from Europe or South Africa.

Reinforced concrete poles, are dominant in industrialized countries. They cost more but can be manufactured on site when transporting the equipment is difficult. The material quality and origin of the sand and formwork used must be carefully checked.

Galvanized steel poles cost more but are very hard-wearing and are flexible in use. While they are less established in DRE practices than traditional solutions, they are well-suited to the characteristics of rural mini-grids (shorter height, with small diameter conductors whose weight is compatible with the poles' mechanical withstand).

The main design complexity of a mini-grid does not lie in the choice of materials or sizing of the lines. There are many standardized computing tools that provide precise answers, inspired by those used to design urban grids.

However, the route around the locality is a subtle exercise, and crucial for the population's acceptance of the project. It will by force exclude some dwellings, but a complementary electrification solution should serve them.

The interface with the end user created by the connection is one of the operating infrastructure's nerve centres

The mini-grid's last technical link is the user connection, that practice has split into three categories (domestic, economic, community). This mini-grid/user interface is vital for the social, economic and functional equilibrium of the set-up.

A solar mini-grid, designed to deliver a finite amount of energy every day, must be capable of keeping each user's consumption in check. Even if dissuasive pricing can act as a natural regulator, a solar mini-grid designed to supply about ten "productive" economic actors will be technically unable to satisfy the demand of ten additional activities.

The interface with the user plays a few essential roles

Control over the power use and amount of energy used is wielded via the router installed on the user's premises as the main communication tool between the operator and the user. Apart from exchanging information on use, the on-board devices ensure that the contractual clauses are adhered to and protect the electrical installation and with it, property and individuals.

To limit the installation's capacity, fuses or ordinary circuit-breakers can be installed but their trigger points are ill-defined, and they take longer to react than production inverters (electronically triggered). There are increasingly powerful, adjustable and affordable electronic power controllers on the market (costing tens of euros), that can balance the load to suit the plant's production capacity. They trigger on the user's premises if the user connects an unsuitable receiver.

The amount of electrical energy used per day must also be restricted, because it is limited by the source itself. Some power controllers have energy controllers... they allow a finite quantity of kWh to "pass" on the user's premises over a 24-hour period.

Other equipment, such as time switches **can limit service operation to certain times of the day and optimize grid production capacity for users' needs.** Thus, the number of high energy consuming economic actors connected to the mini-grid can be increased by spreading their use of the service between the morning and afternoon, during the strong sunlight period.

The customer interface must also include the protective devices for humans and property, for a few kW of electricity distributed by a solar mini-grid is just as mortal as its city counterpart. Thus, a minimum number of these protective devices are installed – circuit breakers and if necessary, differential protection.

Obviously, users must understand the whys and wherefores of the device. It is important in addition to the awareness-building campaigns, to distribute illustrated instructions on how the service works, its limitations and risks. Sealing the box or installing any other kind of protection device can

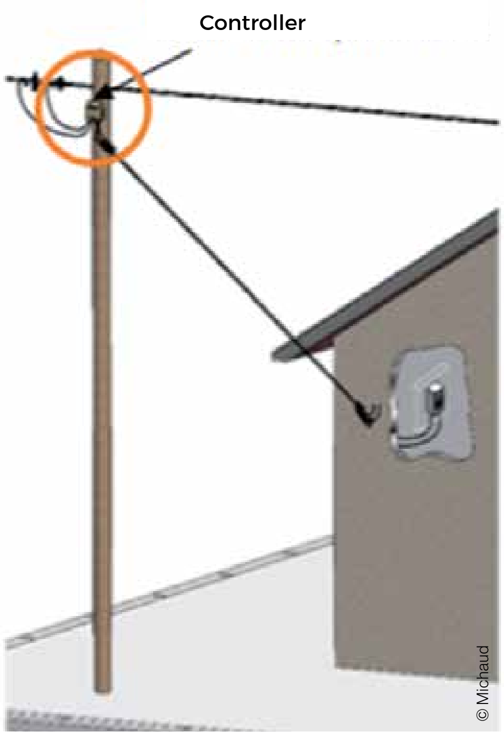
Rotten wooden pole

Concrete pole

be envisaged to prevent fraud, especially if there are no human operators on site. Awareness-raising and exemplary behaviour of some consumers are also cohesion and adherence factors to the rules of the game (cf. 3.5.3).

Electricity metering is the key to a mini-grid's invoicing and economic balance

The first mini-grids were fitted with conventional electromechanical meters as found in urban grids. They were heavy-duty, standardized and accurately metered the electricity used, enabling invoicing to be made on an actual basis. In practice, the customers paid after using the kWh once the period had elapsed.



Limiting the usable power… household *vs* economic actor

The power that a household can use can be limited to 200 W, to avoid the use of domestic appliances, and the same controller can be calibrated to 2 500 W for a joinery shop.

Limiting the quantity of energy used: household *vs.* economic actor

This value could be capped at 0.5 kWh for a sparsely equipped household (with a maximum of 200 W of power), by rewarding it with a low kWh rate in return, and calibrate the same device at 3 kWh for an economic actor (with a maximum of 2 500 W of power), at another kWh rate.

Apart from the issues of payment collection (cf. 2.4.4.), this device, which is still common, is being rapidly replaced by pre-payment systems, whose recent progress encourages their distribution within rural mini-grids.

Pre-payment is simple, ergonomic and is becoming widely used

Pre-payment for the electricity service, which resembles the '*Pay-As-You-Go*' consumption habits that have taken root through the mobile telephony boom in Africa, applies a simple principle… a credit in kWh is purchased in advance and then used.

This system that is very widespread in many African capitals, theoretically limits fraud and ensures that the electricity actually used is paid for.

- in simple systems, mini-grid users get a code (equal to a kWh credit or time credit) and enter it on their meter, which is activated and will inform them when the credit is running out so that they can purchase a top-up.
- in recent and more sophisticated mini-grids under development, the coding is no longer manual but remotely controlled through smart meters, already used by PAYG operators (cf. 3.2.2.).

In actual fact, applying this innovation to mini-grids is not so simple after all:

- introducing the device can be illogical, for some households use less than 0.1 kWh per day, making the intelligent meter the biggest energy user, outstripping the receivers. This often overlooked point of detail, may upset the energy balance of the mini-grid as a whole.
- it is expensive for small operators to use, as

Customer interface installed as part of the Pehgui project in Guinea

The problem with circuit breakers on standalone mini-grids

The customer interfaces of many mini-grids tend to be equipped with ordinary circuit breakers (like in the city…). Their purpose is to disconnect the load in the event of overcurrent (use of a too powerful appliance) or an outright short circuit (faulty electrical receiver) in a dwelling. However, the response times of these cut-off devices that are designed for urban grids, are generally longer than the plant inverters' electronic protection cut-outs.

Accordingly, in the event of an outright fault on a user's premises, the circuit-breaker does not open, but the whole plant switches to inhibit mode! It will only be able to restart once the fault has been corrected. The question is how to trace the short circuit's origin in amongst hundreds of connected users? It can take a few hours, presuming a skilled technical operator can be immediately mobilized on the spot.

This is just one of many examples that should make designers think twice about minimizing the presence of skilled technical operators on site.

installing a pre-payment device with complex, more delicate electronics than in a conventional meter, requires the on-site presence of computer equipment, an Internet connection, skilled staff and sometimes, payment of an annual STS type license (cf. inset). While these incidental investments can be considered by an operator with several mini-grids and thousands of users, the economics are unviable for an isolated installation with a few hundred customers.

That said, the manufacturers have developed purpose-designed integrated smart metering solutions for rural mini-grids, as pre-payment is the sturdiest technical solution to remedy the payment collection problem and strengthen the operators' economic health.

They are inexpensive to purchase and use little electricity and offer various options that make them suitable for the application's constraints: power and energy controller, pre-payment, connected meters, pricing by time range, invoicing by the number of kWh or lump sum on a time basis, etc.

They operate using proprietary software and are often subject to a subscription and specific management system. However, they prevent the operator from upgrading to another solution, in contrast with STS coding which is more scalable and open to use with many certified meters (cf. inset).

A professional has her say
Camille André-Bataille

EOSOL develops and operates solar mini-grids in Madagascar using connected pre-payment systems. What are the advantages of these digital systems apart from collecting payments?

"Using a smart, remotely accessible metering and monitoring solution is a definite asset. It is both a monitoring and analysis tool and also a decision-making tool. These systems enable us to offer various pricing schedules and modern payment methods that are suited to rural context (pre-payment, post-payment, instalments), but most of all to monitor and analyse consumption in real and cumulative time (applying indicators such as the type of user, type of connection, period, frequency, etc.). Thus, we can forward plan technical (extension) or commercial requirements (action or targeted awareness-building, incentive offers, marketing events, etc.). We aim to provide quality services while ensuring that the model is economically sound".

Camille André-Bataille, is an engineer and energy and low-carbon project economist. She has worked for 5 years in DRE and the emergence of strong rural communities in Madagascar and Africa.

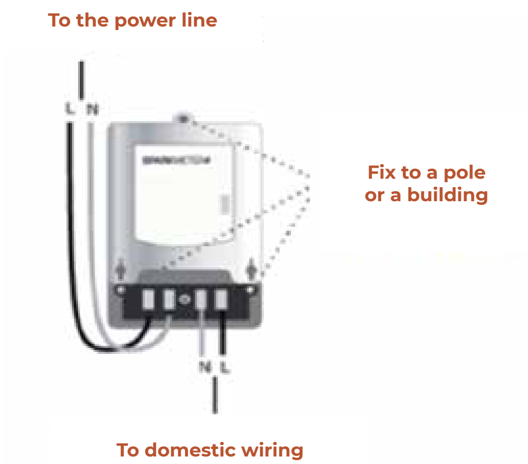
Find the whole interview in French on the book's webpage: http://fondem.ong/electrifier-lafrique-rurale/

As it stands there is no ideal technical mini-grid management solution. It would be sensible to pool the feedback on the various trials conducted to orient the profession to standardizing the interfaces. But the inroads made by ten or more new actors, without any concertation or regulation, appears to rule out any prospect of this in the short term.

However, it is now possible to draw many lessons from the mini-grids projects conducted over several decades by the historical DRE actors.

Example of a prepayment meter used for electricity

Example of a smart meter suitable for rural mini-grids



Source: Spark Meter, *https://www.sparkmeter.io/.*

Pre-payment: *Standard Transfer Specification* (STS) coding

The STS standard defines the technical framework of a secure data transfer system between a point of sale and an electricity meter. It is administered by the international STS association, based in South Africa and co-founded by several electricity meter manufacturers, that is the guarantor of STS licenses awarded to manufacturers for laboratory-tested and approved meters. It also references the operators that use these devices and supplies them with specifically customized encryption keys.

The STS system firstly guarantees interoperability between STS standard compliant system components made by different pre-paid meter and sales system manufacturers. Thus, operators are not tied to a single manufacturer. They can turn to another supplier that holds an STS license without modifying their current infrastructure if the hardware is faulty, manufacturing is halted, or the tariff becomes prohibitive.

The second strength of the STS license is that it prevents fraud and black-marketeering of energy credits. Each token generated by the operator on the user's request will only be valid on the user's meter and encoded so that it cannot be forged (impossible to modify data such as the allocated amount or the meter settings). Furthermore, if a ticket, meter, or servers and encryption boxes are stolen, the generated tokens will be unusable on other meters, or with another operator.

Allowance for these paid services must be made in the operator's business plan. The operator will have to pay the STS association joining fee ($ 2 150 or € 1 888 in 2018), an annual fee ($ 2 150 or € 1 888) and purchase "blank" tokens (pack of 10 000: $ 150 or € 131).

On small sites with only a few users, this financial cost is prohibitive as its cost can run to $ 1 or € 0.88 per month per user.

3.5.3. Renewably sourced rural mini-grids – feedback and lines of approach

This section summarizes with many but not all of the various factors to be incorporated into the collaborative process to successfully design, build and operate one or more mini-grids from targeting the territory to servicing electrical infrastructure, price scheduling to selecting the manager (or operator).

It sets out to highlight the practices that are likely to redress the shortcomings of existing models and share the multiple questions raised by an electrification scheme that is not fully mature. It is illustrated by examples and tangible feedback from the field.

Planning shortcuts – what are the criteria for rolling out a mini-grid?

