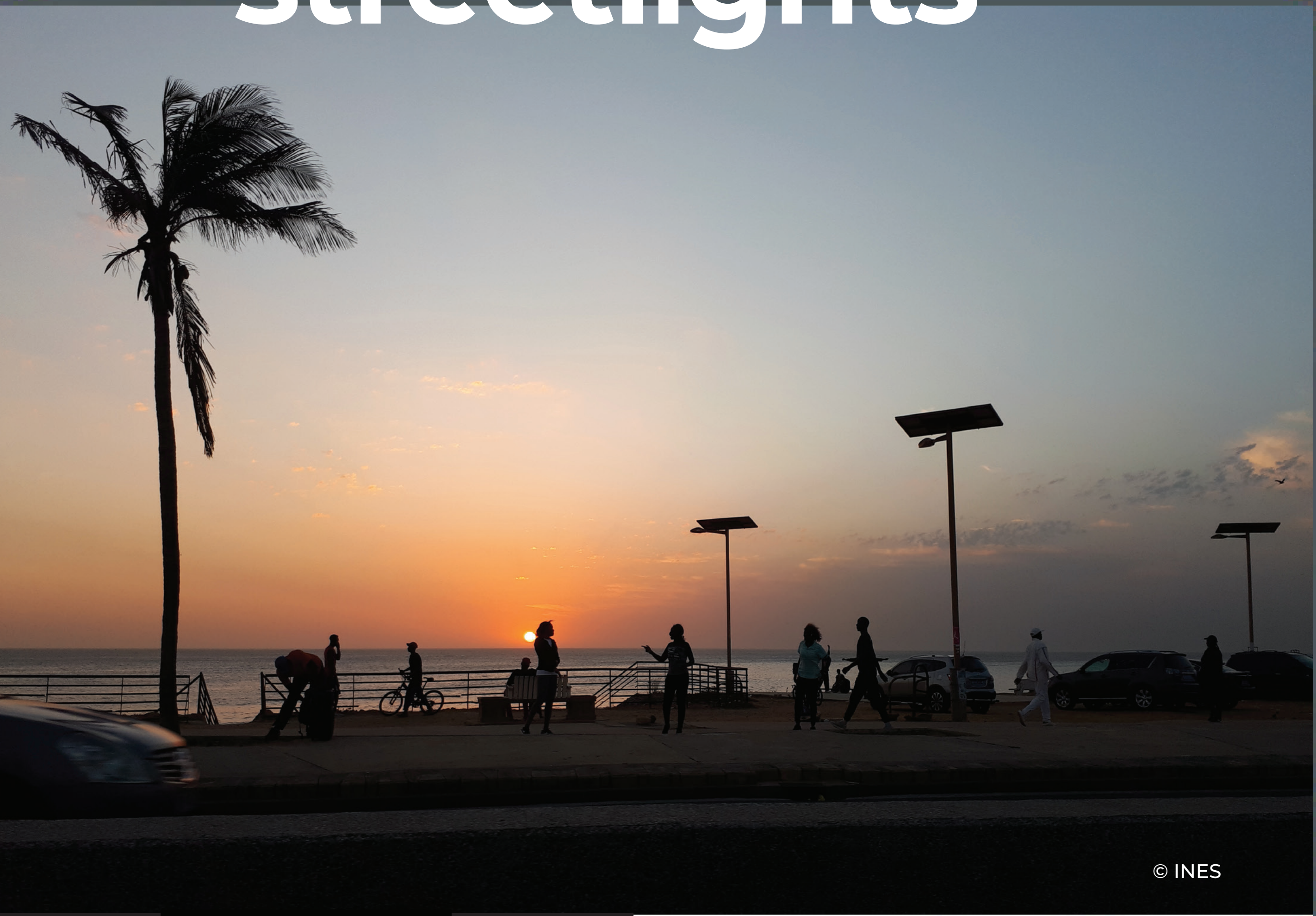
DRAFT VERSION - February 2019

PRACTICAL GUIDE BOOK

Solar streetlights



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This document is intended to be a guidebook handy for any kind of solar streetlight projects. It sheds light on the deemed most relevant practical recommendations. These recommendations are gathered in successive chapters consistent with the different stages of a project, from initial need assessment to final operation and performance evaluation, through the key stages of financing and implementation. The guidebook aims at giving everyone the opportunity to grab hold of repetitively validated practices, without seeking to be of universal use. Adaptation may be necessary depending on the conditions and the local environment.

The collective endeavor steams from a working group (*) gathering industrials, NGOs, and representatives of ministries, Ademe, and AFD, led by INES, National Institute of Solar Energy. The working stream met from September 2017 to June 2018. Evolution is yet to be brought about, as this document will evolve, and made available on the websites of the International Solar Alliance and INES. Toolkits will also be available online to can be used as templates for each step of a solar streetlight project. All comments and additional contributions can be addressed to: solenn.anquetin@ines-solaire.org.

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EXECUTIVE SUMMARY

A. Society, financing and quality issues background

Main objectives of autonomous solar lighting
Public lighting is worldwide a symbol of modernity. Autonomous solar systems represent a formidable tool for economic and social development, which is addressed to rural areas without access to electricity, peri-urban areas where the electricity network is absent or intermittent or urban for the sake of energy savings.

