MEASURING THE IMPACT OF DECENTRALIZED ELECTRICITY PROJECTS:
a triangulation approach

Jean-Claude Berthelemy
Emeritus professor at University Paris 1, senior fellow at FERDI

Jean-Claude Berthelemy is emeritus professor at the University Paris 1, Panthéon-Sorbonne. A specialist in development economics, he helped set up the interdisciplinary journal Field Action Science Reports as editor-in-chief of its economics section, and is associate editor of the Journal of African Economies, Savings and Development and of the Revue d'Economie du Développement. He was previously director of research at the OECD's Development Center as well as director of France's Center for Prospective Studies and International Information (CEPII). He leads the FERDI research program on access to electricity.

My thanks to Mathilde Maurel for her comments. This contribution was prepared as part of FERDI's sustainability program and as such it benefited from support from the French government, delivered via the Future Investments program of the national research agency (ANR) under reference ANR-10-LABX-14-01. Further information about CoSMMA can be obtained from the following address:

https://ferdi.fr/en/programs/access-to-electricity

FERDI has created a unique initiative to evaluate the impacts and identify best practices in projects for access to essential services, using decentralized electrification projects as its basis. Large amounts of evaluation data covering such projects have been collected into a database called CoSMMA (Collaborative Smart Mapping of Mini-Grid Action). The evaluations available are of variable scientific quality, with most being of low quality. An innovative approach is suggested to overcome this drawback, based on the triangulation principle, which makes it possible to evaluate the success of a project with an acceptable level of accuracy. It is then possible to construct a meta-analysis to identify factors for success.

There are two primary lessons to be drawn from the data available in CoSMMA. The first is that projects seeking to increase the uptake of very low-power equipment have little chance of lasting success. Success for projects of this type will involve construction of mini-grids, not individual solutions, and therefore require collective action at the local level. The second lesson, informed by this first observation, concerns the importance accorded to questions of governance. Bottom-up governance models are more likely to succeed than top-down approaches. Lastly, good quality regulation of the sector increases the probability that the project will succeed. However, this conclusion also serves to highlight the lack of available data on the local governance structures overseeing these projects.

INTRODUCTION

Electricity is an essential service, but access to it is very limited in many rural areas, particularly in sub-Saharan Africa. Power grids cannot be extended because of the costs involved, but decentralized electrification solutions are now possible. Considerable experience in this field has been acquired in recent years, driven in large part by the falling cost of manufacturing photovoltaic panels. But scaling-up remains difficult in the absence of identified best practices capable of being widely applied.

Most rural electrification initiatives encourage people to adopt individual solutions (SHS, Solar Home Systems), as these are by far the easiest and fastest to roll out. SHS uptake has unquestionably been a vector for progress, but SHS has their limitations. These are low-power installations, generally less than 1 kW, and this limits the ability of projects to kick-start sufficient socioeconomic uplift to ensure their sustainability. But work to evaluate decentralized electrification projects has also tended to focus on SHS, making it harder to highlight the superiority of other solutions with certainty. In particular, micro- and mini-grids that rely on collective management of generators of a capacity greater than available with SHS have been relatively little evaluated. Similarly, the focus on SHS has largely prevented examination of the types of governance specific to the collective action models encountered in mini-grid projects, as apply to all projects setting out to produce public services at a local level.

Analyzing these projects serves a twofold purpose. Above all, it leverages the available data to identify the success or failure of decentralized electrification projects; success being defined by the observation of proven socioeconomic uplift in localities where such projects have been installed. Next comes the idea of using the data to pinpoint best practices, by which we mean factors liable to increase the probability that such projects will succeed. These analyses center on the construction of a unique database, CoSMMA. Data available in CoSMMA is of extremely variable quality in terms of standard scientific criteria, with little data of good quality. We have developed an innovative approach to overcome this drawback. By combining good quality data with low quality data we have access to sufficient information to attempt to identify best practices.