The first large-scale electrification planning studies for Africa date back to the early 2000s, when diesel-powered mini-grids were deployed under the auspices of the World Bank, aided by the newly created rural electrification agencies. These studies that were often founded on overly macroscopic or fast analyses, envisaged several rural electrification schemes for a territory, combining different solutions... SHS for dispersed housing, grid extensions for localities close to electrified towns, mini-grids for high-density rural localities.

Even today, a number of planning study reports take for granted the technical soundness of the envisaged solutions, the local operators' capacity to ensure sustainable operation and even the institutional bodies' capacity to guarantee their regulated supervision. According to this concept, the mini-grid option should be adopted when the following conditions are in place:

- a significant population and high housing density;
- significant economic growth potential (agriculture for food processing, tourism, fishing);
- "local wealth", in other words the ability to pay for the electricity service.

However, the practitioners and field observers describe quite a different reality. The correlation between the theoretical capacity of a territory to equip itself with a mini-grid and the effective sustainability of the infrastructure has not been proven. Much more complex equilibrium is needed to achieve sustainability.

Choosing to deploy a mini-grid in an area calls for a fine, multi-dimensional and patient approach. The project bearer should take all the time needed to be fully persuaded on the following points:

- the real acceptance level of the future users, beyond the apparently unanimous "yes" raised by the announcement of an electrification project;
- the nature of the demand and its potential for growth;
- the real capacities for local ownership;
- the capacities and willingness to pay for the electricity service;
- the sociological and economic impacts of electricity's arrival.

Selecting a target area – a long, complex and sometimes discouraging process for the populations

For several generations, the rural communities of Sub-Saharan Africa have seen a procession of NGOs, institutional financial backers and foreign companies making seldom-kept promises of infrastructures in various sectors (health, education, agriculture, water and so on).

Implementing a mini-grid takes time. On average it takes 2-5 years between identifying a site, the preliminary surveys and powering up the grid. These lead times baffle the local populations and damage the credibility of the project developers and the national authorities, while they discourage future users (who are often asked to contribute to prove their interest or commitment to being connected at a later date).

Sometimes mistrust grows. There is too little local community involvement in the preliminary work that is essential if the project is to be successful – socio-economic surveys, infrastructure sighting surveys, grid mapping. Often, the surveys have to be revised once the populations have tangible proof that their locality will be electrified.

The context local also changed between the first socio-economic surveys and the commissioning of the mini-grid. Homes were equipped with SHS, high-potential economic actors had moved sites or business, or an electoral deadline changed the authorities' support for the project.

Negotiating for plots, locality of Kouramangui (Guinea)

Feedback from the field

In Guinea, when a village was to be electrified by a hybrid solar power plant, it took nearly two years of preliminary surveys to identify a plot where the plant would be constructed and a grid layout that entailed installing poles on private property.

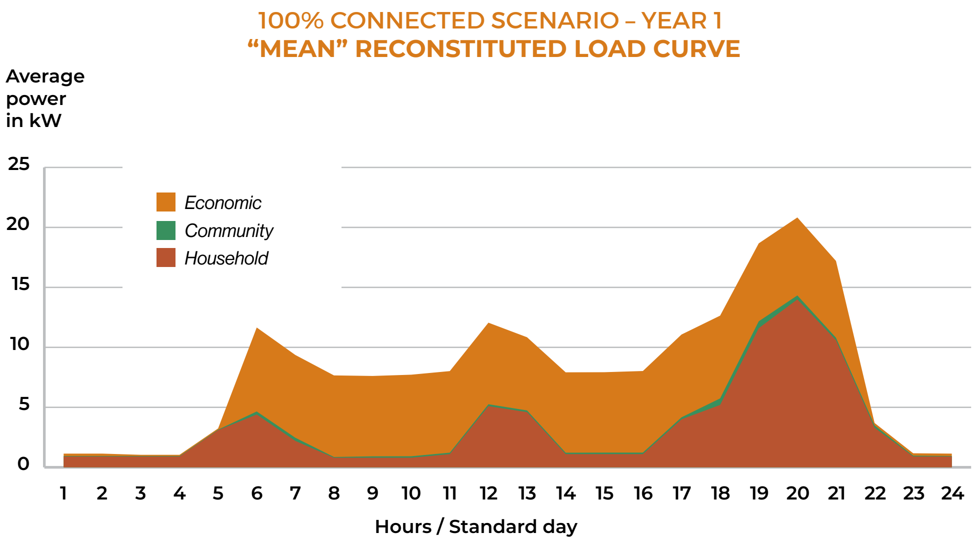
As the populations and local authorities had little trust in the project developer, they had allocated plots of supposedly communal land to the latter to be accommodated. Several months later, when the civil engineering firm arrived to start the earthworks, all the plots granted were challenged and several days' discussions were required to find new agreements.

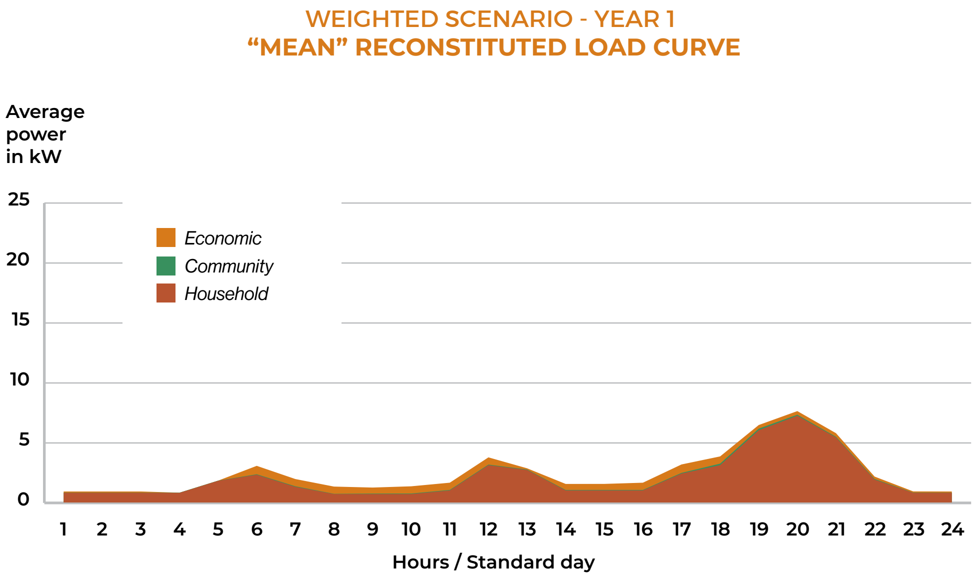
The soundness of the ties formed during this long maturing period generally only emerge once the first poles have been erected.

Analysing demand... a complex exercise

The components of a solar power plant, which do not change for about 10 years, determine the daily amount of energy available. So, how can one predict the nature of the electricity demand of a rural locality with several thousand inhabitants that

Example of a load curve: maximum scenario vs. weighted scenario





Source: Fondation Énergies pour le Monde.

have never used electricity before? How can one estimate the change in this demand 10 years from now? The exercise, which seems impossible, is nonetheless essential.

Detailed socio-economic surveys, the use of standard ratios based on feedback, macroscopic and statistical approaches... it is interesting to observe that if they are properly used, these various methods result in generally coherent results, that take the form of a village load curve.

But this curve alone only provides partial and insufficient data with which to assess demand. Some simple questions will help understand the extent of the uncertainty, in Sub-Saharan Africa and elsewhere:

- What will be households' new energy behaviour? Will their adoption of the electricity service provided by the mini-grid depend on its pricing (undefined at this stage of the project)? Will they really give up using solar lamps or candles?
- Households are getting equipped wholesale with connected and other SHS. What will their attitude be when the mini-grid arrives?
- Who would have predicted 10 years ago, that you could achieve proper lighting with just a few watts? What electricity consumption should we expect of lighting and multimedia devices in the near future?
- Behaviour changes when electricity arrives in an isolated village. Will there be a demographic impact? Will it really stimulate employment?
- Economic actors, especially those with high energy needs (craft trades, agriculture for food processing), use most of the electricity consumption and their presence sometimes justifies the installation of the mini-grid. If they are already equipped with generator set or a thermal machine, will they become customers of a distributed or an electricity service? How can you be sure?

Hence, decentralized electrification system design should be preferably guided by project developers' experience, their detailed knowledge of the local socio-economic factors, analysis of feedback gathered close to the site and the acceptance of a margin of uncertainty.

Economic impact of a mini-grid... watch out for delusions

There is a common assumption that the presence of electricity through a mini-grid will naturally lead to the creation of new high value-added economic activities. Feedback shows that there is no hard and fast rule on this.

Rather than imagine that such and such an activity will be created, it is better to cast an eye on the businesses being run in the neighbouring electrified towns.

Feedback from the field, Mauritania

A Mauritanian village electrified by a diesel mini-grid since 2010 and hybridized in 2014 by a photovoltaic farm with storage elements, supplies electricity to a locality with about 2 500 people, with roughly 300 customers connected.

Since it was commissioned, the number of connections made within the first 2 years has remained unchanged. Between 2012 and 2017, electricity consumption dropped by 8% (the operator confirms this) to approximately 0.3 kWh per customer, all sectors taken together.

Feedback from the field, Madagascar

In Madagascar, although a hybrid solar mini-grid has been installed in a rural locality with a healthy rice-farming activity, the owners of the three existing rice hullers (15 kW each) have refused to be connected to the grid.

Rice huller

Their reasons are fully understandable.

The users' view: (i) they have already invested in a reliable and sturdy thermally-driven rice huller, (ii) they do not want to outsource their activity's energy supply. What will happen if the power plant breaks down the very day they need to operate the huller practically round the clock?

The mini-grid operator's view: designing a plant that could supply one or more rice hullers that alone would use the equivalent of the entire village's electricity needs for a few months of the year, would call for production overcapacity that would be unused the rest of the year.

Defining the grid perimeter – a fine line between being pragmatic and political contingences

The "grid perimeter" notion is accepted as the coverage area, or territory within which any building can be connected to the upcoming distribution grid. Given the stakeholders' divergent interests, how should it be defined?

- **the investor/operator's view:** pragmatism dictates that the coherent consumption points alone (economic activity sites, high density housing areas or along the main thoroughfares) should form the basis for mapping.
- **the regulator's view:** in principle nothing can justify the exclusion of particular dwellings or public buildings from the grid perimeter, even if they use very little electricity or are bad payers (cf. inset).
- **the local population's view:** the perimeter should be as broad as possible and take account of local hierarchies, serve certain "strategic" homes (dignitaries, traditional or religious chiefs, councillors and former councillors, the families of politicians serving at national level, important members of the diaspora, etc.) to guarantee the operation's stability and social cohesion. The power of these leaders affects how the rules are upheld and the operation's economic equilibrium.

So, defining a grid perimeter is a delicate task, that calls for diplomacy and flexibility. Significant changes will inevitably occur between the preliminary sizing studies and laying the equipment.

How should production facilities be designed?

The first step is to make an energy analysis of the works for the purpose of sizing the power and energy characteristics of the plant's main elements. Energy sizing is based on analysis scenarios of the demand, building in the above-mentioned uncertainties.

Sizing the main parts of the plant involves comparing the availability of the energy resource with the expressed electricity requirements: peak PV power (or nominal power of another source), inverter capacity, battery bank capacity, generator set capacity for hybrid systems.

Example of grid mapping
Red line: main grid
Orange lines: secondary grid
Blue lines: tertiary grid

Installation of a mini-grid in Madagascar

Public infrastructures… *in or out ?*

When electrifying a rural locality, it would seem logical on social grounds to integrate public buildings (schools, health centres, places of worship, etc.) into the mini-grid perimeter.

In practice, the situation is not so straightforward, as private operators are faced with several clearly identified problems. First of all, plants are often sited outside the centre of the locality, which increases connection costs. Then even if the infrastructures' forecast electricity demand is low, their working budgets are too tight for them to pay their electricity bills regularly.

This leads to difficult arbitrage between social peace and profitability, which does not always side with the public infrastructures. In practice, at the end of the day some community-based buildings are not electrified.

The source-related imponderables have to be added to the uncertainties surrounding needs assessment:

- Should provision be built in for extended periods of no wind or sun, low-water periods on watercourses?
- Should continuous year-round service be provided, or should the length of the daily service be adjusted to renewable resource availability?
- Is system hybridization planned for daily supplementation or for abnormal conditions (heavy rains, exceptional demand)?
- What will the site's source be in 10-20 years' time? Are there likely to be considerable changes? How can the effects of climate change be prepared for, especially the river flow rates?

