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A New Electrification Model to End Energy-Poverty

An example from a novel rural electrification approach in Madagascar

By Lucas Richard, Nicolas Saincy, Nolwenn Le Saux, David Frey, Marie-Cécile Alvarez-Herault,
Bertrand Raison

Highlighted by the United Nations Sustainable Development Goals to ensure universal access to clean, reliable and modern energy services by 2030, the world is increasingly getting concerned by the energy poverty and its consequences on human development and the environment. Yet, even if numerous initiatives and a significant amount of money are directly addressed to tackle the energy-access challenges, a billion people are still denied access to basic and modern electricity services, especially in rural places of Sub-Saharan Africa and South-East Asia. The African continent has seen in the past two decades an encouraging improvement as the number of people gaining access to electricity rose from 9 million per year between 2000 and 2013 to 20 million per year between 2014 and 2019, outpacing for the first time population growth. However, the vast majority of those recent improvements are mainly restricted to urban and peri-urban areas of a small number of countries located in Eastern or Western Africa and the population without access to electricity in Africa is expected to increase in the coming years following the health crisis and economic downturn caused by Covid-19. This definitely proves the fragility and the poor resilience of the electrification solutions favored nowadays. While grid extension and conventional microgrids suffer from low inclusivity and replicability, Solar Home Systems are only a stopgap measure failing to boost socio-economic development. A third way must be proposed to combine quick and affordable access to basic electricity services and a community uplift through socio-economic development, answering both greatest challenges that the developing countries are struggling to cope with nowadays. With this objective in mind, Nanoé, a French-Malagasy social company, is developing the Lateral Electrification model based on the collaborative and progressing building of electric infrastructures, which is presented in this article, first from a general point of view then through a focus on Nanoé's experience in Madagascar.

1. Why? The need for a new electrification model

1.1 Challenges

Sub-Saharan African countries are facing two energy challenges of separate timescales. On one hand, the short-term challenge, energy access, consists in quickly providing basic and affordable energy access to the vast majority of the unelectrified population. More than 770 million people are still lacking access to modern and reliable electricity services in Africa and the population growth in rural areas is expected to be greater than the rate of electrified people in the coming years. A high proportion of unelectrified people resides in rural places, far from any existing national or local grid with little hope to be connected

in a close future. Such poor energy access situations have dramatic consequences on the life conditions of communities, which usually rely on unhealthy, low quality and expensive alternatives to electricity such as kerosene lighting or biomass cooking, both emitting harmful fumes. Moreover, those alternatives are also a direct threat to the environment. Biomass cooking has a major responsibility in the increasing deforestation witnessed in developing countries and battery powered devices generate a high quantity of toxic waste. In addition, basic health facilities cannot operate without a reliable electricity delivery and poor energy access directly affects the life expectancy of the unelectrified communities. Last but not least, due to the absence of electricity powered devices and proper lighting, many daily life tasks are really time-consuming which impacts negatively the life of many Africans, especially women and children.

On the other hand, the long-term challenge, sustainable development, relies on the progressive building of decarbonized and decentralized sustainable power infrastructures, which could boost the economic and social development of Africa. In Sub-Saharan African countries, informal work is very common, especially for the young people. More than 2/3 of the Sub-Saharan population is less than 35 years old and is usually working in bad condition, without a fixed and sufficient revenue nor social security. In addition, low-energy access often traps Sub-Saharan workers in inefficient, time-consuming working tasks, which do not enable them to improve their life standards. Therefore, the youth of the Sub-Saharan African population should be an opportunity for the energy access challenges, which should rely on this highly motivated part of the population to accelerate the energy revolution. More than 12 million young people are entering the employment market in Africa each year and the responsibility of building lasting 21st century electric infrastructures for their countries should be put within their hands, which would also develop local job markets and reduce unemployment.

It is the belief of the authors that any rural electrification actions and initiatives in Africa should seek to tackle both these short and long-term challenges and that current practices in the sector have unfortunately proven their inability to cope with both at the same time

1.2 Conventional methods to tackle poor energy-access

Current practices for rural electrification can be broadly divided in two families : Grid solutions and Individual home-scale solutions.

1.2.1 Grid solutions

Conventional micro-grid, mini-grid and national grid extension can be grouped in a first family of solutions that have in common to be based on the construction and operation of heavy and costly power production and distribution infrastructures to cover an entire village, district or region in order to sell 230 V AC power to final users in a regulated public service approach. However, national grid extension is failing to reach the vast majority of unelectrified communities due to high upfront connection costs. Moreover, households close to the national grid cannot always afford to pay for the connection or to buy electricity once connected. Similarly, microgrid solutions are economically viable only to over 300-500 households' densely populated villages and need fairly stable and financially supportive institutional environments, unfortunately not the typical place where most off-grid Africans live today. Both solutions are therefore offering little to no replicability and are confined to a small perimeter of the energy access problematic, reducing the inclusivity of such solutions and failing to cope with the population growth. In addition,

national grid extension or conventional microgrid are solutions of the past, relying on centralized top-down architectures, designed to distribute to millions of small users electricity produced by a small number of large production plants. Indeed, it deprives the African energy sector from the opportunity of a major technological leapfrog toward a decentralized, bottom-up power infrastructure, a challenge that developed countries are nowadays struggling to overcome. As experienced with the tele-communication sector, for which Africa has directly embraced the wireless revolution, the African continent can jump to a progressive construction of decarbonized and decentralized electric infrastructure, which offers modularity and scalability. Moreover, conventional microgrids are usually oversized when installed, generating large upfront costs hard to recover, and then often undersized after a few years of service due to the increasing demands of the communities. Thus, given their extreme capital intensity, grid extension and conventional microgrid deployments are often the prerogative of foreign players, limiting the local economic impact of those projects. In addition, grid solutions often rely on fuel-based generation, limiting their resilience and their economic and environmental sustainability. Last, such energy access solutions do not create perennial jobs in the electricity sector, even though it enables socio-economic development thanks to high-power electrical services but only to the small share of the population that can afford the connection costs. Nevertheless, nowadays, those two solutions are still usually chosen to continue “business as usual” but they do not fully tackle any of the challenges the African continent is facing.