COSMMA, A COLLABORATIVE DATABASE FOR MEASURING THE IMPACTS OF DECENTRALIZED ELECTRIFICATION

Mindful of the tremendous diversity of decentralized electrification projects, be it in terms of geographical context, technical characteristics, governance or the method used to evaluate projects, identifying best practices in this field is a complex task. It is only possible to draw lessons from these evaluations by systematically collating evaluations in a manner that codifies the information they contain within a harmonized framework that renders the information comparable.

This was the thinking behind the construction of CoSMMA. The database houses large quantities of information on decentralized electrification projects completed since 1980 in countries in development and transition. The data come from project evaluation documents published, for the most part, in scientific reviews. The data have all been checked and added to through a process of dialogue with authors. The database is not exhaustive, but representativity is ensured via systematic searches of referenced publication databases (Academic Search Premier, Business Source Complete, Econlit, GreenFILE). The first characteristic identified by the database is that the large majority of evaluations submitted rely on descriptive statistics or expert statements rather than on rigorous statistical tests. We need to treat what we term non-scientific evaluations with caution as they are not comparable with evaluations based on statistical tests, which we term scientific.

CoSMMA contains 403 evaluated projects. Any one project may have been evaluated from multiple angles, notably as regards topics that relate to the various Sustainable Development Goals. The most frequently reported effects correspond to SDG 7 on access to modern energy sources, but many evaluations consider effects linked to other SDGs, particularly the eradication of poverty (SDG 1), health (SDG 3), education (SDG 4), gender equality (SDG 5) and economic transformation (SDG 8). Certain effects tested also correspond to social and environmental improvements: community (SDG 11), environment (SDG 13) and security (SDG 16). Lastly, some of the observed effects do not particularly relate to the SGDs but can nonetheless be noteworthy, such as effects on allocation of time or access to information and communications. The database catalogs a total of 2,712 effects observed.

Owing to the widely dissimilar nature of effects examined by assessors, we consider all effects relevant in terms of providing information on the success or failure of a project. With our approach, a project is considered potentially successful if, and only if, it has led to significant economic, social or environmental uplift within the implementation area.

An effect is considered significant at the 5% threshold, where there is less than a 5% risk of mistakenly concluding this effect exists where it does not. These are what we term false positives, although this expression is potentially misleading in the context of our work because a false positive can also mean we are mistaken in concluding that a project effect is favorable or unfavorable. To evaluate a project we seek to identify whether it has had a favorable effect, and we translate the results obtained by constructing a 95% confidence interval for the true value of the effect. We do this by assuming that the usual estimators are bias-free and distribution is symmetrical, so that in the case of a significant effect on the 5% threshold there is only a 2.5% risk that an effect judged positive is in fact negative.

Table 1 shows how scientific attempts to test the impact of decentralized electrification projects have focused primarily on education and health, and access to energy to a lesser extent. In contrast, descriptive evaluations and expert assessments focus on access to energy, economic transformation and the environment.

TABLE 1: DISTRIBUTION OF EVALUATION DATA BY TYPE OF EFFECT

Type of effect | Evaluation method	Scientific data	Non-scientific data
SDG (SDG number)		
Education (4)	205	144
Health (3)	174	139
Access to energy (7)	136	847
Economic transformation (8)	32	212
Income and living conditions (1)	30	61
Gender equality (5)	24	57
Safety (16)	21	35
Community (11)	1	81
Environment (13)	0	222
Other effects		
Allocation of time, leisure activity	51	31
Information and communications	38	53
Housework	34	15
Financial transformation	6	52
Migration	0	11
TOTAL	**752**	**1,960**

In terms of the technical characteristics of projects, we consider two primary factors: energy source and installation power. For these two factors, use of scientific data alone leads to sampling bias, with a very strong focus on low-power solar installations. These systems are primarily SHS, solar lanterns and public solar lighting. They have been subjects for research because they use a new technology that is affordable and easy to install. The complete CoSMMA database includes many other types of projects, using other energy sources and offering higher power. However, these types of projects have been scientifically evaluated far more infrequently (see tables 2 and 3), meaning it is hard to use these evaluations to draw generalizable lessons regarding best practices.