The decisions resulting from the energy assessment are tricky but also decisive. They affect the quality of the electricity service as they do the operation's CAPEX/OPEX balance. There will be as many sizings and CAPEX/OPEX balances from a single load curve for a given site as there are engineers, and constraint or value analysis methods:

- an NGO that covers most of the investment with a subsidy will design a solar system with a large battery bank (high CAPEX) to limit the OPEX while maximizing the installation's service life. That will enable it to offer all users an affordable electricity tariff, calculated exclusively on the basis of operating costs
- a private operator making investments, on the other hand, will seek to reduce the size of the battery bank and the infrastructures in general to limit CAPEX and capital risk. Thus, the generator set will soon become a daily top-up, which complicates the operation technically and economically. The battery bank will have to be renewed more often, which calls for good planning and in particular creates high requirements for profitability that can defend renewing these heavy investments.

How to construct mini-grids

The prime contractor designs the overall electrical system architecture from the energy decisions and production unit and associated mini-grid sizing. At this stage, balance has to be found between the requirement for quality (performance and service life) and economic coherence (adjusted investment costs).

There are many possible approaches, but two main methods currently hold sway:

- **the first, a proven strategy, encourages the broad transfer of skills to the local actors,** ownership of the technologies by the operators, using local construction firms, preferring the use of materials and components that are available and responsibly managed in the region
- **the second, which is technologically more innovative, is geared to "containerized" solutions.** Production plants are designed, assembled and cabled on the supplier's premises (often European) then delivered "plug-and-play" to the site. The remotely monitored electrical infrastructures are maintenance-free, and do not require any permanent local staff except for a warden and possibly a sales representative for the first connections. Its management is totally paperless thanks to pre-payment by *Mobile Money*. This model needs to prove its relevance over time as it is a far cry from citizen's re-appropriation of the common energy facility and still at the experimental stage (cf. inset).

Installation of a solar mini power plant in the south of Madagascar

Containerized solutions... how long will they last?

These solutions, which are less expensive and simpler, but also have less literature written on them, are too new for us to draw any conclusions on how populations will adopt them, or the manufacturers will fulfil their contractual commitments on guarantees and equipment follow-up.
Yet, containerized/connected systems are in principle based on market logic, which is somewhat alien to the human development fundamentals on which DRE and the best practices highlighted by the practitioners are based.
Some West African countries have had many "turnkey-delivered" mini-grids constructed to perimeters defined from satellite images, with no operator or maintenance staff on site, no preparatory user awareness-raising or skills transfer to local actors.
Hence, it is hard to see a solution for the future in these systems, at least in the way they are currently deployed. They will have to revise their economic model (by incorporating support costs) and/or organize their manufacture differently (by carrying out the assembly work in the South as opposed to the North) if they are to include local ownership rationale).

The operator, an essential actor whose quality is critical for the sustainability of a mini-grid

There is no standard definition for a mini-grid operator, who participates in different ways, plays a central role in all project phases:

- the operator, who may be institutional, voluntary or private, bound by a licencing, concession or leasing (public service delegation) contract or otherwise, is responsible for managing the electrification works in place, and so may also be called the "manager"
- the operator is responsible for the production, distribution and supply of the electricity and associated services in the deployment area regardless of whether or not it is one of the investors in the infrastructures whose use and/or property it enjoys

Before the mini-grid commences service, the operator works towards project acceptance and achievement

If the operator has already been appointed, it has a duty to take part in the preliminary demand and works sizing analysis studies, or at least in validating their findings. Its opinion must be taken into consideration when arbitrating on the definition of the electrification perimeter. As the future users' preferred contact point, it must take part in awareness-raising and information campaigns and take care to ensure that the project terms are accepted and owned by the local authorities, be they elected or traditional.

Through its on-site presence during the works, the operator must ensure that the common law rights and any land-related constraints that were not identified in the study phase are upheld. The operator must play an active part in training the equipment suppliers and in receiving the works on site.

A professional has her say
Elodie Hestin

You offer "containerized" solutions with Li-ion batteries. Many experts are sceptical about the viability of these systems in climatically harsh and very remote environments. What is your view?

*"We have set up a technical team in the Energy Storage BU that is totally dedicated to turnkey projects. It comprises specialists who work on one-off containerized solution specifications. So, the teams, taking as their basis solutions on a known, tested standard offer, and building on our experience with UPS (*Uninterruptible Power Supply*) solutions, factor in the specific features, primarily environmental, of every project to define the right air-conditioning, paints, firefighting equipment and so on. In addition, as we are in regular contact with the world's leading battery manufacturers, we are kept informed of the changes to safety measures. Thus, we keep control of the solution supplied and ensure its viability."*

Elodie Hestin trained as an engineer and has a master's degree in Innovation Management. She joined SOCOMEC in 2008 as the Product Manager for the source inverter range, then in 2016 joined the "Energy Storage Solutions" team.

Find the whole interview in French on the book's webpage: http://fondem.ong/electrifier-lafrique-rurale/

During the operating phase, its operational responsibility is extensive

In the first place the operator is the guarantor of the fulfilment of the reciprocal undertakings between the service supplier and service user, and thus must forge close ties with the users:

- it ensures that the users fully understand the invoicing, whichever scheme is involved (post-payment, pre-payment, fixed fee, subscription)
- it encourages the locality's dignitaries and public actors to be exemplary in following instructions, complying with power and energy limitations, but not using prohibited appliances, and payment for service
- it encourages the users to form user committees to appoint a single user spokesperson, keep permanent and constructive dialogue open, be receptive to any dissatisfaction, and be able to adjust the offer if necessary, offer payment facilities during the hunger season, and make innovative business offers, etc.
- it has enough power and authority to set an example by disconnecting users who do not meet their contractual obligations or who commit fraud
- it must technically forestall and understand the plant's energy flows to adjust the service and manage the various production sources (balance responsibility).

Service quality, in which control of consumption and equipment reliability participate, is a vital element of its brief:

- the operator contributes to controlling the energy consumed by users by offering suitable services and products: advice on use, LED bulbs, low-consumption television sets and refrigerators,
- it prepares for the expenses incurred by end-of-life component renewal, by making well-judged savings

The operator must also ensure that the compliance regulations are upheld and safeguard any essential information for envisaging capacity extension or increase:

- it derives from customer registers and strict accounting, that are available to the sector authorities and also the financial partners,
- it regularly reports to the project owner, the investors and pays the taxes and fees agreed in the operating contract.

What makes a good operator?

Given the many tasks to be assumed by the operator, it takes more than having expertise as an energy player:

- **the operator must have the required technical skills** to understand how the power plant works, to run it on a daily basis and carry out preventive maintenance. It must also have the necessary technical agents to manage breakdowns or replace faulty parts swiftly. Over time, the operator must ensure that new users are connected as demand increases.
- **but the operator must be locally known, liked and respected.** Its activity must be understood by the community as being part of a long-term development rationale rather than an opportunistic rationale. Otherwise, the users will soon call it into question. One of the key selection criteria for operators is the amount of respect they enjoy.

An operator who has all these skills and qualities is a rare bird, without whose intervention the sustainability of a mini-grid could be a hopeless gamble.

Feedback seems to confirm that the operation lasts longer when the operator takes part in the investments in the production and/or distribution facilities (classic model of granting a concession driven by the rural electrification agencies). Equipment ownership and servicing will be that more thorough if the operator takes them on, or if it performs the construction work. That clearly confirms the very capital-intensive approach of electrification models. A rural electrification operator must offer the dual profile of investor and social entrepreneur, while upholding the rules of a public service delegate.

Local authority and civil society involvement is a costly gamble that pays off

"Involving the population", "strengthening local stakeholders' capacities" ... these buzzwords are used in all the development actor and access to electricity publications. The active participation of the local authorities and civil society, while trivialized, if not misrepresented, is decisive for the short-, medium- and long-term success of a rural mini-grid project. It is a structured anthropological and sociological approach as much as simple respect for others and good observation and listening qualities (cf. 2.4.2).

The arrival of a mini-grid in a locality cannot be contemplated without close consultation between all the stakeholders. The information that they convey is precious and their influence crucial for the sustainability of the electricity service:

- **regional authorities** often have limited resources but are encouraged to take on decentralization. They must be kept informed when the preliminary studies on the installation of a mini-grid kick off and throughout the completion stages. Their support may be essential to prevent or resolve relational or political deadlocks, identify hidden risks and report on the area's past or future infrastructure programmes.
- local councillors are the immediate opposite numbers on the ground during all the project phases. They must have a perfect grasp of the rules and challenges and accept them. They inform their constituents and must encourage them to adhere to the project implementation terms. The involvement of the mayor and the mayor's advisers in the various steps is an excellent indicator of local cohesion, that pledges the operation's success.
- **the informal authorities** be they religious or customary are influential, and thus act as a powerful go-between for future users. Dignitaries, who are often hard to approach or unwilling to join discussions, only intervene in the second instance but must be quickly identified because their influence may be decisive, especially with very remote populations. A dignitary who regularly pays for the electricity will be held up as a model and a token of authority supporting the operator.
- **the committees or local associations** are key structures of the development community that raise potential users' awareness then quickly rally those willing to get connected. They are accustomed to expressing the economic and commercial concepts of the industrialized nations to the rural populations. They convey the project's key elements in a suitable way: timing, service limitations (power and energy), tariff schedule, payment methods, connection costs, each person's responsibilities, etc. Furthermore, an electricity users' association is an excellent vehicle for establishing constructive dialogue with the operator, leaving the local authorities and their councillors to retain their observer role.

These processes must be enshrined in the specific time-frame of the rural context. They generate additional funding requirements, but they have an irrefutable positive impact on the sustainability of the economic model and risk control.

If these types of groundwork are not undertaken, the project developers are bound to pay a heavy price, when it is too late for targeted and effective action.

Pricing is the central component of the economic model and must be suitable and understood by all

Proper understanding of the electricity service and associated pricing are crucial for the success of a mini-grid project. However, it is not easy (cf. 2.4.4), as the future users spontaneously refer to urban grid services and conditions... no usage limitation, more or less reliable service, "affordable" billing, sometimes even non-existent.

Two points are essential in the case of a mini-grid:

- **the price** – the economic viability of the mini-grid model, with or without subsidy, calls for a higher per kWh sales tariff than in town for reasons that have already been mentioned (cf. 3.5.1),
- **the service** that is generally delivered 24/7 and is a quality service, will be limited individually to a daily power, and sometimes usable energy quantity. It will be impossible to use some high energy-consuming appliances, sometimes the operator will insist on the sale of receivers (LED bulbs, low-consumption television sets).

It is thus vital to transmit a minimum of energy culture to the users to guarantee acceptance of the mini-grid rules. They need to understand that a LED bulb uses 10 times less energy than an incandescent bulb, that in order to use a soldering iron a special plan will have to be taken out, etc.

The time spent on this awareness-raising prior to system installation equals the time that will be saved righting the misunderstandings that will arise during the first months of operation

Renewable mini-grid component replacement – the other unknown of the economic model

Solar and wind energy plants[1] that supply mini-grids, regardless of whether or not they are hybridized, are equipped with electrochemical battery banks. The batteries' service lives are limited to about ten years (cf. inset).

Replacement of this component, which can amount to up to 40% of the investment cost of a production unit, should not be taken too lightly. It can absorb up to 50% of the electricity sales price paid by the users, so the price scheduling must factor this in, and the replacement expenditure must be prepared for.

While the electronic components required for regulating and converting electricity flows have become very reliable, nonetheless, after ten or more years' operation a few components will need to be changed. Once again, the replacement cost will have to be factored in.

Therefore, a mini-grid business plan must provide for:

- **total renewal of the battery bank after a certain operating time**, 7-12 years for lead batteries, calculated on the basis of the initial sizing and conditions of use, especially extreme heat,
- **renewal of the power electronics,** which is subject to severe usage constraints that are likely to trigger sudden breakdowns after several years of proper functioning

Several questions naturally spring to mind apart from the difficulty of forecasting the replacement date:

- can provision be built in for technological progress? What will the best technology be when the time comes to renew the mini-grid batteries and/or power electronics? How compatible will the "old" and "new-generation" components be? Won't it be economically and technically more relevant to change the entire plant?

1. Hydropower is not covered here as better control is wielded over the technical operating costs (routine maintenance, replacement of a few wear parts)..