1.2.2 Solar Home System

Solar Home Systems, small power kits composed of a solar panel and a battery, are undoubtedly gaining momentum in the rural electrification sector and have already proven their ability to cope with the short-term energy access challenge by quickly providing basic energy services and improving the living conditions of millions of households across Africa. However, they are only a stopgap measure, which lacks long-term sustainability and fails to cope with development challenges. Indeed, Solar Home System are usually low power solutions, with a short expected lifetime of 3 to 4 years, which dramatically reduces the technical and economical sustainability of those solutions that are extremely economically inefficient in the long term due to frequent replacement costs. Moreover, these solutions, restricted to domestic energy needs, are unable to answer productive energy needs. In addition, they are neither socially nor environmentally sustainable. Indeed, Solar Home System ownerships transfer many risks usually taken by the energy provider to the consumers, which must deal with material thefts, breakdowns and recycling or disposal of end-of-life products. African countries are already struggling to cope with the high amount of toxic wastes generated by end-of-life Solar Home Systems, which are too complicated to collect and gather to create economic incentives. Lastly, Solar Home Systems do not enable scalability and modularity, which impedes the final users to progressively climb the energy ladder by increasing its electricity consumption throughout time in a cost-effective manner.

2. What? Towards a new power infrastructure development path for rural Africa

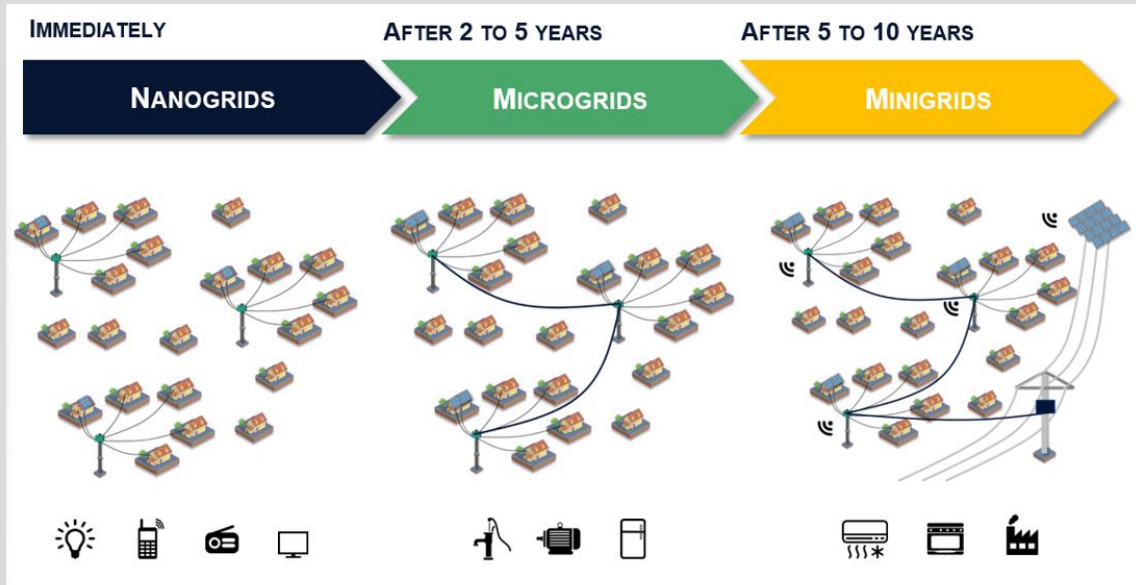
The energy access situation in Africa presented above calls for a new electrification model which combines quick and cost-effective access to basic electricity services to the vast majority of unelectrified communities as well as a community uplift through socio-economic development. It is the belief of the authors that no technological, business or regulatory adaptation would allow any of the aforementioned

solutions to tackle both challenges at the same time and that a radical rethinking is necessary. In this context, Nanoé, a French-Malagasy social company, proposes a model named Lateral Electrification, aiming at tackling simultaneously the energy access and the sustainable development challenges encountered in Sub-Saharan Africa. Lateral Electrification is a concept of progressive and collaborative building of smart power grids in rural Africa from the bottom-up based on renewable energies, digital technologies and local entrepreneurship. This electrification model relies on 3 pillars based on technological, organizational and marketing novelties presented below.

