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Emilie Etienne, Translated by Emilie Etienne, proofread by **Clare St Lawrence**

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Decentralized solar systems, that is to say systems not connected to the main electricity grid, have bourgeoned since the 1990s in the Global South. It is in Africa, the least electrified continent, that these infrastructures are increasing most rapidly, with solutions such as solar home systems (SHS) or solar mini-grids for rural populations (ESMAP, 2019).

A network of actors made up of major international institutions, such as the World Bank, the Green Climate Fund and cooperation programmes, is financing this sector. Rural, off-grid renewable electrification is perceived as technically relevant, in addition to offering environmental, social and economic benefits for populations previously deprived of electricity. In total, US$28 billion has been invested globally in mini-grids and the financing needs for future mini-grids are estimated at US$220 billion (ESMAP, 2019). Beyond financing, the commitment of these major players is reflected in the promotion of regulatory practices to organize the electricity access sector, for example through the creation of national rural electrification agencies from the late 1990s.

However, the sustainability of access to electricity through decentralized solar technologies is questionable. These solutions are technically designed to last at least ten years, or even twenty if the most fragile components are replaced. However, their effective lifespan rarely reaches ten years (André-Bataille, Livache, Ranzanici, 2020; Berthélemy, Maurel, 2021; Cross, Murray, 2018; Dávalos, Herrera, 2019; Feron, Cordero, 2018) (1). Compared to the profusion of projects and funding to electrify new rural consumers, the continuity of electricity access attracts few resources.

Senegal is representative of these tensions. A pioneer of solar technologies (Caille, Badji, 2018) and recipient of large international funding (Mawhood, Gross, 2014), Senegal has the largest number of mini-grids with a solar component in Africa, estimated at between 190 and 272 (ESMAP, 2019; Power Africa, 2019). These solar solutions are part of the national electrification policies through a "locally-initiated rural electrification" (ERIL by its initials in French (2)) programme set up in the 2000s. Despite this financial and political commitment for decentralized solar solutions, the future of the solar mini-grids is uncertain: half of those installed between 2006 and 2017 as part of the ERSEN (Rural Electrification in Senegal (3)) cooperation project have been shut down (Semis, 2020).

While international players and African governments focus on installing solar mini-grids, how can the relative lack of resources attracted for sustaining these grids be explained? In what ways do the actors address questions related to the reliability of this electrical service, from a practical, regulatory and political perspective? How does maintenance become an issue and redefine the interactions between actors?

This article reconstructs the interactions between the actors who benefit from, carry out, finance and supervise the reliability of electricity, focusing on the concept of accountability. Accountability, or the obligation to explain and justify conduct (Bovens, 2007), allows us to look more closely at the

interplay of actors through their responsibilities and interests, both as accountable parties and as recipients of accountability. The article is organized in two sections. The first part outlines the multiple and intersecting chains of accountability (Brisbois, 2020), in both the rural electrification sector in Senegal and the ERSEN project. The second part examines the maintenance of ERSEN project's infrastructure from the angle of accountability, with four lines of enquiry. Firstly, the information channels between actors are examined, and secondly the actors who carry out maintenance operations as accountable parties, subject to sanction and incentive mechanisms, are studied. Given the failure of these mechanisms, the focus is then shifted to State agencies as controlling agencies, and finally the analysis is deepened by considering State agencies also as accountable actors.

ERSEN mini-grids in Senegal: multiple and intertwined chains of responsibility for maintenance

Maintenance of off-grid solar solutions: from a perspective of autonomy to a multi-scalar vision of sustainability

Questions related to the sustainability of infrastructures have mushroomed in sociological research for the past twenty years. These maintenance and repair studies question the "myth of order" (Graham and Thrift, 2007) by showing the routine nature (Denis and Pontille, 2013) of maintenance operations. Infrastructures are intrinsically fragile and they only become visible when they fail (Star, 1999). These research studies focus on the maintenance practices, improvisation, adaptation and creativity of maintenance actors (De Coss-Corzo, 2021).

In the rural electrification sector, on the other hand, the sustainability of infrastructure is tackled in a context of economic tensions, technical characteristics, and local governance. Off-grid solutions are considered as autonomous systems from an economic, technical or social perspective.

The first field study on economic issues seeks to calculate the costs and benefits of off-grid electrification projects, mirroring payment capacities, infrastructure costs and the monetization of their impact (Kirubi *et alii*, 2009). Other analyses focus on the tensions between costly rural electricity and the demand of poor people with fluctuating incomes, who may not be able to generate new income as a result of electricity (Cholez and Trompette, 2019). There is little discussion of equalization between different localities, as sustainability is mostly considered at the scale of each isolated village.

Another field study focuses on technical issues, showing how infrastructure characteristics and sizing, along with consumer behaviour, affect the sustainability of electricity service (Numminen and Lund, 2019) and reparability (Spear *et alii*, 2020).

Finally, another strand of work extends the concept of sustainability by incorporating environmental, institutional and socio-cultural aspects. Ilskog (2008) pioneers multidimensional assessments of off-grid solutions by formulating numerous indicators to measure their sustainability. Other works go into more detail on institutional and socio-cultural aspects, stressing village governance (Gollwitzer *et alii*, 2018), the participation of users and the importance of training (Pipet and Zélem, 2019).

These different approaches indicate that, while all infrastructures are inherently fragile, off-grid solutions are unusual due to their being perceived as autonomous systems. Recent research broadens this specific, localized view by examining how decentralized infrastructures are embedded in a broader framework (Feron and Cordero, 2018). Through a multi-level approach, researchers underscore the importance of incorporating the sustainability of infrastructures into policies and planning (Akinyele *et alii*, 2018), information deficits (Dornan, 2011), chains of responsibility, and incentives (Derks and Romijn, 2019). Using an example of public service delegation in Fiji, Dornan (ibid.) highlights the contradictory demands made of people and institutions responsible for ensuring mundane maintenance and economic equilibrium, with incentives and sanctions poorly adapted to the constraints faced. Derks and Romijn (ibid.) take this analysis to a higher decision-making level by examining how Indonesian national authorities and funding agencies supervise the actors involved in the proper functioning of the facilities. They conclude that these supervisory bodies barely incorporate the reliability of the off-grid electricity service into their activities and planning, due to competing objectives and lack of grassroots pressure.