A professional has her say
Juliette Darlu

The private sector deploys major forecasting resources in the mini-grid sector. Given your NGO work do you feel that their action threatens the social dimension of universal access to electricity needs?

The private sector is not inherently bad, it sometimes even drives innovation. It is called on when small private operators are needed for public-private partnerships. However, some recent initiatives have been motivated totally by profitability (which is needed) and have thus neglected the poverty and inequality reduction goals, but also the creation of local added value (jobs, skills). Allowance is seldom made for environmental and social costs (waste, pollution, recycling). The State's role is vital here: to oversee these initiatives, ensure that the positive outcomes are redistributed to the community. If that does not happen, then yes, it can be a threat, but the NGOs must stick to their watchdog and advocacy role.

How do the price-scheduling definition and its comprehension by the beneficiaries play a key role in the success of a mini-grid project?

Once price scheduling has been grasped, you can understand your electricity bill, learn how to manage your electricity use, and thus be able to gear electricity usage and payment to your income. It also entails being aware that part of these contributions will return to the collective (community, cooperative, etc.) with positive consequences for the territory. Understanding your contract, means that you know your rights and obligations and those of the other party and can ensure they are upheld. Informing, raising the awareness of future users of the tariffs is a pledge of the operation's sustainability for all these reasons.

What would be your recommendations on involving civil society, the local and traditional authorities, the national institutional fabric?

Civil society and the local authorities are well placed to monitor the operation at close hand, encourage and back economic development and may be a counterweight to the national public authorities' and private operators' double act. Their involvement is needed from the start of the project, to construct the governance of electrification schemes, over and above "awareness-raising and informing" to put them at the centre of the system. NGOs, as impartial bystanders, can support the running and creation of these local institutional agreements, the formulation of public or contractual rules.

Do you think the sector should be more organized? Are the regulatory bodies' and agencies' skills and resources enough as they stand?

At national level, the various institutions' prerogatives are often vague and/or overlap between urban and rural, which is counterproductive for establishing a strong electrification policy. There is a case for redefining and reorganizing the areas of competence. It also seems clear that the resources of these institutions should be boosted so that they can fulfil their role thoroughly.

Juliette Darlu, an agricultural engineer, has specialized in access to energy project management. She is the Energy Programme Manager at GRET.

Find the whole interview in French on the book's webpage: *http://www.fondem.ong/electrifier-lafrique-rurale/*

Various price scheduling models are to be found out on the ground

“Post-payment” standing charge and sale of kWh: many mini-grids, drawing on traditional urban models, offer an electricity service comprising a fixed part (monthly or annual standing charge) and a variable part (monthly invoicing) for the kWh used. Some schemes set up different per kWh charges on the basis of consumption thresholds... a low cost for the first 10 kWh of the month, followed by a higher cost for the remainder, or even an attractive cost for high energy consuming economic actors.

Lump sum for small consumers: lump sum payment models can be set up with customer interfaces equipped with adjustable power and energy limiters, regardless of actual consumption. The lump sum entails advance payment for a limited period of use (for example, 1 day, 1 week). Various types of lump sum can be envisaged for different types of user, geared to their actual average electricity consumption.

Pre-payment: despite the constraints mentioned at the start of this section, almost all new operations apply these pre-payment systems. Not only do they reduce the need for local staff, and offer paperless management possibilities, but pre-payment is the best guarantee of an optimal collection rate for the kWh used. Yet, the operator needs to plan for the irregular cashflows generated by this model which is not based on a regular standing charge basis.

User paying her bills, Madagascar

Key figures

The costs incurred by mini-grids to produce one kWh range from $ 0.55 to $ 0.85, with average load factors of 0.22%. By 2030, it should be possible to reduce this production cost to $ 0.22 per kWh. These costs are comparable with the national utilities' costs in Africa, which are highly subsidized.

Source : drawn from a World Bank study carried out on some fifty mini-grids in Asia and Africa (PV and PV/diesel hybrid)

Illustrated example: the 1st of 4 price bands at Kouramangui

SERVICE 1 N'DAYGOU

ÉNERGIES POUR LE MONDE

Usagers domestiques ou communautaires à faible demande en électricité

Service destiné aux ménages et infrastructures communautaires désireuses de bénéficier des **services de base de l'électricité**, avec un **tarif réduit.**

Coût de raccordement	**150 000 GNF** + coût de la distribution intérieure (si non existante ou non conforme)
Coût de consommation	**3 000 GNF / kWh**
Durée de fourniture	24h/24, 7j/7
Appareils autorisés	Ampoule LED Fournie par BDK; Radio; Recharge téléphone; Lecteur audio/vidéo
Appareils interdits	Télévision; Réfrigérateur congélateur; Ampoules à incandescence; Electro-ménager; Outillage
Données techniques	- Puissance appelée limitée à **100 W** - Energie limitée à **0,5 kWh/jour** - 230 V alternatif monophasé - Compteur électronique à prépaiement

Source: Fondation Énergies pour le Monde.

- What other investment needs may compete with equipment replacement? Grid extension, increasing production capacities, modernising the customer interfaces? What subsidies will be available from the electrification agencies?

This issue of mini-grid renewal and modernisation that is occasional today, will become vital in coming years, once solar mini-grids have proliferated. The decision makers, agencies, ministries and financial backers will have to plan for it, by creating the necessary technical and financial support mechanisms today to avoid future damage that could fuel social discontent. Nor should they overlook the environmental aspects relating to the necessary recycling of battery elements, that are highly noxious for health and ecosystems.

Environment, battery usage conditions and service life

The number of charge and discharge cycles that a battery supplies, whatever the technology, will depend on the depth of discharge. Lead batteries, which are mainly used, are particularly sensitive to this.
Lead batteries with liquid electrolyte react badly to partial charging. The power plant should enable a full charge to be made every day, namely, by supplying an additional 5-10% of energy to this "equalizing" charge.
Temperature is a crucial parameter. While some lithium batteries are likely to deteriorate irreversibly above 40°C, lead batteries lose 50% of their cycling capacity with every 10°C temperature rise.
Natural aging of the battery electrochemical cells, the quality of servicing, regulating charge and discharge currents and voltage, are additional technical parameters that affect battery service life.
It is almost impossible to predict the service life of a battery bank accurately, whatever technology is used, when the technological complexity has to face the conditions on the ground.

The control of the batteries is essential to prolong their duration, Madagascar, Ambondro

[Part 3]
Conclusion

Three key takeaways can be gleaned from this extremely broad set of decentralized rural electrification models deployed in Sub-Saharan Africa.

Firstly, it is clear that the various models all have their strengths and weaknesses and that none of them can claim to be able to provide single-handed universal access to in the rural context. Ideally, these solutions should be rolled out in parallel in the same zone. But experience shows that the differing constraints of each solution, and thus the management methods, make combining them operationally complex. Admittedly, mini-grids are making their mark in electrification programming policies as the closest solution to urban electrification and they offer possibility of ample coverage of the array of electricity uses in rural areas. Economic balance and the sustainability of the equipment are the two weakest points of this currently dominant model.

Furthermore, while renewable energies are naturally making inroads because of the sources, technology and industrial maturity stemming from falling costs, this paradigm shift carries a risk: that Africa becomes an experimental ground for the R&D departments of renewable energies players (especially the storage specialists), without considering a major environmental issue... that of equipment recycling, starting with batteries.

Lastly the digital breakthrough streamlines operations, both technically and financially. But although experience has demonstrated that being close to the ground is a key factor of infrastructure sustainability, it encourages operators to distance themselves.

Apart from these observations, the rural decentralized electrification boom is unlikely to be achieved merely by adding better devised and managed projects. It is certainly also determined by actions that extend beyond the scope of “best practices” and “project” scale and depends on sector-wide changes, to guarantee the sustainability of the systems. What changes are in the pipeline and who will implement them? These are the answers that the 4th and last part of the book will attempt to posit in reply.

[Part 4 - Recommendations]

Achieving access to electricity for all calls for an alliance with better-coordinated actors, more suitable methods and resources

Info

Feedback from the field

Definition

Key Dates

Key figures

Introduction

This book reports on the strengths and weaknesses of the rural electrification policies and actions that have been rolled out in Sub-Saharan Africa for almost 50 years. To fulfil its role, it needs to use its observations to make recommendations to the sector... so this is what this final part sets out to do.

Several questions crossed our minds that needed answers to make our contribution relevant as we formulated these recommendations. Are our recommendations different from those already formulated several times by the experts? Do we need to reconsider transformation needs under a new angle in the light of recent technical developments? Which are the priorities for taking access to electricity forward in Sub-Saharan Africa that the DRE actors should be homing in on? Which specific actions should each of them implement to achieve these priorities?

New spheres are being prised open by the technological and commercial upheavals sweeping the rural electrification sector. Technical changes are creating new opportunities and by the same token, new risks by giving scope for diverse distributed services and actors to emerge. From where we stand, the excitement surrounding these upheavals should be seized on to relaunch momentum to reform the sector yet not conceal its structural faults.

Most of the new developments do not resolve the many sector-wide weaknesses observed, because the fault lines are not technical but undermine the governance, organization, and all levels of regulatory and financial frameworks of the actions.

These complex issues persist despite the arrival of the digital age and the increasing implication of private actors. The lack of political resolve and the multiplication of decision-making layers, the failure of taxation and dependency on international funding, the shortcomings of the legal framework and national planning, the lack of coordination between international donors and understanding between the financial and non-financial sectors... All these issues existed when the most recent electrification solutions came on the scene, as we have noted. Most of them do not guarantee electricity services for all in a given area.

Admittedly, many of the points of analysis we have raised are not recent and have been subject to many rounds of recommendations, since those made to the United Nations Commission on Sustainable Development (CSD) and the development actors in 1995.

Although our observations broadly overlap those that form the basis for these recommendations that we could claim for our own, there is little point in repeating them faithfully.

The following tables summarize two recommendation documents dating back to 1995 and 2017. The documents are presented in full on the book's webpage, along with many others.

We have decided to pinpoint the actions that seem essential to us for speeding up access to electricity for the rural Sub-Saharan populations, on the strength of our grassroots experience and discussions with all the stakeholders, but do not claim to be exhaustive.

As not all battles can be led from the front, we were mindful of the following four main principles when drafting these recommendations:
Be practical, namely draw up specific action proposals.
Challenge namely address the recommendations to those who can implement or debate them. The recommendations are not presented by theme but addressed in the following order:
- to the public authorities of the developing countries at national, regional and local levels (4.1);
- to international and regional organizations (4.2);
- to financial backers and the finance sector (4.3);
- to project developers and their direct partners out on the ground (4.4).

Be coherent, namely formulate rational proposals, making allowance for the interactions of the various actors.
Prioritize, namely target the recommendations around the few hot spots to ensure the systems last long while respecting the populations who will be at the receiving end:
- make decentralized rural electrification an interministerial issue, to enhance strategic coordination;
- boost decentralization and deconcentration for more effective local implementation;
- oversee the action of the private actors, to guarantee quality and professionalism;
- uphold the principle of equity between users across a zone.

We hold that these priorities should be adopted by all the actors in the countries in question and that their implementation should be supported by the international community and fund raisers.

As we are making selective recommendations and directly addressing them at main stakeholders, we hope to spark off a realistic debate that will encourage them to pool their resources for better coordinated operations with better directed finances. These recommendations are primarily geared to the development of collective electrification solutions, which when combined with individual solutions, seem essential for achieving universal access to electricity and should thus be at the centre of the strategies.

(RE)SOURCES Think Tank recommendations: Recognizing and guaranteeing the right to electricity

- **A right to electricity must be recognized as a basic human right, just like the right to water and sanitation**. Therefore, a country-specific needs audit and inventory of what a right to energy would entail (in terms of quality, availability, accessibility, continuity, cost recovery) must be carried out in the same way that it was for the right to water.

- **Duty bearers also need to be identified** in order to guarantee the effective implementation and enforcement of this new right.