TABLE 2: DISTRIBUTION OF PROJECTS BY ENERGY SOURCE

Type of effect | Evaluation method	Scientific data	Non-scientific data
Solar	59%	38%
Biomass	0%	20%
Hydroelectricity	12%	14%
Wind	0%	9%
Diesel and other	18%	8%
Renewable hybrid	0%	4%
Diesel hybrid	12%	4%
Geothermal	0%	2%
Renewable unspecified	0%	1%
TOTAL	**100%**	**100%**

In particular, scientific evaluations concentrate on nano systems to such an extent that this constitutes a major shortcoming in the existing literature on evaluation (Eales et al, 2018). This raises a problem, because we expect nano solutions to generate relatively few effects as the appliances they power are mostly electric lightbulbs and cellphone chargers, sometimes refrigerators or televisions, and only rarely electric motors.

TABLE 3: DISTRIBUTION OF PROJECTS BY POWER

Power | Evaluation method	Scientific data	Non-scientific data
Nano: <1,000 W	71%	19%
Pico: 1 to 5 kW	0%	3%
Micro: 5 to 100 kW	18%	50%
Mini: 0.1 to 1 MW	6%	12%
Small: 1 to 10 MW	6%	17%
Large: 10 to 100 MW	0%	20%
TOTAL	**100%**	**100%**

Regarding project governance, evaluation documents provide little information because, until recently, questions of governance have rarely been covered in the literature. We usually know the decision-making level, making possible a discussion on the relative merits of top-down and bottom-up approaches. Thus, the characteristics of our scientific data sub-sample are not overly different from the other evaluations recorded in CoSMMA, as shown in Table 4, which presents project structures by decision-making level, from national to local.

TABLE 4: DISTRIBUTION OF PROJECTS BY GOVERNANCE MODE

Governance | Evaluation method	Scientific data	Non-scientific data
Decision-making level		
National	59%	47%
Provincial	12%	24%
County	1%	18%
Local & district	28%	12%
TOTAL	**100%**	**100%**

EVALUATING THE SUCCESS OR FAILURE OF PROJECTS

CoSMMA contains few scientifically evaluated projects, and these projects constitute a sample with bias in several important areas: energy source, generator power, and the nature of the effects evaluated. It is not too great an exaggeration to say that scientific evaluations have mostly studied the effects of SHS-style nano solar projects on education and health.

This means that, in order to judge the success or failure of decentralized electrification projects, it is also necessary to use the results of non-scientific evaluations, while keeping in mind the limitations of these data. This difficulty is inherent to the problem of evaluating small-scale projects owing to the high fixed costs of scientific evaluation methods, which require examination of a sample group sufficiently large to be considered representative. That is without the even higher costs associated with drawing up randomly selected control groups, as recommended by Abhijit Banerjee, Esther Duflo and Michael Kremer, who were awarded the 2019 Nobel Prize for Economics for their work in this field.

The approach to resolving this difficulty that we propose is inspired by the empirical approach used by assessors, which consists of consolidating their conclusions by triangulating several independent observations of the same reality (Greene and McCormick, 1985). This approach is all the more appropriate to electrification projects insofar as, in the event of a successful project, favorable effects are expected in a very wide range of domains.

Let us imagine, for example, that an empirical observation makes it possible to note an increase in agricultural output following the arrival of electricity. This observation does not enable a precise conclusion to be drawn in the absence of a significance test, but it does tell us that we have a less than 50% chance of making a mistake if we conclude that the electrification project had a favorable effect on the socioeconomic situation. Let us now suppose that, independently, it is observed that children in the village are doing better at school. There is again a less than 50% chance of being mistaken if we conclude that the project has had a favorable effect. Combining these two independent observations enables us to conclude that we have a less than 25% risk (50%x50%) of being mistaken if we conclude that the project has had a favorable effect on the socioeconomic situation in the village. If we have three independent observations of this type, there is a 12.5% probability of being mistaken in drawing this conclusion.