These approaches reveal the relevance of policy dimensions in understanding the reliability of the rural electric service. The justification of priorities or the need to account for them, along with the creation of public policies instruments to enforce accountability, enable us to understand maintenance issues from the viewpoint of actors, who feel caught in a web of responsibilities, sanctions, and incentives. Related to the concept of "accounting", accountability offers a rich framework for a multi-level

analysis of electricity reliability. We use the definition of "narrow accountability" from Bovens: "a relationship between an actor and a forum, in which the actor has an obligation to explain and to justify his or her conduct, the forum can pose questions and pass judgement, and the actor may face consequences" (2007, p. 447). This definition emphasizes the protagonists, of which there are at least two, and the binding nature of accountability. The "actor" is accountable to the "forum", which can be an individual, an institution or a profession, such as journalists. Each protagonist can be both an accountable actor and a forum, following a chain of accountability. Similarly, the "actor" and the "forum" can reverse their roles, justifying their conduct to the other. This is particularly the case for the relationship between funding agencies and aid-receiving States: the Paris Declaration on Aid establishes reciprocal commitments between funders and States, through "cross-accountability" (Raffinot, 2010). The chains of accountability between actors and forums are therefore multiple. This definition also specifies the elements of accountability (the conduct), the need for information flows (to explain, justify, ask questions), and also possible sanctions, expressed under the broader term of "consequences".

The fragmentation of the rural electrification sector in Senegal: decentralized mini-grids to accelerate electrification

Rural electrification in Senegal involves a multitude of actors and forums involved in accountability chains, as shown by the historical structuring of the sector.

Until the 1990s, rural electrification in Senegal was mainly a public prerogative, led by the National Electricity Company (Senelec). In the 1980s, Senegal, like other African countries, showed mixed results: electrification had made little progress and the country was in debt. International institutions, in particular the World Bank, imposed structural adjustment plans during the 1990s to attract private investment and reduce the scope of action of Senelec, which was blamed for electrification delays (Robert, 2016). Senelec lost its monopoly; Act No. 98-29 of 14 April 1998 delegated rural electrification to an institution created for this purpose, namely the Senegalese Rural Electrification Agency (ASER (4)), which was to provide financial and technical support to the private sector. ASER was also supposed to monitor mini-grid operations. In parallel, another body was created: the Electricity Regulation Commission (CRSE (5)), whose main responsibility was to seek economic equilibrium in the electricity sector. The CRSE establishes and verifies tariffs to protect both consumers and operators by ensuring "normal" profitability for the latter (CRSE, 2002). It provides mechanisms for user complaints about compliance with the agreed tariffs as well as the quality and quantity of electricity. These three institutions, Senelec, ASER and CRSE, remain under the supervision of the Ministry of Petroleum and Energy (MPE, also referred to as "the Ministry" in this article) (6). All these public institutions can be investigated by the Senegalese Court of Auditors.

The main rural electrification mechanism has divided the country into concessions awarded to alliances of Senegalese and foreign companies (EDF of France, and ONE-Maroc of Morocco, among others). A second component, the "local initiative for rural electrification" (ERIL), aims to accelerate the electrification of the country, in particular for villages outside the priority perimeters of concessions or villages managed by Senelec, thus fragmenting the territory (Jaglin and Guillou, 2021). Although the ERIL scheme seeks, as its name indicates, to promote electrification on the initiative of local actors, the sector is not yet attractive enough to generate spontaneous ventures. Instead, international funders feed the ERIL scheme through dedicated projects (Trompette, Etienne, Francius, forthcoming). One of these flagship projects, in terms of its scope and history, is called ERSEN. It is implemented by EnDev (Energising Development), a partnership between the Dutch and German governments (7).

Methodology

This article is part of a doctoral research study on the future of solar mini-grids in Africa. The fieldwork, which took place both in Senegal and remotely, involved 55 semi-structured interviews and four group interviews between June and October 2021 in Dakar and four villages electrified by mini-grids. This article is mainly based on the 28 interviews with institutional actors of different scales and types: funders and international organizations, national and local authorities, operators (both managers and field staff), non-governmental organizations (NGOs), and consultants. In addition, two interviews conducted in 2016 by P. Trompette and R. Francius, and, to a lesser extent, materials from participatory observations and 31 individual and group interviews with users and village managers, were utilized.

To understand the official objectives of each stakeholder and their judgments on mini-grids, two complementary sources of information were scrutinized: legal and official texts (electrification plan, Ministry presentations, project documents, laws and decisions), and national evaluation reports (Cour des Comptes du Sénégal, 2016; Semis, 2020). Other sources, such as the media, both traditional and social (Facebook pages of State electrification bodies), were analyzed to gauge the visibility of electricity reliability issues.

Looking back at the sustainability and implementation of the ERSEN mini-grids: social and multi-level engineering

The 96 hybrid solar-diesel mini-grids installed by the ERSEN project and evaluated by the Senegalese consultancy firm Semis (2020) account for a large proportion of those installed in Senegal. Commissioned between 2006 and 2017, their longevity provides the necessary hindsight to understand issues of maintenance and equipment replacement. The ERSEN project, which has been widely documented, is also linked to Senegalese institutional innovations, feeding the evolution of regulations. It was an experiment of the ERIL scheme and fits into the Senegalese institutional and legislative framework. ASER remains ERSEN's project manager. The international partnership Energizing Development, or EnDev, also disseminated ERSEN's insights beyond Senegalese borders, due to its predominant role in structuring off-grid electrification markets on the African continent. ERSEN is an example of a large-scale pilot project designed to test technical, financial, and institutional innovations.