Source : "Right to Energy", (Re)sources, *http://www.thinktank-resources.com/en/themes/access-to-energy/right-to-energy.*

ELECTRIFYING RURAL AFRICA: AN ECONOMIC CHALLENGE, A HUMAN NECESSITY

Recommendations transpiring from the Marrakesh seminar in November 1995

Setting and context	• Bilateral seminar organized in November 1995 by **France and Morocco**, supported by the United Nations Development (**UNDP**) and the **European Commission**. • Desire to change **the scale and pace** of the decentralized electrification process in rural areas. • Contribution to the United Nations Commission on Sustainable Development session work.
Key topics	• Recommendations on the **training, follow-up and education** of the local/regional populations and bodies on decentralized rural electrification. • Recommendations on the **relations between the private and public sector** regarding cooperation for decentralized rural electrification. • Recommendations on encouraging the uses of renewable electricity. • Recommendations on the link between the various administrative levels: **local, provincial, national and international**.
Recommended far-reaching changes	• To move on from **project scale to programme scale** for the decentralized rural electrification sector. • Envisage **scaling up solutions** (for several thousand different villages). • Consider the international actors (NGOs, cooperation, external funding…) as **exchange forums** and promote **concerted efforts**.

Recommendations of the Alliance for Rural Electrification (ARE)/ Renewable Energy Cooperation Program (RECP) forum, Amsterdam, April 2016

Setting and context	• The Amsterdam ARE/RECP meeting was led by SE4ALL, an **initiative launched by the United Nations secretariat**. • The recommendations made primarily related to the **installation of mini-grids**. The work concentrates on the main obstacles and actions required to develop clean energy mini-grids.
Key topics	• Recommendations on mini-grid **pricing**, procedural **regulation and streamlining**. • Recommendations on the **location** of mini-grids by identifying the key installation sites. • Recommendations on project **coordination**: primarily project-related data **pooling**. • Recommendations on the project **business model** and financing – the strategy to adopt, how to improve the service rendered, and learning from the big winners (World Bank).
Recommended far-reaching changes	• Changes in the **role of the State** – it must cooperate and set up national electricity grid management policies and identify the priority zones for installing mini-grids. • Create a **platform** to collect and pool all the data. • Attention paid to the **nature of investments** – which can be varied. Investors should be aware of this variety.

4.1. Recommendations to the national, regional and local public authorities of the developing countries

It is important that strategies and implementation of DRE projects for Sub-Saharan Africa are defined at the right level:

- at **interministerial level** for political impetus and the regulatory supervision;
- at **regional level (or intermediate institutional level such as "district" or "provincial") for coordinating** the operations across an area. The regional level seems the most appropriate to us to guarantee a coherent, comprehensive view of the area, geared to the specific needs of the populations, limiting the risks of cronyism and conflicts of interest (that tend to be found more at local level, where the representatives, mayor and councillors, are also system users).

In most countries this will entail revising practices and embarking on reforms to ensure that DRE projects are locally implemented, as part of a strong national drive, set in motion by the highest echelons of the State and percolate down to all decision levels:

- prioritizing the subject at government level;
- bolstering the resources allocated to the territories by activating the decentralization and deconcentration levers;
- observing the principle of inter-territorial solidarity;
- investing in professionalization and supervising the sector.

Electrification makes it possible to boost local economic activities.

4.1.1. Recommendations to the national public authorities

National rural electrification strategies are struggling to get off the ground, primarily because of the lack of resolve and resources, satellization of state actors (several ministries, agencies and so on) and sometime piecemeal decentralization.

So, we feel that it is vital to place rural electrification in the direct jurisdiction of the head of government. The national rural electrification agency could then concentrate on equipping the actors and operational monitoring working within the fold of an interministerial cell tasked with strategic and regulatory alignment, primarily of the regional actors in the territory.

"Institutional backing is crucial. The sector's historical inflexibility is such that political resolve and ***strong, decisive and determined commitment by the highest-ranking political leaders is paramount*** *for the promotion of alternative policies in the strategic sector of energy".*

Abdou Fall, former Minister of State, President of the Council of Professionals of Renewable Energies in Senegal (COPERES).

Embodying proactivity in favour of rural electrification through an interministerial mission equipped with requisite resources

Providing territory-wide access to electricity would involve raising the rural electrification stakes to priority level at the highest state bodies. Morocco demonstrates that this is a prerequisite for effective action (cf. 2.2.2.).

Accordingly, we recommend that the access to electricity strategy is led at interministerial level, under the authority of the head of government (Prime Minister in a parliamentary system), by decision of the Head of State, thus symbolically making access to electricity a major aspect of its general policy.

From where we stand, this is the surest way to ensure proper coordination between the various agencies and ministries in question, and to effectively organize the various issues (regulatory, organizational) implied by implementing a national DRE strategy.

In practice, that entails:

- creating an interministerial cell,
- reporting to the Chief Executive,
- who coordinates the Ministries (Energy, Finances, Decentralization) and the State services (agencies);
- and giving it resources.

Its purpose would be to set in motion and ensure effective implementation of the rural electrification strategy, that should ideally be a building block of the rural development policy, which should in turn be at the centre of the government's priorities and driven at interministerial level.

For this reason, the first task of the interministerial mission/cell would be to clarify the aims and roles of the various public actors, and ensure that each has the means to carry out its brief, by:

- clearly defining the roles between the national utilities and the national agencies (electrification, renewable energies, energy efficiency, etc.) and assessing the effectiveness of their work;
- defining and openly disseminating energy infrastructure scheduling (connection of localities to the national grid) by the 5-10-year timeline;
- organizing decentralization at regional level so that the regions have the required skills and resources to implement decentralized actions. This customized decentralization should allow the regions to define suitable strategies;
- bringing the rural electrification policy led by the government to the attention of the financial partners, primarily the international funding bodies;
- defining and justifying the budget allocated to rural electrification before the national legislative and international bodies.

It would also coordinate the development of taxation, procedures and legislative and regulatory frameworks to enable project developers and investors to operate within a controllable risk environment.

For example:

- for the importers – exemption from customs duties for components;
- for the investors – exemption from income taxes for the first years to help them achieve profitability;
- for the operators – exemption from various taxes (such as income tax for a set period), longer concession terms (infrastructures are capital-intensive).

It would also be tasked with laying the foundations and gradually building an equitable pricing system to harmonize prices and the required payments by:

- creating and running a multi-actor taskforce to define the system harmonization principles and their application terms at national level. This system could rule that the reference rate is not unique and could be defined at sub-national levels;
- setting up and managing a compensation fund to indemnify rural operators who cannot ensure the viability of their operation on the basis of the applicable reference price.

Encouraging the national rural electrification agency teams to be more actively involved with the territorial communities

The national rural electrification agency should report to the interministerial mission and become its expert right hand.

To bolster the agency's ability to act and ensure it is effective on the ground, in a field where the number of actors is increasing and diversifying, we recommend:

- entrusting its leadership to a figure with an entrepreneurial leaning, who is not only familiar with the public sector but also the market sector, and who can thus communicate both in public sector and private sector parlance;
- deconcentrating the agency's structure by creating a regional DRE agent network to redeploy part of the field teams, as close as possible to the action.

We effectively advise entrusting project implementation to the regions (or intermediate-level institutions) (see below).

Thus, the agency would be tasked with designing useful tools for the public and private DRE actors, guide the deployment of these tools out on the ground (especially by the regional actors) and assess the impacts of the national rural electrification policy.

In rural Africa, electrification remains largely informal

It would be tasked with:
- becoming familiar with DRE planning and programming tool for more effective use;
- defining minimum quality standards (by adapting international standards that are often too restrictive), and the associated certification circuit and control processes (adherence to these standards should be an eligibility criterion for public tendering).
- setting up training modules for territorial institutions to manage the organizational and technical aspects of DRE;
- designing and setting up awareness-raising tools dispensed by suitably trained local NGOs to the rural populations;
- designing and setting up a training tool for operators and electricity professionals;
- making available to the regions the tools for preparing tenders for awarding different types of contracts (services, supply, public service delegation;
- defining performance monitoring indicators for the national DRE strategy;
- defining economic, environmental and social impact indicators for the installed electrification systems.

All of these strategically important projects call for investments and skills. In most countries of Sub-Saharan Africa, these efforts will not materialize without the technical and financial support of the industrialized countries and their institutions (see 4.2 and 4.3.).
Yet again, it would appear that all these organizational measures will have little impact unless they have the fullest backing from the highest levels of state.

4.1.2. Recommendations to the regional public authorities

As a variant of the national rural development policy, the intermediate operational level, the region (or province, or district, etc.) would be tasked with implementing that policy within its remit:
- by defining a regional strategy[1]. The region should be able to work out rural electrification by combining various solutions based on the actual local constraints and opportunities;
- and by managing the corresponding collective electrification scheme installations. For reasons of scale and territorial coherence, not only should project management fall within the regional purview, but also risk management (conflicts of interest and cronyism that are stronger at local level, lack of proximity and adaptability to reality at national level).

Furthermore, the region can combine electrification, land use planning, economic development and the creation of local jobs. Accordingly, it should have that competence and be equipped with the resources it needs by the State in order to:
- gather the localities' needs to define a regional rural electrification programme (untapped areas of the grid extension), in line with the national plan, in conjunction with the deconcentrated national rural electrification agency cell and possibly extend to local initiatives;
- take on staff with DRE skills, to be in a position to project manage each stage – from design to installation monitoring – with support of the deconcentrated national rural electrification agency experts.

The regional public authorities would also have an awareness-raising and training role to play aimed at the regional institutions:
- encouraging the villages to regroup as intercommunalities to assist the introduction of pooled access to the electricity service schemes in their catchment area, thus making for economies of scale and furthering tariff harmonization;
- training the territorial community personnel (mayors and their deputies) as well as the traditional chiefs and opinion leaders.

These regional missions (primarily data collection on the regional territory and hiring and training skilled staff) could be usefully conducted with the financial and/or technical support of the industrialized nations' institutions as part of a decentralized cooperation programme.

Our final recommendation: national or regional project owners should avoid sacrificing skills transfer and installation quality for fast completion and financing facilities awarded by countries that do not abide by OECD rules. We feel that stopgap equipment installed in untrained communities does a disservice to the access to electricity cause.

1. Hereafter, for convenience the term 'regional' is used to designate the intermediate territorial level between local and national

Lighting improves the conditions of education.

4.1.3. Recommendations to the local public authorities

In the type of decentralization scheme that we advocate, the rural mayors play a major role in supporting regional action and laying the groundwork for the definition of an electrification scheme that benefits their constituents.

Thus, their brief would be to:

- collect local information (basic data) from the populations as input for the regional DRE planning and programme analyses;
- include electrification in their local development plans;
- stimulate local initiative projects;
- regroup as intercommunalities to pool resources and so make for economies of scale;
- ensure they have skilled local personnel (whose training is provided at regional level);
- raise their constituents' awareness of the strengths, limitations and constraints of electrification. Particular attention should be paid to business users (sole traders, small producers, cooperatives, economic interest groups, women's groups, etc.).

They could take up the support offered by local economic development NGOs (with prior training in electricity by DRE sector NGOs).
They would have easier access to funding for their short- or medium-term activities by enlisting the local MFIs in their deliberations.

It would be useful to carry out these projects, that are often difficult for developing countries' rural institutions, with the financial and technical backing of local industrialized nation institutions as part of decentralized cooperation initiatives.

"In the momentum of reforms, there is reason to very seriously contemplate placing councillors at the centre of the political decision on producing and supplying energy to their constituents and aim to give private actors and civil society a better margin of operation in access to energy policies.

As by definition, renewable energy is a decentralized energy, ***making the local authorities responsible for this area should be a major reform priority*** *just as solar energy and digital technologies in particular can pave the way for a real energy revolution carried by the citizens and producers in the region as reforms are burgeoning".*

Abdou Fall, former Minister of State, President of the Council of Professionals of Renewable Energies in Senegal (COPERES).

Which essential principles should be applied to guiding the choice of DRE?

(A non-exhaustive list of previously mentioned principles)

- **Territorial equity**, by breaking down into territorially delimited rural electrification zones and/or defined by a list of localities, each of which represents numbers of potential customers and enticing investment levels for electrification operators.
- **Concerted multi-sector targeted programming**, including two types of complementary projects: **projects planned** from preliminary studies that cover all or part of a rural electrification zone, and **local initiative projects** instigated by public, private developers or NGOs, that cover one or more localities or a rural catchment area. These two types of project are simultaneously implemented as part of annual or multi-annual programmes, adopted by an interministerial body open to all stakeholders including financial backers.
- **Technological neutrality based on lowest cost**, by comparing investments and operating costs associated with the various decentralized electrification options that can be considered described in Part 3 in addition to extending the existing grid.
- Sufficient **financial viability and profitability** to ensure project sustainability and attract electrification operators. That implies, firstly, that the investment costs must be covered by the available financing (own funds, bank loans, subsidies, etc.) and the operating costs are covered by operating revenues (sale of electricity, standing charges, connection, etc.). Secondly, that the project's internal financial profitability rate and return on capital period are sufficiently attractive.
- **Tariffs that match the users' willingness and ability to pay and the tariff policy in force**, while generating sufficient revenue to yield operating results that meet the need for viability and profitability.
- **Environmental viability** provided by corrective and/or mitigation measures and follow-up to eliminate negative impacts or reduce them to acceptable levels, in line with current regulations.
- **Social viability** provided by appropriate resettlement and compensation provisions to reduce and make up for the impact of displacing populations lawfully and upholding the rules and what is acceptable to the fund raisers in question.
- **Competitive and transparent selection of electrification operators** (planned projects), **and local initiative projects**, through calls for applications and proposals, based on clear specifications and transparent, pre-announced selection criteria.