- This means that the accumulation of favorable independent observations makes it possible to rapidly validate the conclusion that the village's socioeconomic situation has seen significant uplift subsequent to deployment of the electrification project. This is the triangulation principle. To obtain qualitatively the same accuracy of conclusion as a favorability test with a 5% threshold value we need to combine between five and six favorable independent descriptive observations. This approach is not, however, without pitfalls, which must be identified if they are to be avoided.
- The observations used must be unbiased, which will usually be the case except where the assessor is manifestly not independent. The most commonly used descriptive statistical indicators, averages in particular, are in theory bias-free estimators. The various observations must also be independent, otherwise the probability of a mistaken conclusion of project success will be under-estimated. With decentralized electrification projects, the fact that projects potentially have effects in numerous independent domains is particularly helpful for the successful use of triangulation. Naturally, if we want to draw conclusions in a specific domain, such as poverty reduction or educational uplift, the available observations are less numerous and less diversified. For this reason, we essentially limit application of this method to the question of project success or failure, assigning the same weight to the various forms of effects that may be produced:
- Triangulation cannot be used to draw conclusions on causality. A situation may have improved for other reasons, possibly reasons that cannot be observed. With standard scientific approaches, it is this that leads to the recommendation to compare observed results against a randomly constructed control group. There is no control group, in the sense of non-electrified villages, in the CoSMMA database, but we can compare a project to other projects. This does not allow us to conclude that providing electricity has a positive causal effect (impact) on socioeconomic uplift, but that is not the essential issue for promoters of these projects. However, it is possible to compare projects against each other, and thereby to identify best practices (see the following section).

In the CoSMMA database, we observe that projects have unfavorable effects in certain domains. For example, a biomass-based project might create land-use pressures that lead to a degraded environment and social tensions surrounding access to land. Unfavorable effects such as this do not necessarily mean the project is a failure. However, to take account of them we will then consider whether a project has succeeded if, and only if, observations of significant favorable effects outweigh observations of significant unfavorable effects.

Application of this triangulation method allows us to significantly increase the number of projects whose success or failure we are able to judge. If we consider only those subject to a scientific evaluation, there are just 17 projects available in the CoSMMA database, 75% of which can be considered a success. If we triangulate using five observed effects as a threshold value, we then have 125 projects, with slightly under 80% of them considered a success. The number falls to 108 projects if the triangulation threshold is six observed effects, although the proportion of successful projects is unchanged.

The relatively high proportion of projects judged a success should be relativized as a function of the elapsed time between deploying the installations and observing the effects of a project. A project can appear to have succeeded in the short term but prove unsustainable in the longer term. We do not always know the date that observations were made, but we do have an indication based on the date that the evaluation was published, in the knowledge that there is an average lapse of 2.5 years between the date effects were observed (when this is available) and the date of publication. According to our evaluation by triangulation, project success rates fall to 70% where the publication occurs after 12-13 years, i.e., an evaluation delay of around 10 years.

IDENTIFYING BEST PRACTICES

In order to identify best practices, we look at which project characteristics are most commonly associated with success. We use an approach that is statistical rather than purely descriptive. For example, we observe that projects evaluated by triangulation are more often judged a success than those evaluated using scientific data (80% versus 75%), but we want to know if this difference is significant, i.e., whether we run a large risk of being mistaken if we conclude this discrepancy is negligible. To do this, we use a standard econometric method called probit, which involves evaluating whether the probability of observing a success correlates in a significant manner, in our example, to the fact that the conclusion of success is obtained by triangulation rather than scientific data.

This method also offers the advantage of permitting a multi-factor evaluation from the outset, by combining various characteristics of interest. When there is a partial positive correlation between characteristics (for example, a solar project is most commonly nano sized), a single-factor analysis would risk biasing attribution of a favorable result on the basis of a specific characteristic.

The results are summarized in Table 5. The table indicates, in each row, the reported parameters that correspond to the average marginal effect[1] of the characteristics on the probability that a project will be a success, with the *symbol indicating if the parameters are significant (***for a 1% threshold, **for 5% and *for 10%). The columns present various alternative specifications.