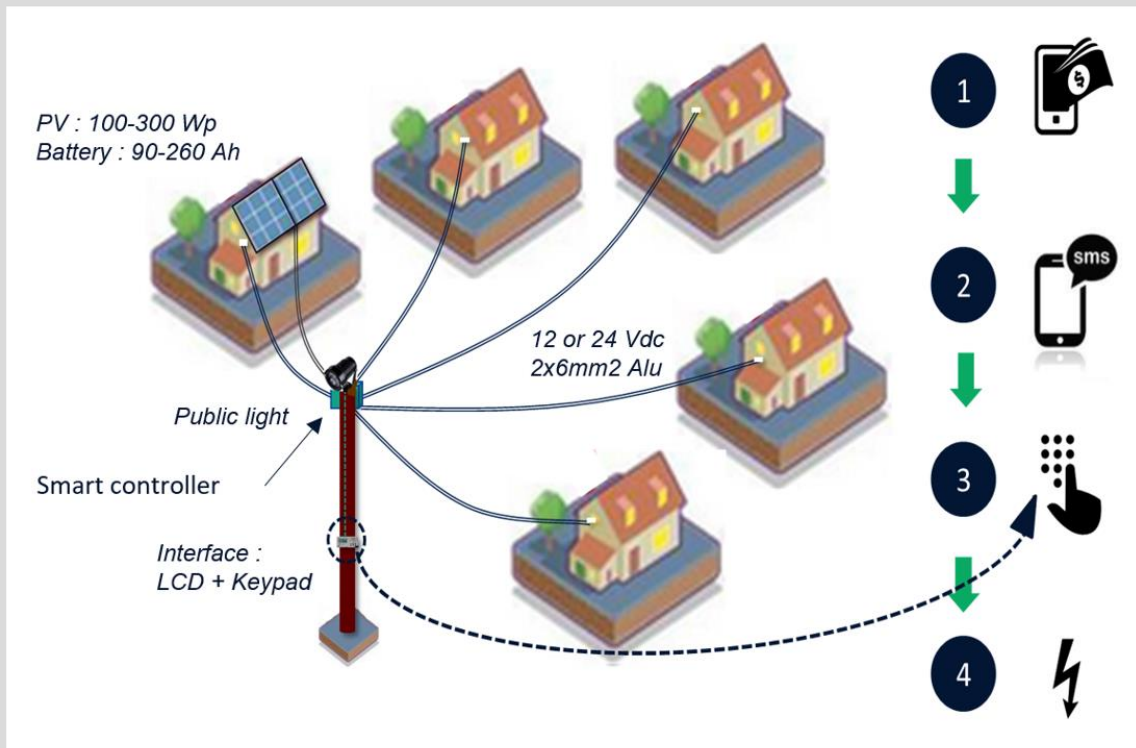
2.1 Pillar 1: Technological approach

Technologically wise, Lateral Electrification follows the swarm electrification concept of progressive building of power infrastructures in a bottom-up manner, enabling modularity and scalability, by nimbly and progressively extending the energy services delivered to the end-users (from Tier 1 to Tier 4 as defined by the multi-tier framework proposed by the United Nations) through the diffusion and the aggregation of basic smart power units regrouping solar power generation, storage and distribution as described in Figure 1 (a). Those basic units, named nanogrids (Figure 1 (b)), are expandable collective solar systems delivering DC power up to 6 neighboring households, commercial or community users (like public lighting). Then, once a critical density of nanogrids is achieved within a settlement (typically a village), these systems can be clustered to form a village-wide lateral microgrid able to deliver an energy service extended to refrigeration, pumping and agro-processing machineries. This progressive approach offers many advantages for the communities and the grid operator. On one hand, the proposed electrification scheme can grow with the needs of the communities, enabling them to progressively climb the energy ladder at their desired pace. On the other hand, for the grid operator, the modular aspect of this electrification model reduces the investment risk by breaking down large capital expenditures in small successive investments with short payback periods. In addition, the flexibility of the proposed microgrid allows a better use of hardware resources by removing or adding new production and storage capacities as needed to optimize the production-consumption equilibrium over time. By mutualizing installed production and storage capacities, such microgrid would use them more efficiently improving the economic viability and sustainability of this rural electrification model.

The final step of this progressive building of electric infrastructure is the interconnection of microgrids between one another or their connection to a national or local AC grid to further extend the energy services delivered to the communities to industrial and thermal uses, such as air conditioners, electric cooking or small production plants.



(a)



(b)

Figure 1: The electrification model proposed by Nanoé: (a) Progressive building of electric infrastructure, (b) Schematic of a nanogrid installation.

Nanoé's case

Nanoé has already installed more than 1500 nanogrids in the North of Madagascar and 10 000 nanogrids are expected by the end of 2024. A nanogrid consists of one solar panel, one PWM regulator, one lead-acid battery and a controller developed in-house to monitor and control the consumption of 4 to 6 houses.

Some villages already contain more than 25 nanogrids, such as Ambohimena where the first DC microgrid with decentralized production and storage has been successfully installed at the end of 2021 after one year of R&D in close collaboration with the Grenoble Electrical Engineering Lab.

2.2 Pillar 2: Organizational approach

This novel electrification model also rests on an innovative organizational approach. Indeed, it relies on an horizontal industry organization powered by local entrepreneurship, which highly differs from traditional and large vertically integrated energy operators of the occidental world. A decentralized industry organization composed of a multitude of locally-implanted entrepreneurs appears both more realistic and more ambitious. The most revolutionary aspect of Lateral Electrification is that it puts electrification within the technical and financial reach of local rural entrepreneurs and that the breakdown of large investments in small successive ones offers them a progressive path to develop their own business. Furthermore, the complexity of the energy situation and of the social organization in Sub-Saharan Africa makes it almost impossible for a single electric operator to operate simultaneously on different villages distant from each other without a regular on-field presence. Through a multitude of locally-implanted entrepreneurs, it becomes possible to disseminate the proposed electrification solutions to thousands of remote villages across an entire country. Indeed, locally-implanted entrepreneurs have a better understanding of the social organization of the community and the reality of the field. They are also more prone to convince communities of the merits of the proposed electrification solutions and to develop a trustful lasting relationship with end-users. In addition, such an organization creates far more value locally, participating in socio-economic development through the creation of multiple local electric operators. While conventional ways to tackle low-energy access mostly benefit to American, European and Chinese companies, the Lateral Electrification model aims at giving the economic benefits of rural electrification to the local communities, installing and exploiting the electric infrastructures. This revenue sharing scheme between the company and electric operators participates in the creation of a trustful economic situation, where each actor is financially rewarded up to its participation, reducing drastically corruption and low-quality services.