And the last recommendation is that the local officials should be exemplary once the collective electricity system has been commissioned, by promptly paying their personal electricity bills and those of the municipal community infrastructures. The economic equilibrium of the system and the sustainability of the service will be undermined without this blameless behaviour.

Electrified community services benefit the entire population.

4.2. Recommendations to the international community

We consider it vital for the developing countries to take this challenge into their own hands. Without the desire of their leaders to give access to electricity to as many as possible, and more broadly, to support rural development, the most out-of-the-way communities will remain deprived of essential services.

However, for as long as the fiscal resources of these countries prevent them from financing infrastructures at a steady pace (the demographic and economic growth pace) they will probably be unable to succeed without the international community's help.

In our view, in order to guarantee the establishment of targeted and coordinated support for the developing countries' actions, the international community should support the changes to DRE governance and organization in the first place as well as professionalizing the sector, by continuing to build on the experience of the most seasoned actors, primarily the specialized NGOs.

It should also raise questions about the renewed solidarity mechanisms between the industrialized and developing countries. Hence, we follow with a line of approach that could include citizens in the effort to fast-track access.

Women are essential actors in DRE projects.

Encourage reforms and support the actions carried out by the public actors in the developing countries

In the first place, the international community and its institutions should continue to represent this active awareness-raising framework at the highest levels of political decision-makers about the new electrification paradigm (renewable energies, decentralized solutions):

- They offer many occasions to share analyses and rationales through their institutions and events. Actors offering project management assistance (especially the specialist field NGOs) should be invited to attend them to share their feedback.
- While we are on the subject, the international community should continue its conversion to pragmatism, relinquishing the "everything connected to the grid" dogma that is still preached by some consultants (who urge those in power to set up models along the lines of the industrialized countries, even though the operating conditions preclude this).
- They should also step back as they listen to the "all-innovation" sirens. Collective thought on schemes that have been put through their paces should be encouraged and nurtured, without losing sight of the universal access goal, and, lastly, being sure that technology is only a mean to that end.

Then, the international institutions, as well as the industrialized and developing countries' regional organizations, should **gear their methodological support towards actions that will assist the introduction of the above reforms** as a matter of priority (see 4.1), namely:

- the organizational reforms required for effective and efficient roll-out of national rural electrification strategies: support for strengthening decentralization, establishing deconcentrated services of the rural electrification agency, recruiting service and public institution personnel and building their skills, promoting action coordination;
- the regulatory reforms needed to guarantee the legal security and reduce project developers' and investors' risk, to clean up the market and ensure equity between users: fiscal rules, tariff harmonization framework, minimum standards for product quality, and so on.

Lastly, the multilateral (such as the European Union) or bilateral cooperation institutions (such as the Agence Française du Développement) should also **bolster their support for structuring a DRE sector in the developing countries through special technical assistance programmes** (primarily training, methodology) devoted to:

- creating and managing firms (equipment supply and maintenance, operating) in the developing countries;
- professionalizing the institutions of the developing countries;
- certifying products distributed in the developing countries.

Promoting understanding between financial and non-financial actors on access to electricity projects in the rural environment

We feel it is vital to find solutions to the investment deficit in collective rural electrification solutions such as mini-grids.

For example in the *Sustainable Energy for All* initiative (SE4All; cf. 1.1.1), it would be useful to set up a think-tank, working party or platform that brings together DRE sector actors (developing country institutions, NGOs, industrialists, researchers) and finance sector players (funding bodies and development banks, investors, primary banks, insurers and reinsurers, actuaries, researchers) from the industrialized and developing countries.

The purpose of this group would be to:

- familiarize each actor with the constraints and operating methods of the other group members;
- clarify the economic and financial risks and opportunities stemming from different types of projects;
- understand how the financial instruments (equity, debt, donations/subsidies) can join forces to finance the various solutions that contribute to the electrification of rural Sub-Saharan Africa;
- define financing scheme that are apt for the development of decentralized solutions, including all the mechanisms, such as grants and subsidies and blended finance and decentralized finance (international funds supplying local credit lines);
- prioritize intermediate project (mini-grid type) financing issues, between € 0.5 M and € 10 M that struggle to find funding.

Create a North-South solidarity fund

We recommend considering the setting up of a North-South solidarity mechanism that would make rural electrification financing easier. It would be a "1% access to electricity contribution" to be charged on the industrialized country users' electricity bills (without penalizing disadvantaged households) to help set up RES electricity infrastructures in rural parts of developing countries.

- a charge of 0.5 % on the EU of 28 consumers' electricity bills would cover the equivalent of the annual electricity bill of about 100 million Africans
- the collected funds should be directed to financing new electrification schemes or extending existing schemes
- it would be vital to enlighten the civil society of the industrialized countries of DRE's challenges prior to setting up this type of mechanism, for example by devising a specific development education programme geared to access to electricity.

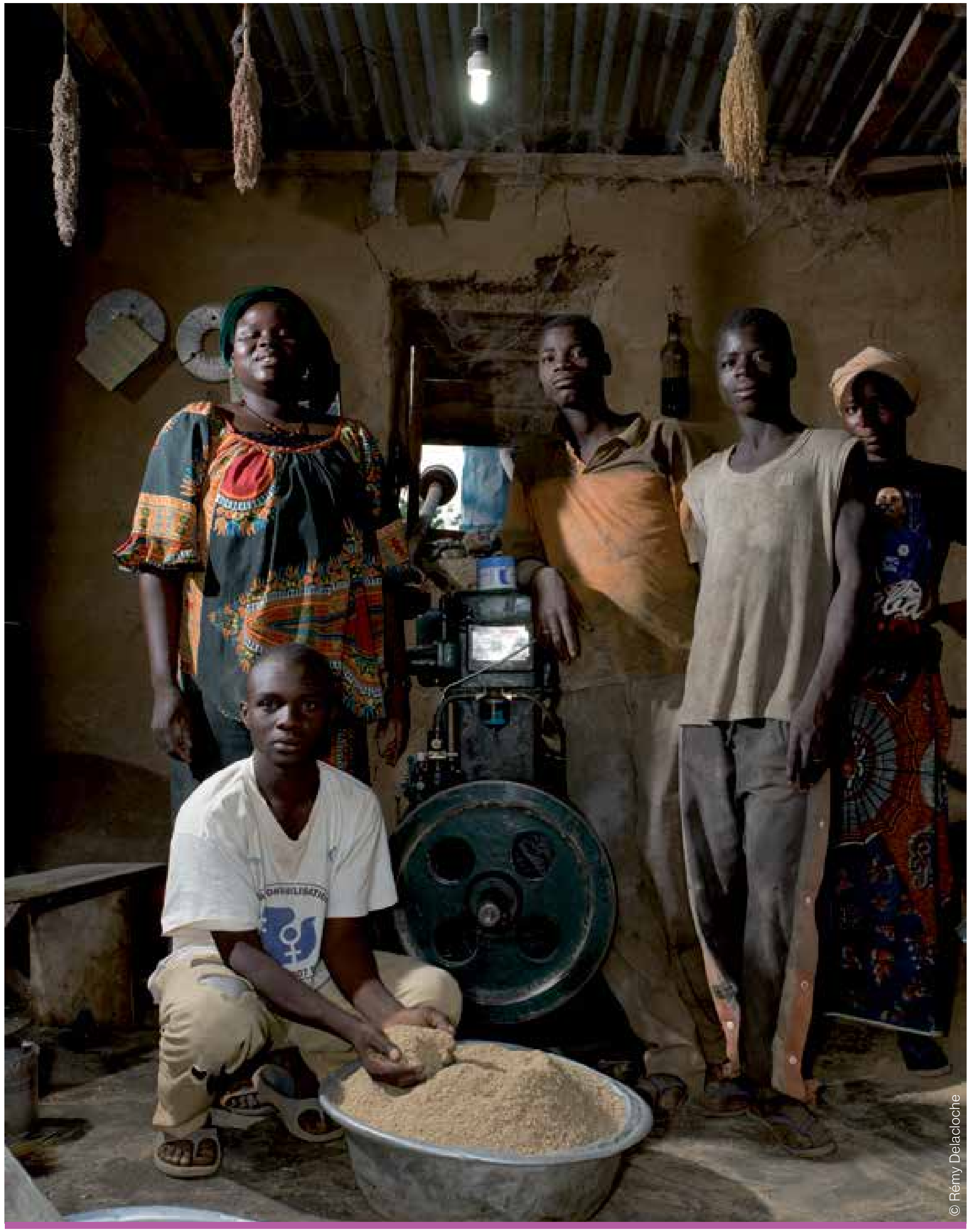
4.3. Recommendations to project financiers

Decentralized rural electrification infrastructure projects are capital-intensive and the relevant financial arrangements are as varied in form as the projects they back (cf. 2.3.2.). Recently, the available range of funding has expanded. International financial backers such as the World Bank now accept the idea of syndicating private resources with grants, for example.

Nonetheless, as previously mentioned, some solutions struggle to find funding. In this regard, while the platform we recommend for dialogue and co-construction of suitable financing devices (see 4.2) is useful, it will not suffice alone.

The institutional funders could improve the existing mechanisms, by integrating their efforts, directing their support differently and adapting how they allocate funds.

Moreover, international investors, like the local financing institutions, would also have a role to play, each at their own level and should modify their practices.



Support for economic activities ensures the growth and sustainability of services in rural areas.

4.3.1. Recommendations to international funders

In our view, the development banks and institutional funders (multi- and bilateral) should give precedence to some major financing principles to guarantee that DRE projects are more relevant and sustainable in territorial and economic terms:

- to avoid the haphazard proliferation of projects, the fundraisers should develop effective coordination of initiatives governed by territorial strategies. There are many examples of coordination of this type in Madagascar, Cameroon, Benin, Guinea, Mali, the DRC and even Senegal, whose access to energy actors meet from time to time to ensure that their actions are coherent;
- these fund raisers could also finance rural electrification primarily through grants, where investors are reticent or to do so or simply cannot do so, as the customers' financial capacities cannot stretch to accommodating the whole of a profit-making price schedule;
- aid should also go the local developing country actors and firms as well as to those of the donor country. We recommend releasing international aid free to the developing country actors, with a view to partnerships and mirroring part of it to the donor countries' firms.