TABLE 5: DETERMINANTS FOR PROJECT SUCCESS

	[1]	[2]	[3]	[4]
	5-factor triangulation	6-factor triangulation		
			(with interaction between nano and eval. delay)	(with RISE off-grid)
Scientific data	-0.162	-0.137	-0.172	0.108
Evaluation delay (eval. delay)	-0.013**	-0.012**	-0.006	0.001
Energy source (ref. = solar)				
Wind	-0.207	-0.339	-0.321	..
Geothermal	,,	,,	..	,,
Hydro	0.168**	0.106	0.093	,,
Diesel hybrid	-0.031	,,		..
Renewable hybrid	0.102	-0.024	-0.043	-0.029
Biomass	0.071	0.002	-0.003	-0.092
Not known	0.122	0.065	0.031	..
Diesel	-0.373**	-0.339**	-0.356**	-0.154
Power < 1 kW (nano)	0.091	0.025	0.159	0.089
Nano * eval. delay			-0.015*	-0.019**
Decision-making level (ref. = local)				
Province/county	-0.048	-0.254**	-0.228*	-0.442***
National	-0.069	-0.146	-0.124	-0.110*
RISE off-grid				0.005***
No. observations	115	95	95	51
Pseudo R2	0.16	0.22	0.23	0.35

Probit estimate with clusters per country - .. parameter cannot be estimated - *** (resp. **, *) significant at 1% threshold value (resp. 5%, 10%)

---

[1] Average marginal effect is the effect on the probability of success of a small variation in the studied variable, calculated at the average point of the data sample. In the case of a 0-1 category variable, the average marginal effect is the effect on the probability of success of the passage from modality 0 to modality 1, calculated at the average point of the sample.

The first variable of interest considered is the evaluation method used to decide whether or not a project is a success, using scientific data or triangulation where this is unavailable. When we use 5-factor triangulation, this appears markedly more optimistic than the scientific evaluations. Projects evaluated with scientific data have a 16% lower chance of being judged a success than projects evaluated using triangulation, and this parameter is almost significant at a 10% threshold value (it is with a threshold value of 12%). This might bias our results for the identification of best practices. To test the robustness of the results, in the second column of the table we enter results obtained using 6-factor triangulation, where the difference with scientific data is smaller and less significant. For this reason we prefer to base our conclusions on this second estimate in the event of divergence with the first estimate, albeit at the cost of reducing the number of available observations. There are around 20 projects in CoSMMA for which we have five non-scientific evaluations of the effects, which have been subjected to 5-factor triangulation but cannot be subjected to 6-factor triangulation.

The evaluation approach is inspired by the empirical approach used by assessors, which consists of consolidating their conclusions by triangulating several independent observations of the same reality

In both cases, the evaluation delay (evaluation publication year minus deployment year) significantly reduces the probability of obtaining a favorable effect. Our interpretation of this result is that, even if many projects have a positive effect in the short to medium term, they are not always successful over the long term, which points to a problem of sustainability. Sustainability problems have often been cited in studies of decentralized electrification projects (Feron, 2016; Roche and Blanchard, 2018; Katre et al., 2019). Poor sustainability is often associated with problems in the maintenance of installations.

Project technical characteristics are then considered in terms of two primary factors: primary energy source and generator power.

Regarding the primary energy source, we use solar as our reference because it is the most commonly used. The use of diesel generators gives significantly fewer favorable results than solar panels. Generators using other renewable primary sources, including hybrid systems, do not appear to differ from solar installations. This is doubtless because relatively few projects have been analyzed, making it impossible to obtain more precise results. This means that hydroelectric systems, known for their technological simplicity and low cost, score better than solar systems in the sample using 5-factor triangulation, but not in the smaller 6-factor triangulation sample.

We test the effect of generator power by comparing nano systems (capacity under 1 kW) with higher power systems. In the sample with 5-factor triangulation, nano systems exhibit more favorable effects than other systems, but this parameter is not significant and is considerably lower when examining a 6-factor triangulation sample.

The variations in the effect of power revealed by these results can partly be explained as an interaction with evaluation delay, as shown in the third column of Table 5. Power increases the probability of success for a project where the delay between commissioning and observation of effects is around 7.5 years or longer. Nano projects are less sustainable than higher power projects.