Nanoé's case

Nanoé offers a free 4-month full-time training to local entrepreneurs willing to be actors of the energy transition through 4 offices in different cities. 9 training sessions have successfully been achieved, teaching the basics of electricity, customer relationships and electric infrastructure operation to up to 100 nano-entrepreneurs, recruited locally with the only condition of having basic knowledge of math and logic. Each nano-entrepreneur is then attached to a particular geographic area, from which they are usually native, where they should find customers, install and exploit nanogrids. The electricity revenues generated by a nanogrid are then shared between the company, the owner of the nanogrid and the entrepreneur operating the nanogrid.



(a)



(b)



(c)



(d)

Figure 2: Nano-entrepreneurs training: (a) Practical training, (b) Learning the basics of nanogrid operation, (c) Field installation of a first nanogrid, (d) Graduation ceremony.

2.3 Pillar 3: Marketing approach

At last, the Lateral Electrification model also differs from current electrification solutions by a singular marketing approach, which relies on an exhaustive service offer, the Lateral Electrification operator being a power producer, a grid operator, an appliance provider and a domestic electrician. This contrasts with usual economic actors in the energy access sector, which normally either sell electricity (i.e. kWh) or electric materials. In opposition to urban and mature power system environments where each market-segment is sufficiently large to be economically viable on its own, remote rural environments do not favor vertical specialization. Therefore, vertical integration is indispensable in rural African areas to allow small locally-implanted operators to generate sufficient revenues from their activity and to decrease the overall cost of the energy services and increase its safety and its reliability. Thus, the Lateral Electrification business model rests on an hybrid commercial offer with an initial fee for device and then a fee for service as shown on Figure 3. Clients must first buy appliances proposed by the operator, which deals with their installation and maintenance. This permits to ensure that only energy-efficient, long-life and high-quality devices are used in the nanogrids, improving the economic and environmental sustainability of the proposed technological approach. In addition, clients are equipped with tailored and fixed circuitry made to last, traducing the durability of the proposed electric services in comparison to plug & play temporary installations such as SHS. Once equipped and connected, each client has to pay a daily fee to power these appliances. Several subscription levels are proposed, with different maximum power and daily energy depending on the energy services needed by the end-users. This tariff structure offers many advantages.

- For the clients, it is more flexible as they only pay the days when they consume.
- For the operator, the initial fee for device enables to assess the motivation and financial health of the end users, which helps to limit installations of nanogrids to clients who will later not use them, and to decrease the economic risk of the nanogrid investment for the operator.
- Such economic scheme is also more cost-reflective for the operator than selling kWh and traduces better the energy situation in Sub-Saharan Africa where the reliability and safety of the electricity services are equally important to its power and energy rating.

In addition, such tariff structure offers a progressive electric consumption path for the end-users who can increase their service subscription at any time, the electric operator guarantying to add or replace PV panels and batteries if necessary. This limits the risks of legacy infrastructures which often prevent the end-users to enhance their electricity services for economic reasons. Lastly, such marketing approach permits to better deal with end-of-life products as they are not left with the end-users, but rather managed by a skillful electric operator, gathering and recycling at once a high amount of end-of-life products, increasing the economic viability of the heavy recycling process.

Nanoé's case

Nanoé proposes 7 different subscription levels from basic lighting services to multimedia services. Most clients opt for low power subscription with 2 or 3 LEDs and USB charging but there is an increasing demand for multimedia and even cooling services. Day of electric services can be paid through mobile payment, limiting cash exchange and easing recharging process. Local nano-entrepreneurs are also often on the field to deal with the recharging, especially when telecommunication signals are unreliable. Once paid, the end-user receives a code that should be entered in a keypad interface. A day of electricity services is counted once the appliances have been on for more 5 minutes to avoid frustrating errors.








FEE FOR DEVICE		FEE FOR SERVICE	
Device	Initial fee (in \$)	Service	Daily fee (in \$/day)
 3W	10 \$	10 Wp 50 Wh/day	0,15 \$/d
 4W	~ 10 \$	18 Wp 90 Wh/day	0,23 \$/d
USB  5W	~ 10 \$	30 Wp 150 Wh/day	0,30 \$/d
 8W	~ 15 \$	42 Wp 210 Wh/day	0,45 \$/d
PL  12W	~ 30 \$	66 Wp 330 Wh/day	0,60 \$/d
 15W	~ 100 \$	100 Wp 500 Wh/day	0,91 \$/d
 60W	~ 850 \$	125 Wp 1250 Wh/day	1,50 \$/d

Figure 3: Exhaustive service offer.

3. How? Roadmap for development

The proposed electrification model requires technological and organizational developments to ensure its viability and to prove its scale-up potential. Technical challenges are inherent to the swarm electrification approach while institutional challenges remain of major importance for the quick dissemination of the presented solutions. To overcome those challenges, this section presents Nanoé's development through technological and scale-up roadmaps.

3.1 Technological roadmap

3.1.1 First step: nanogrids

To achieve the first step of the Lateral Electrification model, Nanoé has developed hardware and software solutions. Nanoé proposes a mature technological innovation, the nanogrid, an autonomous collective DC solar system powering 4 to 6 households. End-users can buy days of access to electricity through mobile money, as presented in Figure 1 (b). The proper operation of those nanogrids mainly relies on the smart controller developed in-house by Nanoé R&D team (Figure 4 (a) and (b)). This smart controller is composed of sensors, a micro-controller, a memory card and a bidirectional user interface. Its main purposes are to:

- monitor and control the power and the daily energy drawn by the end-users,
- handle the mobile payment system,
- prevent any fraud attempts,
- manage the consumption/production equilibrium while protecting the lifetime of the battery.