On the merits of the supported projects, it seems essential to prioritize some subjects:

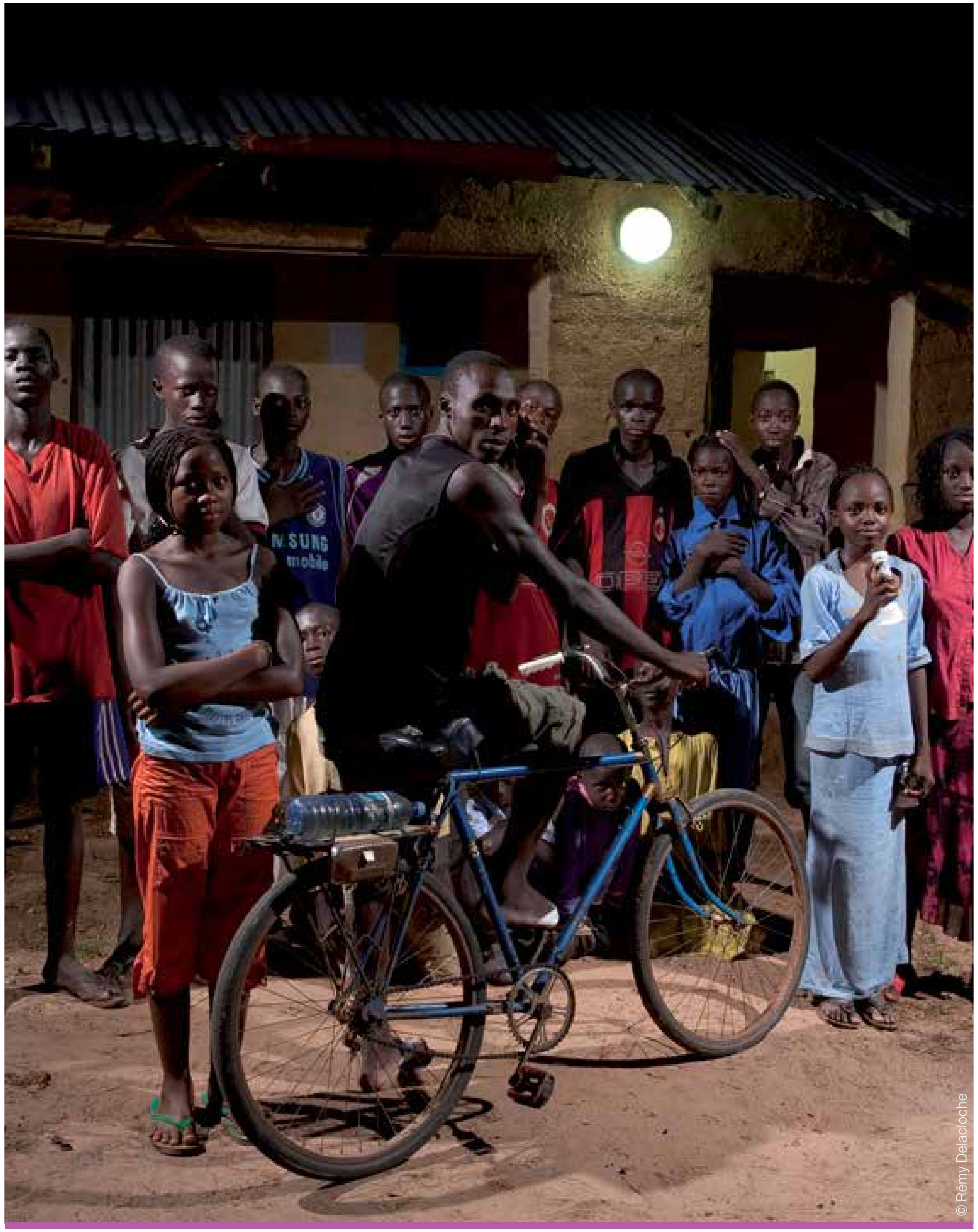
- funding the back-up and awareness-raising, follow-up and study (preliminary, impact) measures that can be complex and burdensome in out-of-the-way rural environments;
- help the states structure the new institutional organization (national leadership at interministerial level, strengthening decentralization and the deconcentration of rural electrification agencies).

In our view, the financing procedures would call for:

- setting up delegations to handle project applications below a certain budget level, which would reduce transaction costs, strengthen local proximity (e.g. EU national delegations, local AFD outposts, the economic services of the embassies, economic representations, etc.) and would enable smaller projects to emerge (from € 300 k to € 1 M). It would be interesting to set up dedicated facilities for these types of projects and offer NGOs a particular role to play in them.

This decentralization of industrialized country organizations would warrant the broadening of direct funding to the territorial institutions of the developing countries (acting as project owners):

- prolonging their support period in collective electrification projects that are mainly long and complex;
- basing all the funding mechanisms on an appraisal of the project's performance in three areas (economic, social, environmental) for the purposes of blended finance (dialogue with the impact investors);
- improving investors' risk coverage (to back up sovereign guarantees), for instance by setting up a dedicated guarantee fund accessible to the local funding sector;
- making allocation of grants, subsidies or loan ties to a private operator conditional on its active participation in data and experience sharing (at an international platform, see proposal in 4.2.).



The electrification of rural areas helps to make them attractive.

What essential principles should be applied to financing DRE projects?

(Non-exhaustive reminder of the principles already mentioned)

- **Pooling and sustainability of funds** for the investments needed to develop and undertake rural electrification projects. Fund raisers' resources dedicated to this type of project must be federated in a fund or multi-funder facility, whose financial support allocation procedures apply to all the projects implemented under the national rural electrification policy.
- **Allocation of sufficient public financial resources** to cover the running costs of the administrative bodies tasked with rural electrification and provide the required counterparts to the fund raisers' support. The allocation must be funded by informal taxation on electricity sales to gradually allow public co-funding to increase and eventually aim for the self-financing of rural electrification projects.
- **Partial subsidy for the initial investment** (development, infrastructure and equipment construction/installation), to ensure the financial viability and appeal of rural electrification projects. However, no subsidy for operating or future extensions.
- **Results-based subsidy payments** in line with technical specifications detailed in the project's subsidy agreement, that define the intended goal and results to be measured, including how they will be measured, depending on the implementation of the electrification operator's business plan, attached to the agreement. Payments may be subject to reductions or premiums depending on the quality of the results compared to the required level.
- **Cofinancing** of the initial development and infrastructure and equipment construction/installation investments **by the electrification operators**, from own funds topped up if necessary, by bank loans.
- **Commitments by the electrification operators to insure and finance the installation and equipment operation and maintenance**, including any upcoming extension and component renewals.
- **Periodic technical and financial audit of the fund or multi-fund raiser facility** by an independent body to ensure proper management and transparency, both in terms of administrative procedures and the decision-making methods and mechanisms used for carrying out the projects and follow-up.

4.3.2. Recommendations to international investors

We feel it is important to share the feedback between financial and non-financial actors. Investors (conventional funds or SRI, *impact investors*...) could thus take the approach of being willing to listen and learn at the suggested platform with all the DRE actors to enhance their assessment of the investment opportunities in decentralized rural electrification and develop this activity in coordination with the project developers.

4.3.3. Recommendations to the finance sector in the developing countries

The financial institutions, especially the primary banks, could usefully internalize DRE expertise within their dedicated rural development teams, for instance to support DRE development.

The local financing institutions, especially the microfinance institutions at territory level, could back the micro-entrepreneurs as they develop their economic activities (equipment, receiver purchasing) or the local operators with servicing the production facilities (purchasing replacement equipment):

- they join in on regional discussions and awareness-building actions to enhance their assessment of the opportunities and risks;
- they could affect the interest rate in force, the decreased credit risk thanks to the support measures and equipment quality guarantees enjoyed by the borrower (two points that NGOs bear in mind when they develop projects).

4.4. Recommendations to project developers and their direct partners on the ground

The change of scale required by Sub-Saharan Africa poses a methodological problem. Is it possible to tailor projects to each territory while bringing DRE to the masses? Or would that amount to squaring the circle?

In our view, project developers will have to go for a two-handed approach to achieve this by:
- working in 'half-measure' or 'intermediate standardisation: defining site morphotypes, each linked to a combination of suitable electrification solutions;
- acting on a broad scale over a single area making capital of pooling and compensation between villages, with a single operator and only one project management team.

There are three other principles that should guide DRE system project set-ups, regardless of who the developer is:
- approach the regional bodies to extend the user catchment area to cover at least 10 000 users;
- commit to covering the most vulnerable populations, by resorting to all available solutions (cf. part 3.) in addition to the main solution developed;
- join forces with the DRE sector NGOs of the industrialized countries and the local rural development NGOs.

This collaborative work between actors is particularly crucial to arrive at an accurate appraisal of the economic, social and financial risks. This appraisal may be time-consuming but should not be neglected under any circumstances. By guaranteeing the support of the populations and local entrepreneurs, it will remind all that electrification is only a means to an end and that the final uses of electricity, especially the productive uses are the real goal.

Additionally, the developing country NGOs should help the local populations express their wishes, to refuse projects that do not meet their expectations, and encourage their involvement in the projects that are acceptable to them.

For their part, the industrialized country NGOs could no doubt take better account of the sea changes currently going through DRE, primarily the sector's privatization, by changing their role:
- their mission as the natural guardians to universal access to electricity and to upholding this right for the most vulnerable populations, is to plead and make their voices heard more
- we also feel that they should keep a central operational role in the implementation of decentralized solutions in two instances: (1) to ensure that sites where investors are averse to or cannot intervene are electrified, and (2) to lead pioneering technologically innovative projects and support their implementation on the ground
- in the other instances, their mission, underpinned by their extensive field experience, would be better geared to technical support, especially in social engineering, for public (industrialized country institutions working in decentralized cooperation projects, for example) or private project developers.

They could thus play an essential role in training and professionalizing local actors and selecting the operators that have both entrepreneurial and social wisdom, in conjunction with the solution providers.

The latter would also have a hand in maximizing the positive externalities of the installed systems by:
- supervising experimentation in production, distribution, or storage solutions: identifying a mature territory, dispensing precise information on the risks incurred by the experimentation;
- providing training and skills transfer to the local private sector to set up spare parts supply streams;
- organizing the equipment recycling stream.

PRACTICAL MINI FACT FILE

How to prepare a DRE project application?

Preparing a DRE project application takes time and resources that should not be underestimated. It depends on many factors, primarily the country in question, who is the project developer, the type of project and the foreseeable funding sources. Here we restrict ourselves to listing the main recommendations that apply more often than not.

Administrative, technical and financial eligibility.

Before embarking on the project, the developer must check that it is eligible to operate as an electrification operator, and whether it is entitled to any tax benefits and available funding. This assertion needs to cover three areas, each of which could possibly result in its ineligibility:

- Administrative: provide documents that certify the project developer's legal status, its incorporation date, its corporate purpose, its capital, the associates' names and their respective shareholding and its statutes.
- Technical: present the developer's main reference sites for similar projects or that prove it has the required technical expertise (experience consisting of operating and managing mini-grid customers may be a major asset); supplying an organizational flowchart and the curriculum vitae of the key players intending to take part.
- Financial: provide banking data, the last three years' audited balance sheets of the company as well as all proof of outside financial contributions (fund raisers, banks, etc.) that can supplement its own funds.

If it is a consortium, each partner must provide the same supporting documents as the developer, a memorandum of partnership must be signed by all as well as one or more mandates to represent the consortium.

Project relevance, coherence with the local context and its realities

In order to be viable and sustainable, the intended project must be consistent with and be able to contribute to the implementation of the national, regional and local rural electrification policies and strategies and more generally, socioeconomic development (public services, health, education, economic activities).

Accordingly, the project developer must specify the basic information and working assumptions on which it is based and justify its relevance:

- Basic information: collect the available data and conduct the necessary investigations and field surveys of the local institutions, public services, households and economic actors, covering:
  - demographic and socioeconomic data, development potential;
  - expectations and motivation of councillors, local officials and customary authorities;
  - on-going and upcoming programmes and projects in the short- and medium term;
  - current energy sources and expenditure on lighting, battery charging (cell phones), audio-visual, household appliances, craft trades, etc.;
  - market surveys (capacity and willingness to pay) of households and other potential access to electricity customers, and patterns of use (consumer categories, average consumption by category, peak demands, the seasonal factor, load curves, etc.);
  - habitat types and densities, distances between villages, categorizing the land and possible mini-grid routes.
- Project relevance:
  - describe the relevance to the local aims and priority(ies) local, primarily with regard to the zones identified as being conducive to off-grid electrification, along with any other need, such as economic development opportunities, the environmental and health aspects, etc.;
  - demonstrate the relevance in relation to the needs and limitations of the potential beneficiaries;
  - estimate the number of potential direct and indirect beneficiaries;
  - show how allowance is made for the environmental, health, social integration and gender inclusion aspects.