ERSEN targets villages that meet three criteria: a modest size (less than 700 inhabitants) to avoid competition with the activities of concessionaires; a distance of at least 8 km from the electricity grid to ensure that decentralized solutions are economically competitive with grid extension; and the presence of a school and a health centre to maximize the social benefits of electricity. The main contractors are six Senegalese small and medium-sized enterprises (SMEs). Some of these SMEs have a strong link with Germany either because their managers were trained there (interviews with Salensol and Energie R managers, 2021 and 2016), or because there is a business association with a German company, as in the case of Enersa (Ulsrud *et alii*, 2018). These six operators, selected by tender, are responsible for the installation, operation, maintenance and renewal of the equipment for 15 years. The infrastructure remains the property of the State, which finances 70% through international funding. The remaining 20% and 10% are paid by the operators and users respectively, in the form of fees according to the tariffs set by the CRSE. These tariffs do not vary according to users' actual consumption but on the basis of their subscription package (8).

Figures 1 and 2. An ERSEN mini-grid, with its 24 solar panels, battery and inverter storage room (left) and diesel generator (right)

Source: É. Étienne, October 2021.

All the infrastructures in the ERSEN project are identical: the mini-grids consist of a 5 kilowatt-peak photovoltaic field and a 10-kilovolt-ampere generator. Mini-grids are presented as being able to provide a similar electricity service as that in large cities (PERACOD, 2011).

The ERSEN programme has relatively complex social engineering, with a "tripartite commitment between the rural community, the operator and ASER" (ibid.). This includes the creation of village sub-committees and monitoring committees, which were not very active during our field work. The scheme is intended to promote the "sustainability of equipment" and "private sector investment and operations" (ibid.). Relations between operators and ASER, between consumers and operators, are supposed to be framed by contracts. The term "social engineering", displayed in the project documents, resonates with the idea of planned intervention by experts to change or create institutions or behaviour, as defined by Olivier de Sardan (2021).

Within the village, one or two people are in charge of initial maintenance ("caretakers") or fee collection ("collectors"). All the caretakers and collectors met during the fieldwork were male. Chosen by the villagers for their links with the authorities or their skills, they are compensated by the operators in cash payments or free electricity, based on an oral or written agreement. The caretakers maintain the facilities: they clean the premises and equipment, and add distilled water to the lead batteries. To carry out these functions, they are trained and have pictorial instructions in the technical room (figure 4). When hazards exceed their skills, they are expected to call in the operator. In some villages, a collector gathers the monthly cash payments and hands them over to the operator. As well as

**Figures 3 and 4. Batteries in a mini-grid (left).
Some are no longer working and have been disconnected by the operator.
On the right, a poster in the room housing the inverters explains the responsibilities of mini-grid caretakers**

Source: É. Étienne, October 2021.

having a control role, these two "peasant managers" (Laurent, 2000), collectors and conductors, also play an interface role with users, receiving their complaints. They monitor activities that may degrade the electricity service, such as illegal connections, the removal of power limiters (9) and the connection of unauthorized equipment. Such misuse is usually resolved through dialogue and, more rarely, by the operator cutting off the electricity supply.

The table below summarizes the formal responsibilities of the main actors involved in the mini-grids, the incentives for fulfilling their responsibilities and the sanctions for non-compliance.

The project engineering thus presents multiple chains of accountability between stakeholders, who act as accountable actors and/or accountability forums depending on the circumstances. At the local level, users have to pay their bills and follow instructions on usage. In return, the operators must guarantee them a certain quality of service by maintaining the equipment. There is therefore a cross-accountability relationship. Caretakers act as an interface between users and operators to circulate information and as subcontractors to operators for collection or infrastructure maintenance tasks. They are accountable to both users and operators. The operators, and to a lesser extent the caretakers, are therefore directly responsible for both the maintenance and, ultimately, the reliability of the electricity.

At the national level, operators must justify their performance to ASER through the EnDev partnership, while ASER itself needs to meet rural electrification targets. ASER reports to its donors and the Ministry of Petroleum and Energy. As public institutions, ASER, CRSE and the Ministry can be audited by the Court of Auditors. ASER and EnDev, while also accountable to other institutions, and to citizens in the case of ASER, have a primary role as an accountability forum for operators.

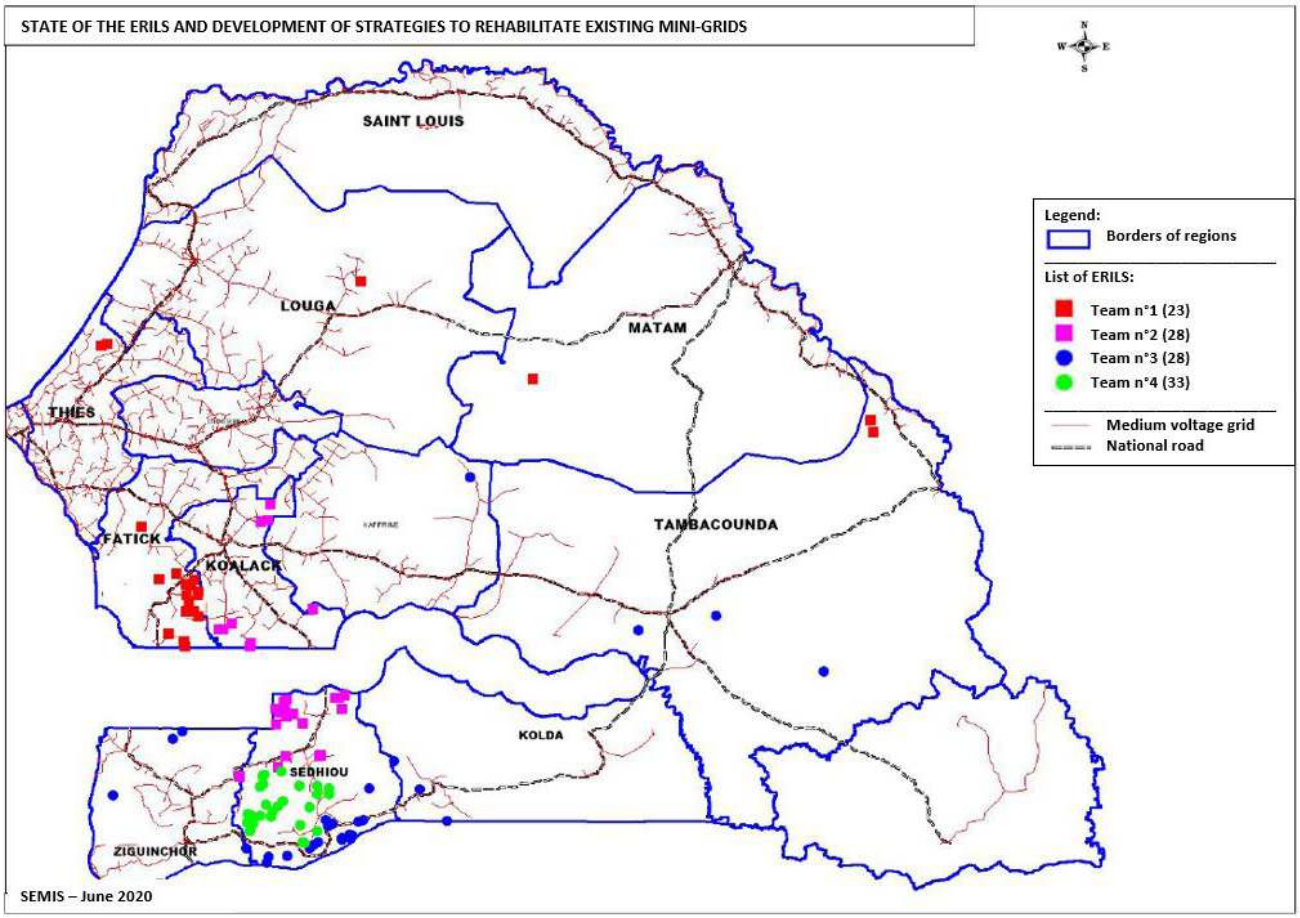
In July 2020, a report commissioned by the German cooperation agency drew up an assessment of the ERSEN project with mediocre results. Of the 96 ERSEN mini-grids studied, 52% were at a standstill (Semis, 2020). In the mini-grids still in