In addition, the presence of a memory card enables to collect consumption data of the end-users, which once analyzed allows to anticipate any likely change of fee for service by the end-users. Those consumption data are also necessary to study the relevance of the interconnection of the nanogrids within a village-wide lateral microgrid. Furthermore, this smart controller is linked to an interface keyboard where the end-users or Nanoé's employees can communicate with the smart controller, either to recharge end-users subscription or to check that everything is operating well. After an initial period to test and validate the proposed solution, Nanoé is now developing an industrialized version of its smart controller to be deployed by spring 2023.

Furthermore, Nanoé's R&D team has also developed and deployed software solutions for the employees and the nano-entrepreneurs, through a "Lateral Electrification Platform", an Information System facilitating the whole nanogrid installation and exploitation process. An intuitive map containing all the prospective clients and the nanogrids installed enables to follow in a time-effective manner the geographical dissemination of the proposed solution. The control of warehouses and maintenance operations, of particular importance in remote areas, is eased thanks to an on-line inventory tool and an intervention list. The online platform also regroups key statistics, performance indicators as well as technical and commercial information (material datasheets, payment descriptions) and centralizes and summarizes the operation of the electric operator in a user-friendly way, giving a comprehensive overview of their activity as shown in Figure 4 (c).

Both tools have enabled Nanoé to deploy more than 1500 nanogrids in 4 years, with an averaged time of 2 weeks between the end-users agreement and the nanogrid installation and an usual installation time of only 2-man-days of work (including commuting time which can be significant in rural areas).

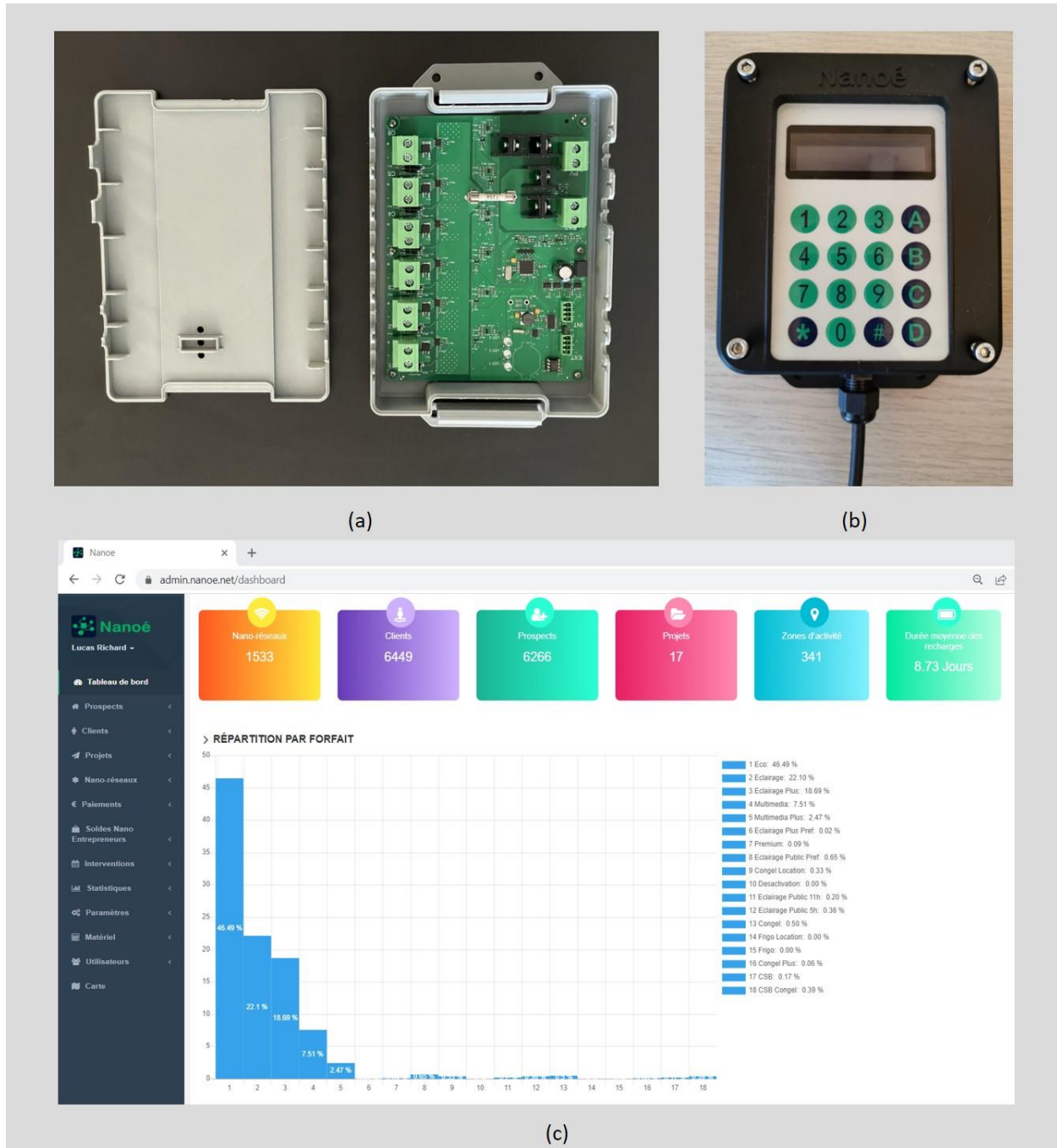


Figure 4: (a) In-house developed smart nanogrid controller, (b) Communication interface of a nanogrid, (c) Dashboard of the Lateral Electrification Platform.