A descriptive analysis by type of effect also illustrates the variation in effects according to generator power (Table 6). Smaller sizes can have more favorable effects in terms of providing access to modern energy sources owing to the simplicity of the systems deployed. Similarly, favorable societal and environmental effects are more frequent among projects relying on lower power systems: we observe favorable effects relating to access to public lighting or meeting places, which are not dependent on the level of power, whereas environmental benefits can be offset by pressure on natural resources exerted by higher power installations. We also see greater risks of conflict surrounding the allocation of power with higher power systems. Conversely, nano systems are markedly less favorable in terms of economic transformation and increased earnings. This may explain why they are less sustainable in the long term: production of economic benefits reinforces the willingness and ability of a project's beneficiaries to pay the maintenance costs required to ensure the sustainability of the installation.

TABLE 6: PROPORTION OF SUCCESS BY TYPE OF EFFECT AND POWER

Type of effect	5-factor triangulation		6-factor triangulation	
Power	**nano**	**> nano**	**nano**	**> nano**
Access to energy	69%	58%	71%	52%
Individual wellbeing	88%	92%	88%	88%
Income and economic transformation	64%	100%	58%	80%
Community wellbeing	63%	50%	80%	40%

Aside from the technical aspects, the primary factors that can influence the success of projects seeking to produce local public services tend to center on governance. Mindful of the local nature of these projects, the first question that arises is what is the most appropriate decision-making level? Traditionally, a difference is made between top-down approaches, where decisions are taken centrally, and bottom-up approaches, where decisions are taken by an authority at the local level (Tenenbaum et al., 2014).

Theoretical works, notably as initiated by Ostrom (1999), advocate the bottom-up approach. Ostrom shows how problems in collective actions caused by the free-riding phenomenon are better when managed locally than centrally. This applies to mini-grids (Berthelemy, 2016).

However, a project's decision-making level may have different types of consequences in practice. On one hand, a project decided on locally may take better account of local people's needs; it may also be rooted in a governance structure that is keen to promote cooperative management of resources. On the other hand, projects decided on at the national level may benefit from a greater degree of expertise, experience and future-proofing. Economies of scale in the accumulation of knowledge and greater skill levels may help to identify, at least from a technical point of view, solutions that are the most efficient.

There is no obvious answer to the question of choosing between the two approaches, top-down or bottom-up; it remains an empirical question. Our results, however, show that locally decided projects succeed better than others. In our estimates based on data from a 6-factor triangulation, we also note the appearance of a V-shaped effect curve, indicating that projects decided at intermediate administrative levels (province, county) are the least successful. The V-shaped curve illustrates the fact that there are arguments in favor of top-down as well as bottom-up.

Aside from the technical aspects, the primary factors that can influence the success of projects seeking to produce local public services tend to center on governance

Aside from this choice, the quality of governance methods can be highly variable at both the national and local levels.

Our data do not allow examination of the question of local governance, which is without doubt important. There is a need to study the principles developed by Ostrom for designing governance methods suited to stimulating good cooperation between local actors for management of the commons (Gollwitzert et al., 2018).

We can, however, examine questions of governance at the national level. The electricity sector is highly regulated and regulators such as rural electrification agencies, in the case of decentralized electrification, can act to facilitate or hinder the success of projects.

Sustainable Energy for All (SE4All) and the World Bank have collated the available information on institutional frameworks for access to energy policies in a database known as RISE (Regulatory Indicators for Sustainable Energy). The most recent available ESMAP synthesis (2018) concludes that regulatory and incentive policies have a major role to play. We fed all this data into CoSMMA to explore these questions within the specific context of off-grid electrification.

The RISE database lists five criteria concerning off-grid electrification: existence of a national program, existence of a legal framework, ability of operators to incorporate costs into tariffs, financial incentives and technical standards. The average of these five criteria provides an indicator, standardized from 0 to 100, of the quality of the institutional framework in the decentralized electrification sector, which we have termed RISE off-grid.

We introduce the RISE off-grid indicator as an explanatory variable for the probability that a project will succeed (column 4 in Table 5). Owing to data missing from RISE we lose several observations, which limits our ability to simultaneously evaluate the role of the choice of primary energy source (several sources have only a very small number of observations, all positive, which prevents them from being taken into account). Despite the limited number of observations, this equation shows the very significant positive effect of the quality of national sector governance. This effect is also highly sensitive: on average, a 1% improvement in this indicator translates to a 0.5% increase in project success. This result confirms the important role that governance plays in the success of projects.