Figure 5. Summary of the theoretical responsibilities, incentives and sanctions of the network of actors involved in the use, management and supervision of mini-grids. Sources: Information compiled by the author from interviews, ERSEN documents, grey literature and the user-operator contract of one of the villagers interviewed (marked with an asterisk)

	Users	*Mini-grid village managers*	*Operator ERIL*	*State agencies: ASER and CRSE*	*Cooperation partnership: EnDev*
Formal responsibilities	Pay for electricity service Respect technical instructions	Caretaker: maintains the mini-grid, calls the operator in case of problems Collector: covers the monthly fees	Guarantees at least 6h/day of electricity Repairs the systems within 3 days* Replaces faulty components	ASER: supervises the operation of mini-grids CRSE: controls the tariffs	Finances the initial infrastructures Supervises the operation of mini-grids on behalf of ASER
Theoretical incentives	Quality of electricity	Between 6,000 and 10,000 CFA francs monthly (9€ – 15€) in cash or in kind	Profits through user payments	Political legitimacy? Credibility to receive external funding?	Developing market approaches for rural electrification
Theoretical sanctions	Fines: 500 CFA francs* (€0.8) per month in arrears Disconnection after 6 months of non-payment*	Withdrawal of monthly compensation Replacement by another person	Fine by the CRSE (amount unspecified) *	Sanctions by vote National audits by the Court of Auditors	Losing credibility

Source: É. Étienne

Figure 6. Map of planned mini-grid locations for the status report, June 2020



Source: Semis, 2020.

operation, the rate of operation is on average three hours per day, with wide disparities (between 1 and 24 hours per day), far from the six hours planned by the project. These figures are relatively homogeneous between the six operators despite their different geographical locations, varying between 38% and 60% of mini-grids still operational. As shown on the map below, the mini-grids are concentrated in the groundnut basin (Kaolack) and the middle Casamance (Sedhiou).

Electricity reliability, an issue with little accountability

This detour through the stakeholders of the ERSEN mini-grids has traced the chains of accountability between actors and forums, highlighting their theoretical cross-responsibilities, sanctions and incentives. The mixed results of mini-grids in terms of electricity reliability were then discussed, raising four questions:

- How do accountability forums obtain information about electricity service reliability?
- What are the theoretical consequences for the actors responsible for ensuring service reliability in case of failures?
- How is electricity reliability constructed as an issue by the accountability forums ASER and the Ministry?
- How are these actors accountable themselves for the continuity of electricity?

These questions will be answered in the following four sub-sections.

Electricity reliability monitoring systems: multiple information channels

The supervision of existing mini-grids is normally the responsibility of ASER but, in the case of the ERSEN project, the EnDev partnership fulfils this role as it is seen as a transitional situation before the transfer to ASER (interview with EnDev advisors, 2021). EnDev monitors the project at two levels: the villagers and their productive activities on one hand, and the infrastructure (batteries, inverters, etc.) on the other, for which a software package is being developed. At present, the operators fill Excel spreadsheets with this information but this method is considered tedious with many tos-and-fros between the operators and EnDev (ibid). The veracity of information is also highlighted as a risk:

> "If ASER tries to find out, it has to go through the concessionaires or the operators who don't really have an incentive to give any information" (interview with Funder 1, 2021).

This current bottom-up mechanism conveying information from the operators to EnDev and ASER is therefore imperfect. To remedy this, there are also top-down mechanisms. This top-down monitoring takes two forms: field visits and major reports. In both cases, these are rather unsystematic actions due to the multiplicity of localities and difficulties reaching them during the rainy season. Two studies, in 2020 and 2021, were carried out to draw up a complete overview of the mini-grids, with the help of international funding and temporary staff (interns, consultants).

Alongside these predefined information mechanisms, both bottom-up and top-down, there are unofficial mechanisms. When users and caretakers are not satisfied with the operator, they directly contact state agencies (mainly ASER and the Ministry) or EnDev. This flow of information takes the form of phone calls and messages and, to a lesser extent, official letters:

> "[users] send us letters, sometimes it's SMS, sometimes it's pictures they send us. (...) Today, I had more than eight calls from the same area, because it is a village with a generator, the generator is broken. Since this morning, they have been calling us" (interview with ASER project leader, 2021).