3.1.2 Second step: lateral microgrids

The second step of the Lateral Electrification model is the interconnection of nanogrids within a village-wide microgrid. After an initial period where the nanogrid solution is progressively disseminated within the geographical area of intervention, some villages, such as Ambohimena in Figure 5 (b), offer a high density of nanogrids within a close area. During this dissemination period, the nanogrids are necessarily

oversized to prevent any black-out on rainy days and to adapt to the likely increase of the electricity demand by the end-users. A consumption data analysis carried out in Ambohimena over 3 months (September to November 2020) shows that the averaged Depth of Discharge (DoD) of the nanogrid batteries is of 13.9% as shown in Figure 5 (c). This confirms that the mutualization of installed production and storage capacities in a village-wide microgrid will improve the economic and environmental sustainability of the approach by decreasing the amount of production and storage resources installed and will help communities progressively climb the energy ladder (by transitioning from Tier-2 to Tier-3 electricity services).

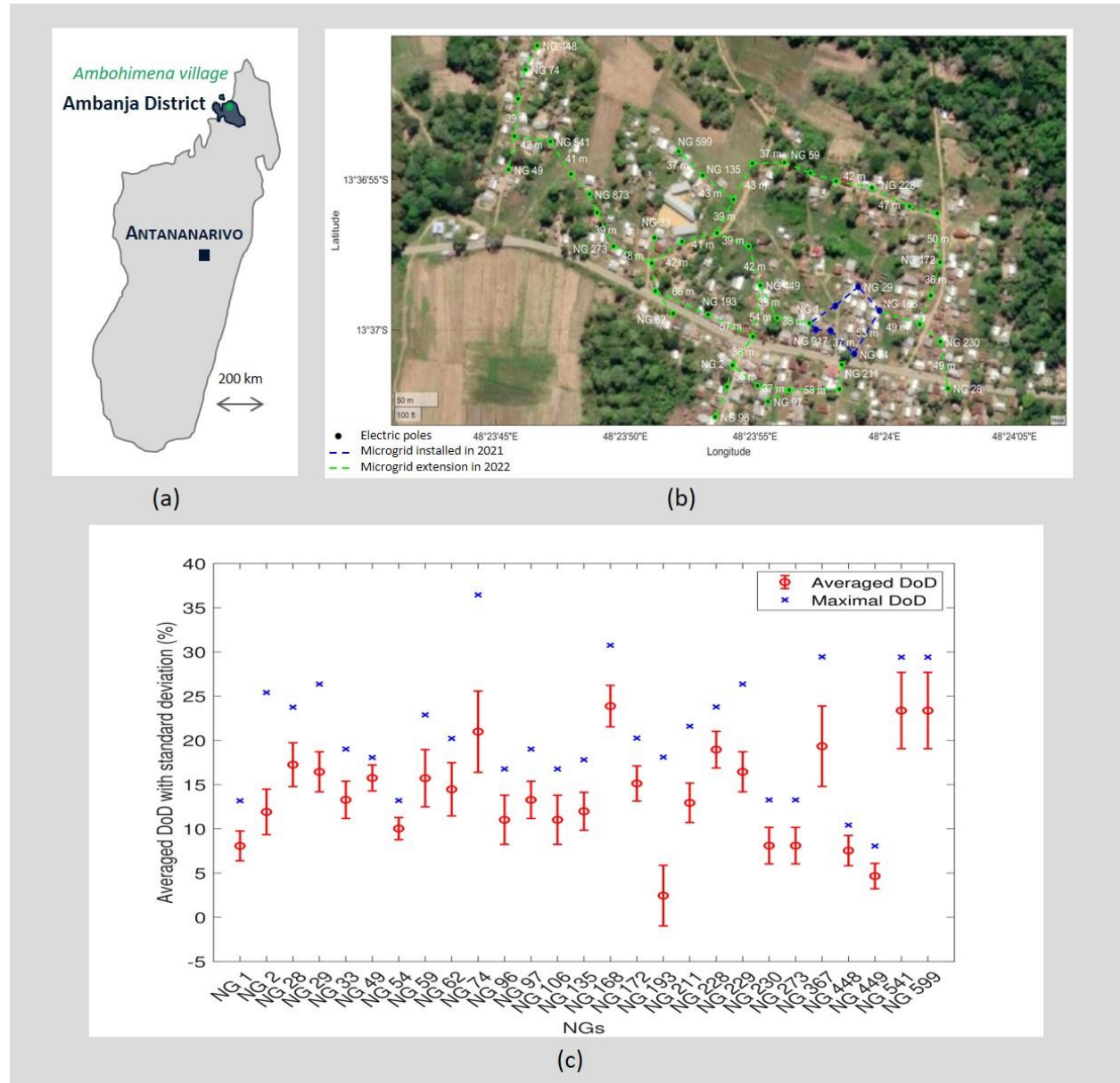


Figure 5: Ambohimena, a typical village of Madagascar: (a) Zone of intervention, (b) Nanogrid and microgrid installation, (c) Analysis of the consumption data of Ambohimena through the Depth of Discharge (DoD) of the nanogrids.

To achieve this second step, Nanoé has established a scientific collaboration with the Grenoble Electrical Engineering Lab (G2ELab) to develop a first prototype of a DC microgrid with decentralized production and storage (Figure 6). The main element of the proposed microgrid is the interconnection module installed at each nanogrid, composed of:

- a DC-DC bidirectional buck-boost converter dealing with the power exchange,
- a command card driving the converter and managing the data recording, the User Interface and the communication with Nanoé employees for data collection or other interventions.