CONCLUSION

The weakness of evaluation systems is a major obstacle to the development of essential services in rural areas, including decentralized electrification. Using scientific methods to evaluate development projects of this nature is extremely costly owing to the small size of these isolated projects, with the upshot that we do not have irrefutable proof of the soundness of such projects, nor the means to identify best practices in the matter.

FERDI has gathered a large number of evaluations of electrification projects in the CoSMMA database, making it possible to confirm how few scientific evaluations there are, which in any event concentrate on SHS and the effects on education and health. This makes it impossible to draw conclusions on mini- or micro-grids or on other important effects surrounding, for example, economic transformation or environmental protection.

We propose a new method that makes it possible to use these data despite this, by exploiting a portion of the non-scientific evaluations via a triangulation method.

This approach makes it possible to evaluate the success of the projects listed, which runs at an average of around 80%, but falls to 70% five years after installations are commissioned, pointing to a problem of sustainability that practitioners have observed time and time again.

The method has also enabled us to highlight the following elements of best practice.

- Solar projects are more efficient than those that use diesel generators. On the other hand, we have insufficient evidence of differences in efficiency between solar projects and projects using other renewable resources.
- Nano-sized projects are efficient in the short term but are less sustainable than projects offering more power, such as mini-grids. This might be explained by the fact that lower power systems are not suited to uses that deliver economic transformation and increase users' incomes, in turn reducing their ability and motivation to pay. But it is important to take account of the potentially negative societal and environmental effects of larger-scale projects.
- Project governance is a key determining factor in their degree of success. Bottom-up approaches tend to be the most efficient. It is, however, necessary to take account of interactions between the local and national levels, a fact confirmed by the influence that the quality of sectoral regulation has on the success of projects. Unfortunately the available data do not allow an exploration of local governance methods, which must inevitably play a prominent role in bottom-up approaches.

This points to twin directions for complementary research: the development of low-cost evaluation methods based on the triangulation principle; and explorations of the characteristics of project governance methods at the local level.

REFERENCES

Berthélemy, Jean-Claude. *Mini-grids as an application of Elinor Ostrom's theses on polycentric governance as a way to cope with the tragedy of the commons.* Revue d'économie du développement, 2016, vol. 24, no 3, p. 85-106

Eales, Aran, Walley, Luke, Buckland, Hannah, et al. *Social impacts of mini-grids: towards an evaluation methodology.* 2018 IEEE PES/IAS PowerAfrica. IEEE, 2018. p. 354-359

ESMAP. *Policy Matters: Regulatory Indicators for Sustainable Energy (RISE).* Washington, D.C., World Bank Group, 2018

Feron, Sarah. *Sustainability of off-grid photovoltaic systems for rural electrification in developing countries: a review.* Sustainability, Z016, vol.8, no. 12, p.1326

Greene, Jennifer, and McClintock, Charles. *Triangulation in Evaluation: Design and Analysis Issues.* Evaluation Review, 1985, vol. 9, no 5, p. 523-545

Gollwitzer, Lorenz, Ockwell, David, Muok, Ben, et al. *Rethinking the sustainability and institutional governance of electricity access and mini-grids: electricity as a common pool resource.* Energy Research & Social Science, 2018, vol. 39, p. 152-161

Katre, Aparna, Tozzi, Arianna and Bhattacharyya, Subhes. *Sustainability of community-owned mini-grids: evidence from India.* Energy, Sustainability and Society, 2019, vol. 9, no 1, p. 2

Ostrom, Elinor. *Coping with tragedies of the commons.* Annual review of political science, 1999, vol. 2, no 1, p. 49

Tenenbaum, Bernard, Greacan, Chris, Syanbalapitiya, Tilak, and Knuckles, James. *From the bottom up: how small power producers and mini-grids can deliver electrification and sustainable energy in Africa.* Washington D.C., World Bank Group, 2014