These calls are made on an ad-hoc basis, in an individualized manner according to the problem. Contrary to Bovens" (2007) definition of accountability, which considers that accountability is only carried out ex-post, a different temporality can be observed here. Information flows are also continuous and spontaneous—a modality already described by Dumez (2008). However, the first point of entry for complaints remains the operators. In the event of breakdowns, users turn to the village managers. When the difficulties go beyond their knowledge, village managers contact the operator, usually by telephone.

Figure 7 summarizes the multiplicity of information flows by differentiating between planned channels (green) and ad-hoc information channels (dotted green) that bypass operators.

The "obligation to explain and justify one's conduct" expressed by Bovens in his definition of accountability thus involves different informational mechanisms, top-down and bottom-up, institutionalized and informal, regular and spontaneous, constituting a real "test of knowledge" (Florentin and Denis, 2020). Although none of these mechanisms alone provides exhaustive, reliable and regular information, the combination of all of them ensures that the accountability forums and maintenance actors have a good overview of the status of the mini-grids. The delays in resolving certain outages therefore do not seem to derive from a lack of information. The research therefore turned its attention to the consequences of failures in the electrical service for the actors directly responsible for maintenance, i.e., village managers and operators.

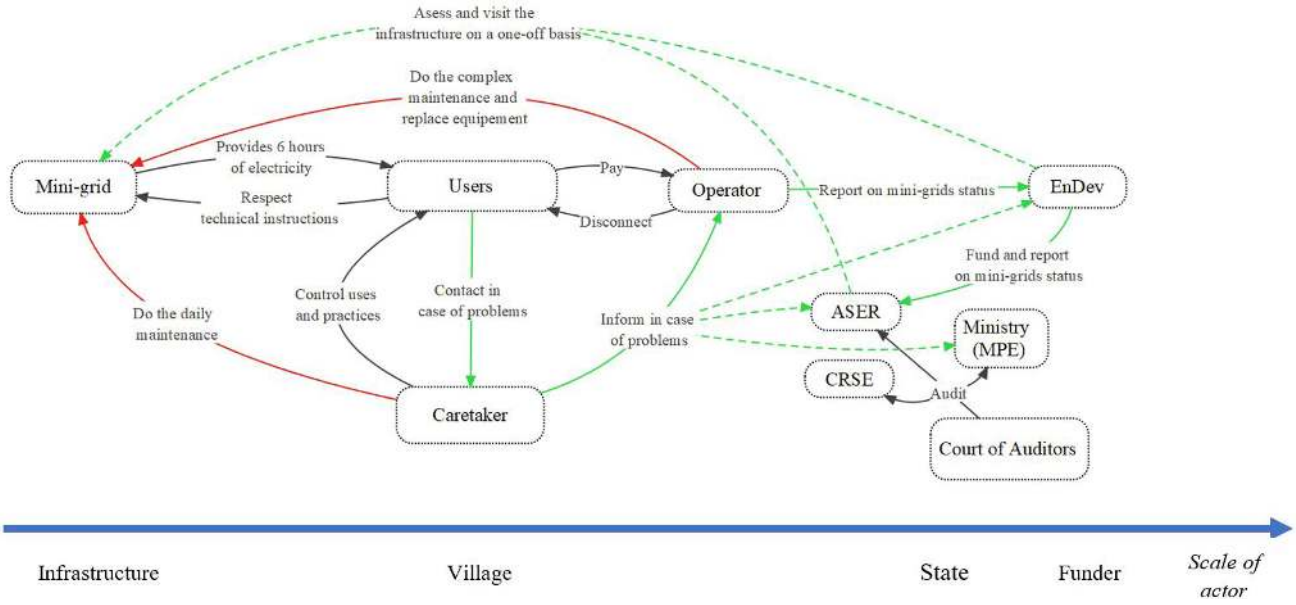
Insufficient penalties and incentives for comprehensive maintenance of mini-grids

To ensure the reliability of electricity, sanctions and incentives are provided for caretakers and operators. While the notion of "consequences" described by Bovens refers to punitive measures such as "fines, disciplinary measures, civil remedies or even criminal sanctions" (Bovens, 2007, p. 452), it is extended here to include positive consequences in terms of market incentives.

The compensation received by the mini-grid's village managers depends on the proper functioning of the installations; if the electricity service is interrupted, the users no longer pay the bills and the conductors and collectors are no longer paid or benefit from free electricity. They may also be replaced by another villager, as happened in one of the villages studied. Moreover, the village managers" concern for the reliability of the electricity service goes beyond financial benefits; managers of the four surveyed villages emphasize a strong feeling of responsibility towards their community.

As far as the operators are concerned, pursuant to the contract with the users of one of the villages studied, the electricity service must be restored within 72 hours. According to the

Figure 7. Simplified accountability chain diagram illustrating the key responsibilities of actors (red for those related to maintenance, black for others) and the information flows related to electric service reliability (green). The green dotted links indicate ad-hoc information mechanisms



Source: Compiled by the author from interviews and project documents.

project design, market mechanisms would encourage operators to guarantee the continuity of electricity since their revenues depend on this. In practice, the operating costs (such as travel and fuel purchase) and the costs of the equipment (batteries and inverters in particular) are very high, while the revenue is low. This observation was shared by the operators, ASER and the Court of Auditors (Cour des Comptes du Sénégal, 2016).

CRSE sanctions could be applied to operators for this breach of the user contract. However, the implementation of sanctions comes up against two obstacles: the absence of a contract signed between the operators and the Ministry, on the one hand, and the economic fragility of the operators on the other.

In terms of operator-Ministry concession contracts, only one of the six operators, Enersa, has such a document signed. These contracts should specify, among other things, the tariff for electricity. The tariff is calculated by the CRSE according to the investments made by the operators and their costs, in order to ensure a "normal" profit of around 12% (interview with two CRSE economic experts, 2021). Enersa signed its contract in 2014 after four years of exchanges with the CRSE to agree on an adequate tariff for both the operator and the users (Ulsrud *et alii*, 2018). For the other operators, the calculation of the rate of return was further complicated by the combination of funding sources, between subsidies and equity (interview with ASER project leader, 2021). In addition, from 2015 onwards, discussions on the future harmonization of electricity tariffs across the country discouraged the CRSE from approving contracts that would soon become obsolete. According to Ulsrud and her colleagues (2018), the CRSE was also reluctant to decide on such a sensitive issue as tariffs. Tariff harmonization was finally agreed in 2018 and contracts were expected to be signed in the near future (interview with ASER project leader, 2021). The absence of a contract limits the range of sanctions that the State could impose on operators, although the withdrawal of their operating licence and transitional "partnership agreements" remains possible. The absence of contracts also hampers operators' ability to obtain bank loans to finance equipment renewal (interview with Operator 3, 2021).