An interconnection module links a nanogrid to the 72 V DC bus of the microgrid and must control energy sharing, based on a decentralized and communication-free algorithm. This type of control algorithm enables to avoid a single point of failure and is affordably deployable even in areas where telecommunication signals are inexistent or unreliable. Thus, an interconnection module assesses the local availability of energy through the State-of-Charge of the nanogrid and the global level of energy through the local measurement of the DC bus voltage. A high or a low DC bus voltage means the microgrid is respectively globally charged or discharged. This control algorithm ensures relevant power flows on the DC microgrid while guaranteeing overall stability and maintaining the DC bus voltage within a predefined range of $\pm 10\%$. The voltage level of the DC bus has been set to 72 V as the best compromise between safety of operation and permissible power on the DC bus.

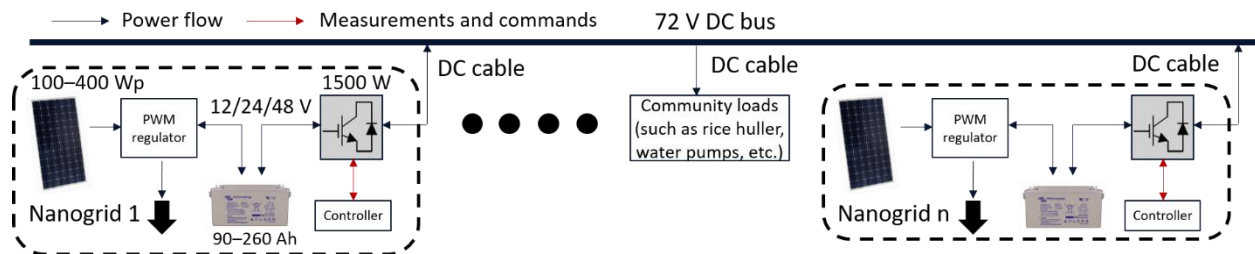


Figure 6: The configuration of the microgrid developed by Nanoé and G2ELab.

After one year of R&D with G2ELab, Nanoé has installed its first microgrid in November 2021, interconnecting 5 nanogrids in Ambohimena. The interconnection modules, printed in France, were locally assembled in Madagascar by Nanoé staff (Figure 7 (a)). Labor works lasted 3 days with more than 250 meters of 16 mm² electric cables and 2 additional electric wooden poles installed (Figure 7). Then, the microgrid has been launched for the first time the 3rd of December 2021 and the first tests were successful. The microgrid contains three 12 V nanogrids and two 24 V nanogrids (24 V is preferred for high-power nanogrids). On purpose, the nanogrid 917, a 24 V nanogrid recently installed with a refrigerator, was slightly undersized to check the supporting capability and global control of the microgrid power exchanges. Indeed, all the other nanogrids injected current on the microgrid to support the weak nanogrid when necessary, as shown in Figure 8 with the currents of the interconnection modules on the low-voltage side. Note that a positive current is injected on the microgrid and vice-versa.

After this successful first field-pilot, Nanoé has deployed, at the end of 2022, a village-wide microgrid in Ambohimena with 24 interconnected nanogrids and has tested other use cases such as nanogrids without

battery or communal loads based on DC motors to enable productive use of energy. Up to February 2023, the microgrid is still running well, without any major issues.

Overall, this first microgrid is an important milestone in Nanoé's technological roadmap as it confirms the technical feasibility of the Lateral Electrification model. The microgrid operation opens up a myriad of future possibilities for Nanoé to improve the economic sustainability of the Lateral Electrification approach and to improve the electrical services delivered through the use of high-power communal loads, boosting local socio-economic development.



Figure 7: Field installation of Ambohimena microgrid: (a) Assembling of the interconnection modules, (b) Installation of the electric cables, (c) Installation of an interconnection module, (d) Cable connection on an electric pole.

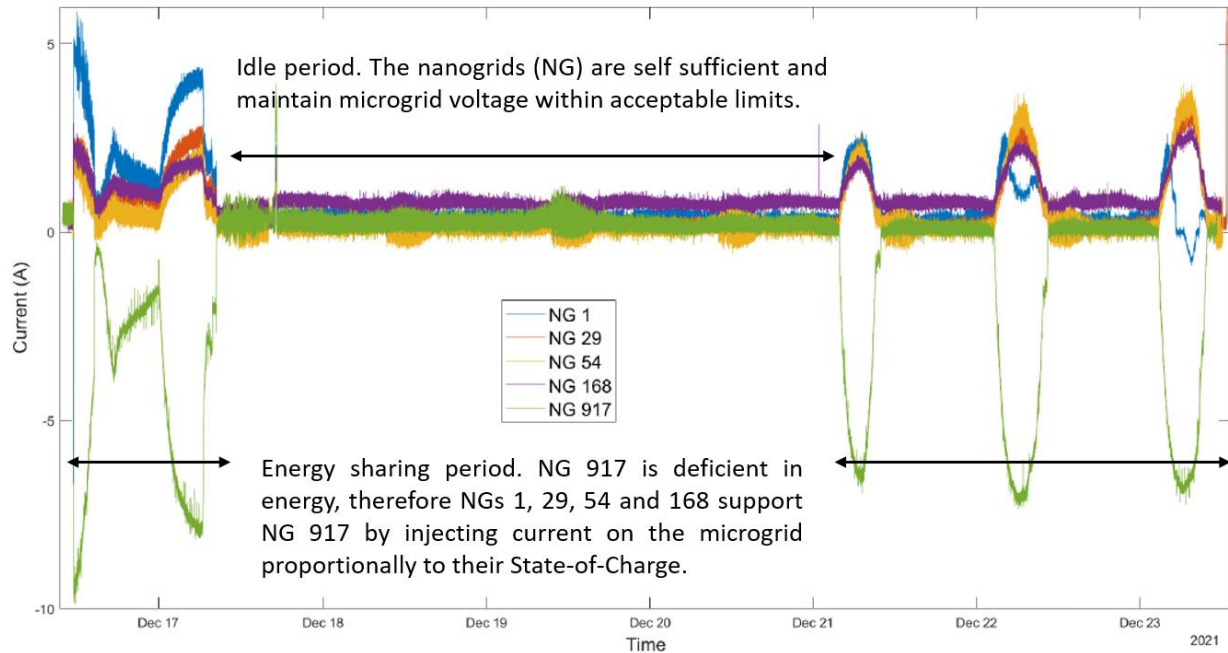


Figure 8: Power exchange on the microgrid for one week.