Logical framework

This is followed by drawing up the logical framework – a crucial and decisive step. It is effectively the baseline that clarifies the project's aims and expected outcomes, the course it will take, the indicators that will measure its performance and the associated assumptions and risks. It plays out as follows:

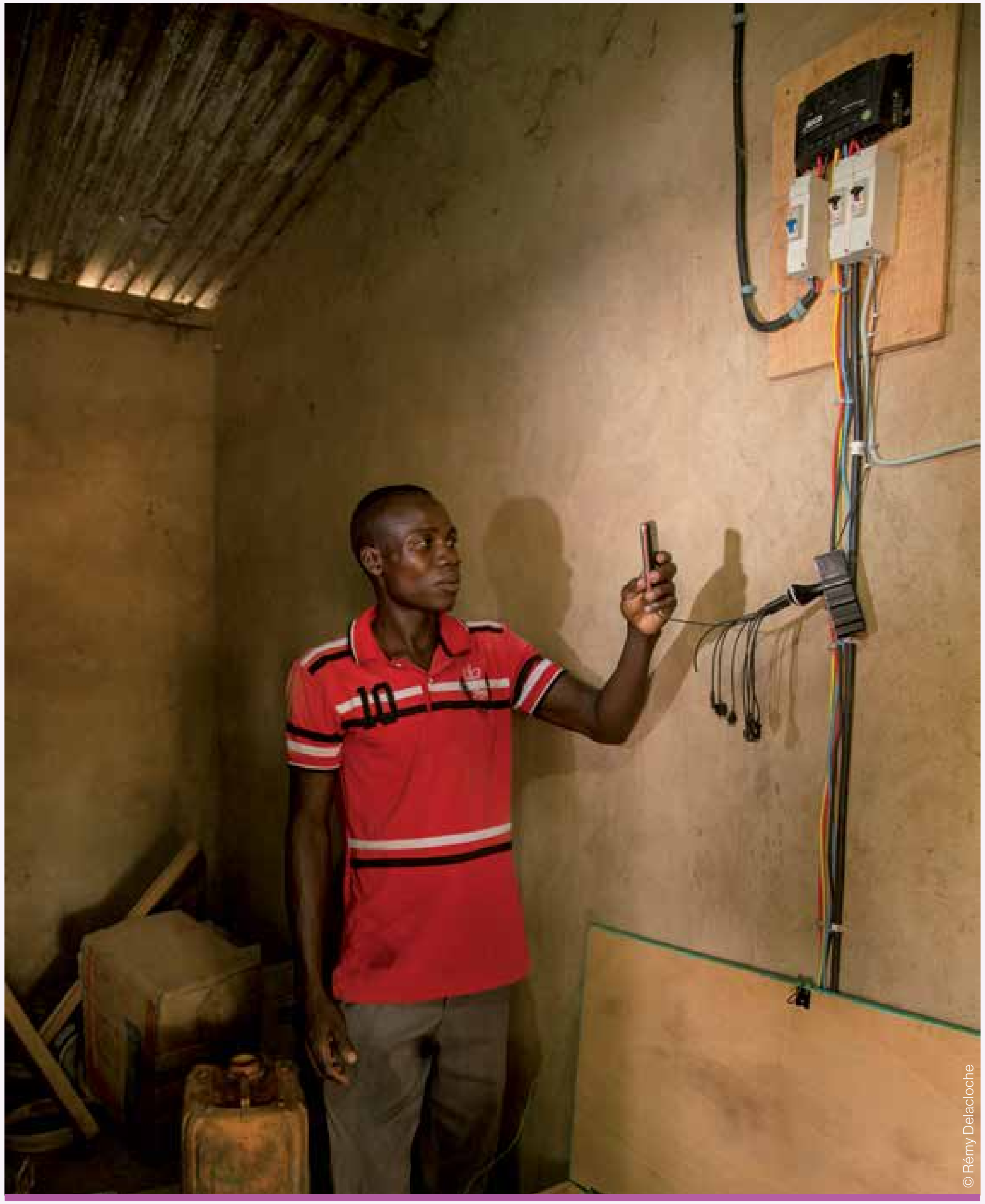
- Problem statement: describe the main issue to be resolved, emphasizing the challenges facing the main beneficiaries, primarily the most vulnerable groups
- Project goals: provide a concise presentation of the project's overall and specific aims, in line with the local policies and strategies and any calls for proposals.
- Expected outcomes, and for each one:
  - the objectively ascertainable, quantitative and qualitative indicators used to gauge the goods and services provided by project;
  - the verification source, the responsible party and collection frequency;
  - the assumptions and risks surrounding the achievement of the expected outcome;
  - the main activities planned to achieve the outcome, not forgetting to include the support activities such as for example promoting productive applications and any measures to mitigate social and environmental risks.

Working plan

The logical framework must be backed by a working plan that highlights the key project implementation steps throughout the implementation period. The steps must be realistic and achievable, possibly detailed on a quarterly basis and presented as a table.

The developer must ensure that chronological order is followed:

- the pre-sizing demand analyses and surveys;



Mobile telephony, engine of the electrification of rural areas.

- obtaining the licence/approval to operate must precede commissioning;
- sufficient lead time must be allowed for importing the equipment;
- sufficient and realistic lead time must be allowed for obtaining the licence/approval to operate, production and distribution.

If a subsidy application is submitted, the logical framework and working plan may be included in the subsidy agreement, and the release of funds may govern the achievement of the key steps.

Business plan

This is the key project preparation component, that doubles as the basis for the project assessment by the institutional and financial partners. It supports and justifies the approval (operating, production and distribution licences) and/or financing applications (subsidy, bank loans). It is usually presented as a spreadsheet with several tabs:

- Working hypotheses: forecast demand (kWh p.a.) per user category over the life of the project; pricing proposal for the various user categories (often up to 5); estimated annual sales;
- Investment plan detailing the unit cost, quantity, frequency and its justification for each expenditure item (description, needed for the project, calculating rationale, real costs and information on the supplier and equipment origin):
  - equipment purchases and installation: acquisition, transport, installation, training, replacement, and so on;
  - operating: operation and maintenance, repairs, invoicing, other costs;
  - furtherance of local activities: training, project management and follow-up, communication, and so on;
  - distribution and management: distribution, support personnel expenditure, administrative, equipment, management control expenditure, and so on;
  - costs of plots of land, buildings, and so on.
- Finance sources (amount, interest rates, terms): own funds, participation and contributions from partners and other third parties, bank loans, concessional loans, valuation of contribution in kind, subsidies.
- Disbursement plan over the subsidy period.
- Business plan for 20 years, operating results, cash-flow and internal profitability rate with and without subsidies.

ELECTRIFYING RURAL AFRICA: AN ECONOMIC CHALLENGE, A HUMAN NECESSITY

Conclusion

If there is one and only one lesson to be learned from 50 years of decentralized rural electrification through renewable energies, which one should we choose?

Perhaps that this electrification is first and foremost a matter of subsidiarity from national to local, from broad to specific, from national policy to service for users in the rural environment. The territory and the individuals who people it, in the regions and villages, must form the basis of the analysis and the action. This observation goes beyond the confines of access to electricity and developing countries.

Thanks to the recent exploitation of renewable energies in the industrialized countries, available at the point of use, we are witnessing the fragmentation of actors and the return to local management of electricity production, distribution and use. The above recommendations acquire their full sense in this context.

If everything is measured on the basis of a territory, this lesson contains another one. Electrification is powerless to engineer inclusive rural development on its own. An energy infrastructure is just one of many infrastructures, that only organized land use can capitalize on... for there can be no regional development without a rideable road or value chain enhancement, no local development without a dispensary or a school, without a drainage system or entrepreneurial stimulus.

Ongoing technology breakthroughs are conducive to the design of new electricity infrastructure models, that tend to lean towards this territoriality and proximity, despite the fact they are based on dehumanizing paperless operation. Without organized regulation on the part of the public authorities, these disruptive trends locally implemented by the access to electricity actors cannot be viable. Decentralized electrification will satisfy the greatest numbers from the combination of fair involvement of the three governance levels (national, regional, local). The same holds true for water and waste management.

Thus, this conclusion is a source of both hope and misgiving. The hope that a more relevant collective action will emerge, founded on a holistic vision of rural development, that organizes the coordinated installation of basic infrastructures, such as those that bring electricity to everybody.

And the misgiving is that these commons, water or electricity, become trade services and elude part of the population, the most vulnerable, least profitable portion. If the growing intervention of the private sector entails the funding, innovations, skills that DRE really needs, yet the universality of access to electricity with respect for equity between citizens cannot avoid having a regulated framework. This goes just as much for the developing countries as their industrialized counterparts.

Perhaps Africa, which has a much stronger commons culture than Europe, holds the key.

« Maybe Africa didn't invent the idea of universal, but it has developed all sorts of notions of "commons", where what counts is the relation and not the being, where social and the individual complement each other. Concepts that could serve as the basis for criticizing neoliberalism, whose ethos is every man for himself. »

Achille Mbembe, a Cameroonian historian, philosopher and political scientist (Le Monde, 2016)

Glossary

Business Plan
Document comprising an application for financing comprising detailed and quantified information on all aspects of a project. It primarily includes a detailed analysis of the events likely to occur during the duration of funding and affect the achievement of the project goals (sensitivity study).

Capital expenditure (CAPEX)
designates the development and supply costs of non-consumable parts for a product, enterprise or system. It covers the preliminary studies, system component acquisition, technique support with installation, etc. in the case of electrical systems

Demand
Power required to meet the demand for electricity. This term is often used to designate the peak arising from a sudden surge in electricity demand.

Gender
This concept designates the relations, duties and socially and culturally constructed roles of women and men. It is a political and social construct as opposed to the notion of sex, which covers the biological features of individuals.

Generator set
Standalone device comprising a thermal motor that can run on different types of fuel and operates an alternator capable of producing electricity.

Informal sector
All the economic activities that are conducted outside of state control, criminal, social and fiscal legislation.

Interventionist approach
The historic approach to territorial electrification, based on historic coordination and the involvement of civil society to implement a collective electrification solution.

Liberal approach
The recent approach to territorial electrification, based on the intervention of a private actor as part of a commercial exchange with a customer for the acquisition of electrical goods or a service against cash payment or payment by instalments.

Load factor
Ratio between the energy produced by an electricity production plant over a given period, and the energy that it would have produced over that period if it had operated steadily at full power.
Operational expenditure (OPEX)
the current expenses for producing a product, or service by an organization. It covers operating personnel expenses, equipment maintenance costs, feedstock (e.g. fuel), spare parts, travel, communication costs and so on in the case of electrical systems.

Photovoltaic cell
The most basic photovoltaic device, comprising a photosensitive semi-conductor material that generates electrical energy (direct current) by absorbing light radiation. As defined by Gérard Moine in L'électrification solaire photovoltaïque. Systèmes autonomes, systèmes hybrides, miniréseaux. (Langres: Observ'ER, 2016).
Photovoltaic conversion efficiency
Ratio of the electrical power delivered to the terminals of the photovoltaic device to the power of the sunlight incident measured in normal test conditions.
As defined by Gérard Moine in L'électrification solaire photovoltaïque. Systèmes autonomes, systèmes hybrides, miniréseaux. (Langres: Observ'ER, 2016).

Photovoltaic module
The smallest set of interconnected solar cells totally protected from the environment. As defined by Gérard Moine in L'électrification solaire photovoltaïque. Systèmes autonomes, systèmes hybrides, miniréseaux. (Langres: Observ'ER, 2016).

Power
Quantity of electricity produced or used at a given instant. It is measured in Watts (W).

Prime contractor
Person or organization responsible for designing the project plans, organization and supervision and selected by the project owner. They coordinate the work of the individuals working on the project and deliver the final product.

Project owner
Project sponsor who defines the specifications (needs and goals, budget, provisional schedule) ahead of the project. Once everything is installed, they become the equipment owners.

Social engineering
All the listening, observation, awareness-raising, training and guidance activities carried out by project stakeholders on the basis of a cooperative, democratic and participative approach to project management.

Storage
Process used to set aside an amount of energy for later use. Electrochemical storage (using batteries) is the most widespread electricity storage method.

Technical engineering
All the activities that make for the design, construction and commissioning of a technical or industrial installation, ranging from preliminary studies to running checks on installed equipment, including sizing, equipment procurement and checking, carrying out works and pre-commissioning testing.

Electrifying rural Africa
An economic challenge, a human necessity

How come the most destitute people pay the world's top prices for electricity? Can this be reversed? Rural electrification efforts have been trialling renewable energies for fifty years, primarily in Sub-Saharan Africa. The time has come to draw on this wealth of experience for the future, make an audit and suggest useful recommendations to all stakeholders.

This book has been written on the basis of the thirty years' expertise built up by Fondation Énergies pour le Monde, ... specialists who are mindful of rural populations' demands and who seek sustainable solutions. It enjoys the benefit of their knowledge of the role of project manager delegate, directing the whole spectrum of players, from users to ministries, including financial backers, operators, equipment suppliers and local authorities.

So many voices who express their opinions in the book and who need to work more closely together to make a difference.

The authors:

Yves Maigne
Gérard Madon
Etienne Sauvage
Sarah Vignoles

ADEME
Agence de l'Environnement et de la Maîtrise de l'Energie

la francophonie
IFDD

Synergie Solaire

ÉNERGIES POUR LE MONDE