The other reason given by State agencies and funders for the absence of sanctions is the economic fragility of the operators, due partly to their SME nature and partly to the regulatory framework. The ERIL scheme was initially designed for relatively small villages (200 customers maximum), limiting revenues and economies of scale for the operators (interview with Funder 1 and ASER project manager, 2021). In addition, the ERSEN mini-grids have the same power in all villages regardless of population size. They are often undersized in relation to demand (interviews with managers of Operators 1 and 2, 2021), which accelerates their decay (Trompette, Etienne, Francius, forthcoming). An ASER project manager summarized the situation as follows:

> "[Operators] have bicycles to carry troops" (interview, 2021).

The new Electricity Code of 2021 removes this subscriber and power limit for mini-grids, recognizing the inadequacy of the legal framework for their financial viability. For existing mini-grids, most of the operators interviewed and some national institutions hope that EnDev or other foreign partners will replace damaged equipment. This expectation is reinforced by the recent evaluation carried out by funders, which highlighted the need for infrastructure rehabilitation. The market is therefore "on life support" (Guillou, 2022).

Beyond the view of operators' fragility, the fact that they are Senegalese raises hopes for their potential contribution to economic development and employment, which also explains ASER's reluctance to penalize them:

> "It is our job, the job of NGOs or others, to strengthen these companies, especially as they are Senegalese companies. If they are strong companies, they will employ many more people, so the unemployment rate will decrease" (interview with ASER Director, 2021)

While village managers prioritize electricity reliability because of monetary incentives and a sense of responsibility towards other villagers, the "consequences" of poor maintenance are mixed for operators. On the one hand, equipment replacement is not a cost-effective investment in all villages and, on the other, CRSE sanctions against operators cannot be legally enforced. Furthermore, State agencies are reluctant to sanction actors that are perceived as both fragile and strategic. The line of research therefore turned to the State agencies to understand their objectives and priorities.

The electrification rate: a priority for State agencies at the expense of electricity service reliability

"Ensure access to affordable, reliable, sustainable and modern energy for all" is the promise of the seventh sustainable development goal of the United Nations. In Senegal, Act No. 2021-31 of 9 July 2021 regarding the Electricity Code echoes this objective almost word for word, referring to "access for all to reliable, modern, sustainable energy services at the lowest cost". Maintenance is related with the reliability aspect.

The government and international funders are acting for the reliability of the mini-grid electricity service: the 2020 study costed rehabilitation options (Semis, 2020), and the government "sub-committee enabling the environment for off-grid rural electrification", chaired by the German cooperation and supported by the Senegalese Permanent Secretariat for Energy, put the overhaul of existing mini-grids on the political agenda.

However, "access for all" prevails over "reliability" in official documents such as the "Plan Sénégal Émergent" development plan and the recent Electricity Code, along with political speeches. For example, a webpage with the evocative title "Universal Access" (10) was created for a round table discussion organized for funders by the Ministry in April 2021. The financing need for new solar mini-grids was estimated at 105 billion CFA francs (160 million euros) (Ministry of Petroleum and Energy, 2020). The rehabilitation of existing mini-grids, on the other hand, was not included in the investor prospectus distributed at the round table meeting, despite a relatively low estimate of up to 22 billion CFA francs (33 million euros) (Semis, 2020). "Universal access" remains the ultimate priority of Senegalese State agencies, the gold standard for success:

> "… we have a plan for electrification by 2025, because the State's objective is to achieve universal service accessibility" (interview with Ministry technician, 2021).

Observing a similar situation in Indonesia, Derks and Romjin (2019) attribute the State's prioritizing of new connections to the detriment of the sustainability of existing ones to its search for political legitimacy, as the State is under strong pressure to show easily quantifiable results. In Senegal, the discrepancy between the indicator of the electrification rate and that of the reliability of the electricity service is also reflected in government statistics. The electrification rate is not updated according to actual access to electricity (interview with representative of the Ministry's Energy Information Service, 2021),

despite criticism from the Court of Auditors during the ASER audit in 2016 (Cour des Comptes du Sénégal, 2016, p. 149).

"Universal access" appears to be a "cogent indicator" according to Boussard's definition (2001). It is a predominant reference for ASER and the Ministry, and permeates these State organizations even though it is "only relative to a specific activity". The concept of "universal access" relegates energy reliability and affordability to the background, even though these values are present in the Electricity Code. These notions are "inert indicators" because they have failed to interest and enrol actors, even though they are part of the official objectives. They mobilize fewer resources, whether symbolic, financial or media-related, leading to a gap or "decoupling" between official objectives and the means to achieve them (Bromley and Powell, 2012). The absence of sanctions against maintenance operators is therefore not explained only by legal limitations or solidarity with actors perceived as fragile; State accountability forums also choose not to make operators accountable because electricity continuity is less of a priority than universal access. This situation is referred to as "forum drift" by Schillemans and Busuioc (2015).

Continuing the chain of accountability, this study now turns to examine State agencies, not only as accountability forums for operators, but also as actors responsible for the reliability of electricity. This responsibility is to funders on the one hand and Senegalese citizens on the other.

State agencies face minor consequences in the event of the discontinuity of rural electricity

Firstly, off-grid rural electrification is largely funded by international agencies, who can withdraw from it. Nonetheless, as security in West Africa deteriorates, Senegal appears as an island of stability for funders, as evidenced by recent projects (such as the electrification of 1000 villages by the Green Climate Fund, and the Gauff project for 300 mini-grids financed by a subsidiary of the German development bank KfW, among others). One of the funders interviewed, however, mentioned moving away from rural electrification in favour of the grid extension carried out by Senelec. This interviewee considers the management of ASER to be too opaque and inefficient, stressing ASER's delays in releasing funds and carrying out audits, in contrast to Senelec, which is described as more competent (interview with Funder 2, 2021).