3.1.3 Third step: mini-grid

The third step of the Lateral Electrification still remains open to debate. Whether it will be the interconnection of microgrids over a few kilometers or the connection to a local or national AC grid, the objectives are the same, i.e. to offer Tier 4 to Tier 5 electricity services to end users, with a better continuity of supply and higher industrial loads. Therefore, higher voltage levels must be selected to reduce losses, so additional electric operator skills are necessary, confirming the process of progressive local skills development, at the center of the Lateral Electrification model. All those questions deserve further investigations which will be carried out once the microgrid development phase will be more advanced.

3.2 Strategical roadmap

The African energy sector is composed of multiple national and international stakeholders (public authorities, development aid donors, industrial players, financial sector, etc.) led by various interests, following different strategies, benefiting from diverse resources and promoting a wide range of electrification solutions. If everyone pursues the same objective of achieving universal access to electricity on the continent by 2030, a common vision of the strategy to reach it is sorely lacking.

The objective of this last section is to analyze the current positioning of the main stakeholders in the energy access sector to identify why and how they could support the emergence of the Lateral Electrification model.

3.2.1 Institutional actors: Adapt the rules

Confronted to a lack of public financial resources, African governments are increasingly counting on the private sector to invest in their national electricity sector. In the underserved rural sector, their efforts are focused on attracting private investors to develop rural micro or mini-grids. Developers are usually offered investment grants within the framework of competitive calls for tenders organized to electrify the areas considered a priority (for political or economic reasons) based on often hazardous national electrification plans. The limited resources allocated, the weak planning capacity of most African rural electrification agencies, the constraints imposed on technical standards and tariffs, and the administrative burden associated with these procedures, however, slow down their deployment rate, which do not keep up with population growth in most countries of the continent. Developers are also generally offered import tax exemptions on the used materials and components, without however exempting them from the complexity of custom procedures. Even without direct subsidization, it should be noted that these exemptions weigh heavily on the state budget of African countries for which import taxes constitute one of the only taxes they manage to collect.

Moreover, national public authorities are also generally sensitive to the content of the various electrification solutions and their impact on job creation, calling for the development of vocational training in the electricity and renewable energy sector without however having the technical and budgetary means to implement ambitious public programs in this area.

In this context, the Lateral Electrification model could represent an opportunity for local public authorities at different levels:

- By enabling faster and more sustainable electrification of rural areas,
- By alleviating the needs for public planning of power infrastructure development and by reorienting the role of the administration towards more control and regulation at the operation stage of electrification projects instead of the permitting stage to accelerate their deployment and maximize their impact,
- By proposing an electrification approach with high local job content and ambitious capacity building and training programs carried by the private sector with limited needs for public resources.

Radical rethinking of the current institutional and regulatory frameworks is however needed to ease the scale-up of this new electrification approach.

3.2.2 International Financial Institutions : Secure the funding

Given their considerable influence on the African electricity sector, the positioning of International Financial Institutions (World Bank, African Development Bank, Agence Française de Développement, EU, etc.) deserves to be examined.

These actors are in fact the first providers of funds in the power sector in the majority of African countries in the form of budgetary support, direct financing of investments or technical assistance to local public

and private actors. Their intervention strategies are marked by a multiplicity of objectives that are sometimes difficult to reconcile, notably between the short and the long-term challenges detailed in section 1.

After having largely funded the development of micro or mini-grids for decades with poor results in terms of energy access, many International Financial Institutions have supported since 2010 the deployment of individual solar solutions in African rural areas with poor results in terms of local development.

However, the overall trends are:

- A massive increase in official development assistance provided to the African energy sector,
- An increase in the share of aid allocated to the private sector and an emphasis focused on supporting public-private partnerships,
- A growing reflection on the evolution of the modalities of this aid in favor of a larger portion paid on the basis of achieved and verified results (Output-based Aid),
- A deep interest in new electrification approaches that could tackle both the energy access and the development challenge.

In this context, the Lateral Electrification approach appears aligned with their intervention strategies although knowledge dissemination and capitalization efforts specifically directed towards these actors are still needed to redirect a fair share of their funding for the scaling-up of the Lateral Electrification model.

4. Conclusions

The Lateral Electrification model proposed by Nanoé answers both greatest challenges the African continent is facing nowadays, energy-access and sustainable development, through the progressive building of electric infrastructures and the training of a myriad of local electric operators. Its experience in Madagascar is a success with the installation of more than 1500 nanogrids, one village-wide microgrid and the training of more than 100 nano-entrepreneurs, showing the high potential of this electrification model for Africa. The hardware and software innovations developed in collaboration with G2ELab as well as the marketing and organizational approaches proposed by Nanoé are field-tested and are ready to be deployed at a higher scale for the replicability of the Lateral Electrification model in Africa. Additional works and discussions must be performed however to convince the electricity-access actors and the donors to ease the dissemination of the model.

For Further Reading

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