Beyond this particular case, the uncertain reliability of off-grid electricity has not seemed to slow down private investment, either in Senegal or in other sub-Saharan African countries. Historically, most international funders have been promoting the liberalization of the electricity sector on the African continent at the expense of public rural electrification since the late 1990s. Many funders are now seeking to prove the viability of a private model (Bhamidipati, Elmer Hansen, Haseli, 2019; Bintou Faye, forthcoming). EnDev, for example, states on its website that "access to energy requires profitable business models. (...) EnDev fights energy poverty with a market approach" (11). The abundance of investor guides produced by the African Development Bank and the UN-backed Sustainable Energy for All (SEforAll) (12), along with the toolkit for "unlocking private sector barriers (13)" from the US-led Power Africa programme, are just a few illustrations of funders' efforts to promote private investment.

In this context, it is not surprising that the 2020 evaluation of the mini-grids of ERSEN, whose steering committee was composed of several funders, attributes sustainability problems to institutional causes and operators rather than the intrinsic cost-benefit tensions of the sector. On the contrary, the Senegalese Court of Auditors points to the lack of financial sustainability of this model: "The high cost of equipment and its renewal costs are serious obstacles to the sustainability of the system" (Cour des Comptes du Sénégal, 2016, p. 145).

Just as the reliability of electricity is not a "cogent indicator" for ASER and the Senegalese Energy Ministry, neither is it for funders. The reliability of rural electricity is relegated to the background by funders, in favour of promoting a market model.

Another type of "consequence" for the Senegalese State could arise via social movements and voting, on account of political accountability (Bovens, 2007). Indeed, the reliability of electricity was one of the major demands during the 2010-2011 anti-cost-of-living riots (Havard, 2018). However, these grievances mainly concerned the urban sector; despite outages in rural areas, there were no large-scale demonstrations demanding better service. ASER's public appeals on social networks, as well as petitions to the consumer association Fojcosen frequently linked to CRSE (interview with Fojcosen Director, 2021), focus more on the electrification of new localities and less on the reliability of electricity. Service interruptions in many rural settlements do not lead to major political pressures. It is possible that the factors that make it difficult to sustain mini-grids, such as the small size of villages and their relative geographical remoteness, inhibit collective demands from several villages. In addition, the difficulties of accessing traditional and

online media due to the lack of electricity hinder contact with other Senegalese villages with similar problems. Finally, in villages in the vicinity of the Senelec grid, the population hope to be connected to the national grid rather than having a working mini-grid. Mini-grids are in practice considered a second-best solution, due to their relatively high tariffs, power limitations and the technical problems experienced (Trompette, Etienne, Francius, forthcoming). Some villagers think that the presence of a mini-grid, albeit dysfunctional, hinders connection to the national grid; they fear that the village will be considered already electrified by the planning authorities.

Conclusion

The rural electrification sector in Senegal has been structured in a fragmented way with grid electrification, concessions and small private operators under the ERIL scheme. The latter have focused on solar infrastructure, co-financed by the State and international funders through specific projects such as ERSEN. With complex social engineering, ERSEN involves users, operators, ASER, CRSE and intermediary actors, such as mini-grid operators and the EnDev partnership. These actors participate in one way or another in the reliability of electricity through complex and intersecting accountability chains, as accountable actors and accountability forums.

Within these accountability chains, information deficiencies are not sufficient to explain the patchy maintenance of solar mini-grids. In practice, the actors in charge of maintenance or supervision have a relatively exhaustive vision of the interruptions of the electrical service through bottom-up and top-down, institutionalized and informal, regular and spontaneous information flows. However, operators face weak consequences in cases of service interruption, which contributes to relegating maintenance to the background of their activities. Income loss is limited and sanctions are not applied by the CRSE, due as much to the legal impossibility as to the recognition of the systemic difficulties encountered by the operators. Accountability forums constituted by State and cooperation agencies choose not to play this role, in a phenomenon of "forum drift". This phenomenon can also be understood as solidarity with the operators, reinforced by the co-production of the electricity service by the State and the operators (Guillou, 2022). Beyond this solidarity towards operators, the comparison between "cogent" and "inert" indicators shows that the reliability of the rural electricity service remains shadowed—by the agenda of access to energy in the case of State authorities, and by the promotion of a market model in the case of funders.

The reliability of decentralized rural electricity has therefore not been shaped as a priority accountability issue; it is not a "salient issue" at the national level (Bonardi and Keim, 2005). Bonardi and Keim define three stages for a problem to be taken up by public authorities. First, a consensus among experts is required; then there should be pressure from the media, and finally the influence of public opinion. Senegal seems to have reached a consensus among experts on the importance of maintenance, with frequent reports on the status of mini-grids and the inclusion of the problem in State working committees. However, pressure from the media and public opinion is in its infancy. The emergence of social movements in villages electrified by mini-grids faces various challenges, whether logistical, informational or strategic. Mini-grids are perceived as a second-best solution compared with the expansion of the national grid. In the media, the reliability of rural electricity, a daily concern far from the centres of power, is less spectacular than the inauguration of new mini-grids or the power cuts affecting urban areas.

The fragmentation of the territory by electrification policies, which has divided the country into urban areas with abundant and affordable electricity, and rural areas with limited and expensive electricity (Guillou, 2022; Robert, 2016), is also reflected in the importance attached to electricity reliability in these areas.

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Emilie Etienne is a doctoral student in Sociology and Economics at the PACTE and GAEL laboratories of Grenoble-Alpes University. Her thesis, carried out with Schneider Electric, focuses on the socio-economic future of solar mini-grids for rural electrification in the Global South. Her research focuses on issues of governance, economic autonomy, and maintenance. She previously worked for ten years in non-governmental organizations on frugal innovations in the fields of energy, water and sanitation, and disaster risk management.
emilie.etienne@umrpacte.fr

Notes

(1) The figures collected, although disparate, question the sustainability of access to electricity: 34% of off-grid systems are reported as out of order in Peru by Feron and Cordero. Almost 20% of solar products have stopped working after 18 months in Kenya according to Murray and Cross, while 90% of systems malfunction after ten years in Bolivia according to Dávalos and Herrera. Based on a sample of 50 mini-grids worldwide, Berthélemy and Maurel estimate that 50% of them have failed. Disconnection rates affecting half the users have also been reported in some Malagasy mini-grids (André-Bataille, Livache, Ranzanici, 2020; Cholez and Trompette, 2019).

(2) ERIL stands for "Électrification Rurale d'Initiative Locale" in French.

(3) ERSEN stands for "Electrification Rurale au Sénégal" (Rural Electrification of Senegal).

(4) ASER stands for "Agence Sénégalaise d'Électrification Rurale" or Senegalese Agency of Rural Electrification.

(5) CRSE stands for "Commission de Régulation du Secteur de l'Électricité" or Regulating Commission for the Electricity Sector.

(6) Other institutions such as the National Agency for Renewable Energies (ANER for their initials in French) and the Agency for Energy Control and Efficiency (AEME in French) are responsible for specific rural electrification projects such as income generating activities and solar street lighting.

(7) ERSEN is part of the Senegalese-German cooperation Programme for the Promotion of Renewable Energy, Rural Electrification and Sustainable Domestic Fuel Supply (PERACOD), which will be replaced in 2017 by the Energy Development Programme (PED). EnDev is one of the world's largest cooperation partnerships to promote access to sustainable energy in the Global South. On its website, the programme claims to have reached almost 23 million people between 2005 and 2019, in more than 20 countries (https://endev.info/about-endev/).

(8) There are four levels of packages, ranging from CFA francs 3,500 (€5) to CFA francs 15,000 (€23) per month. These amounts vary slightly from village to village. In addition, three ERSEN mini-grids were recently equipped with prepayment meters to test this modality, which consists of purchasing electricity credit according to expected consumption.

(9) Power limiters are technical devices that cap the electrical power available to the user. In mini-grids, where the amount of electricity is limited by the size of the infrastructure, the limiters must prevent the overconsumption of electricity by some users to the detriment of others.

(10) See: https://accesuniversel.sn/

(11) See https://endev.info/about-endev/, reviewed on 10/11/2021.

(12) Both institutions have published country guides entitled "Mini-grid market opportunity assessment".

(13) https://www.usaid.gov/powerafrica/toolbox, reviewed on 15/03/2022.

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Abstract – Émilie Étienne – Reliability and accountability of off-grid solar electricity in Senegal

Solar mini-grids for rural electrification are burgeoning in Africa, supported by major international players, cooperation programmes and African States. Despite significant financial and technical commitments, the continuity of electricity through decentralized solar solutions is uncertain: designed to work for at least ten years, the actual lifespan of these infrastructures in the Global South is often much shorter. The reliability of off-grid rural electricity seems to have been relegated to a second-order issue.

The concept of accountability, i.e., the obligation to explain and justify conduct (Bovens, 2007), offers an analytical framework for understanding the interactions of actors related to maintenance, by questioning their responsibilities, information flows, sanctions and incentives. Based on the study of a large public-private solar mini-grid project in Senegal, this article analyses the construction of electricity reliability as a political issue by following multiple and intersecting accountability chains between actors at different levels.

The article shows that, paradoxically, both electricity companies and institutional actors have a relatively comprehensive overview of the problems of mini-grid reliability, based on various information channels regarding the state of infrastructures. Two levels of interpretation explain the weak construction of electricity reliability as an object of accountability. On the one hand, the regulation exercised by the State vis-à-vis electricity companies is limited, with the intention of not making them accountable. This supportive approach recognizes that companies are working in complex legal and economic frameworks. On the other hand, competing objectives attached to "cogent indicators", access to energy and the promotion of a market model, relegate the issue of service reliability to the bottom of the political agenda.

Keywords: solar mini-grids, accountability, maintenance, sustainability, Senegal

Résumé – Émilie Étienne – Fiabilité et accountability de l'électricité solaire hors-réseau au Sénégal

Les mini-réseaux solaires pour l'électrification rurale se multiplient en Afrique, portés par de grands acteurs internationaux, des programmes de coopération et les États africains. En dépit d'engagements financiers et techniques importants, la pérennité de l'électricité au moyen de solutions solaires décentralisées se révèle mitigée : conçues pour fonctionner au moins une dizaine d'années, la durée de vie effective de ces infrastructures dans les pays du Sud global est souvent beaucoup plus courte. La fiabilité de l'électricité rurale hors-réseau semble se construire comme un enjeu de second ordre.

Le concept d'accountability, c'est-à-dire l'obligation d'expliquer et de justifier une conduite (Bovens, 2007), offre un cadre d'analyse pour appréhender les jeux d'acteurs autour de la maintenance, en questionnant les responsabilités, les flux d'informations ainsi que les sanctions et incitations auxquels ils sont soumis. À partir de l'étude d'un grand projet public-privé de mini-réseaux solaires au Sénégal, cet article se penche sur la construction de la fiabilité d'électricité comme enjeu politique, en suivant les chaînes d'accountability multiples et croisées entre les acteurs de différents niveaux.

L'article montre que, paradoxalement, tant les acteurs institutionnels que ceux de terrain détiennent une vision relativement complète des problèmes de fiabilité des réseaux, à partir de canaux d'information divers relatifs à l'état des infrastructures. Deux niveaux d'interprétation expliquent la faible construction de la fiabilité de l'électricité comme objet d'accountability. D'une part, la régulation exercée par l'État vis-à-vis des opérateurs est limitée, avec l'intention de ne pas les rendre redevables. Cette démarche solidaire reconnaît les difficultés des opérateurs à évoluer dans un cadre légal et économique complexe. Par ailleurs, des objectifs concurrents attachés à des « indicateurs prégnants », l'accès à l'énergie et la promotion d'un modèle de marché relèguent au second plan l'enjeu de fiabilité du service.

Mots-clés : mini-réseaux solaires, accountability, maintenance, pérennité, Sénégal