A project of solar street lighting aims primarily at improving the quality of life, through often multiple societal concerns:
▸ The safety and mobility of all users by improving the appreciation of distances and speeds, limiting loss of visual capacity, improving the visibility of the peripheral field and promoting the feeling of security of all for lighting on roads and tracks urban.
▸ A better perception of the living environment and the promotion of public spaces when it comes to lighting around public buildings, schools, and health centers.
▸ Access to information and strengthening of social connections, when it concerns the village square, market, shops or cultural and religious venues.
▸ Support for economic activities, and a subsequent increase of the purchasing power, through the increase of possible hours of activity or even the possible provision of additionally potential money-making services (phone charging...) by stocking some electricity in the batteries.

These objectives are also brought to fit into a vision, which can be, for example, a search for limiting energy consumption and light pollution related to public lighting.

Advantages and challenges
Public lighting systems are perfect for:
▸ New constructions
▸ Remote areas: isolated sites in the network and sites where the network does not provide continuity of service
▸ Existing locations where underground utilities fail or no longer meet standards
▸ Places where electricity costs are high
▸ Eco-sensitive landscapes
▸ Temporary or emergency facilities

The solar option has several advantages:

- ▸ Ease and speed of implementation
- ▸ Reduced maintenance costs
- ▸ Overall usage costs that are sometimes more economical than an extension of a networked public lighting service
- ▸ Better availability of service, if networks are powered discontinuously,
- ▸ Better flexibility of lighting infrastructure due to its independence of the presence of an electricity grid
- ▸ Ecological solution if batteries & other components are properly recycled because it uses clean and inexhaustible energy

But also suffers some shortcomings and constraints that must be managed:

- ▸ Its dependence on sunshine
- ▸ A relevant selection of areas to be illuminated as well as the illumination level required.
- ▸ A lack of international technical standards leading to a great diversity in the origin of product quality and price
- ▸ Maintenance and increased maintenance
- ▸ A higher risk of vandalism
- ▸ Battery replacement after a few years in case of inadaquate sizing or technology
- ▸ The training of technicians in the correct installation and maintenance (cleaning, after-sales service)
- ▸ Taking into account the initial investment and maintenance budgeting to assess the overall cost of the project, keeping in mind the optimal balance CAPEX / OPEX

This document outlines intrinsic quality criteria for stand-alone solar lamp projects. It was written in order to help compare the solutions and especially to give the best chances of success to the project of solar public lighting.

The proposed criteria are intended to avoid counter-references that result in a service rendered defective, wastage and legitimate dissatisfaction that undermine the image of solar energy in general. Respect for these practices is likely to facilitate the setting up of the necessary financing for the realization of the project, and the funds necessary for the maintenance if it is not included in the initial order.

B. Quality Charter for Standalone Solar Streetlights

The Quality Charter for Standalone Solar Streetlights is a tool to help stakeholders (elected representatives, technicians and financial partners) to define the quality expected from their public lighting, with the objective of responding in the best way possible to the major challenges in terms of society, finance and quality. It crystalizes the main practical recommendations which are developed in detail per chapter and which conform the backbones of this guide. The objective is to «light right», that is to say as it should be (at the right level), and when it is necessary (when necessary) to the best overall cost (investment and maintenance). The charter recommends considering a minimum duration of 10 years for the use of the solar street lamp and the calculation of the overall cost.

The presented charter is based on 2 main pillars:
- Commitment to fulfilling the common overall objectives
- Project development methodology in successive stages with stakeholders identified and accountable

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As a stakeholder in an stand-alone solar streetlight project within the framework of the International Solar Alliance, I undertake to:

		Public authority	Contractor	Financer
Initial assessment of needs and means carried out with local population and based on uses	▸ Identify the needs on the ground with local stakeholders, the local project owner and in consultation with the population defining: > Objective of the project based on key issues > The strategic places to be lit, having security as a priority in order to prevent gender-related assaults > The uses (activities and activity schedules, types of vehicle, types of road) of the places to be lighten up > The security of the installations preventing and mitigating vandalism	X		
	▸ Write precise specifications based on the model proposed in the appendix	X		
	▸ Basing technical specifications on needs & uses - uniformity and level of illumination, possible dimming or extinction times, light pollution issues.		X	X
	▸ Carry out comparative analysis of the costs of and savings made by the project	X		
MSetting up an affordable project	▸ Mobilize financing and select the appropriate business model to balance CAPEX and OPEX.	X	X	X
	▸ Secure funds and management devoted to the maintenance and replacement of compo¬nents by ensuring that the sizing of the programme is consistent with the financial capacity of the municipal authority.	X		X
Needs-based design to ensure quality	▸ Guarantee the technical quality of the components, above all the different technologies of the batteries, and of the sizing of the system (autonomy, sustainability and reduction of maintenance rate).		X	
	▸Integrate clauses for quality control, performance commitments and guarantees of long-term operation and maintenance, adapted to local needs and means.	X		X
	▸ Plan service provision to accompany stakeholders, from decision-makers to operators and local populations.	X	X	
Achievement of sustainability commitments	▸ Promote assembly and local implementation to optimize the transfer of skills through school sites.		X	
	▸ Follow the steps closely by developing a control documentation		X	
	▸ Plan upstream the maintenance phase with the training of local staff, simple teaching aids and a dedicated business model	X	X	
Assessment of efficacy	▸ Put in place upstream the conditions to carry out the evaluation: the teams, the supports, the tools of remote monitoring and a schedule.	X		
	▸ Assess the organizational, technical and economic compatibility of the project with the population's expectations and needs.	X		
	▸ Ensure the durability of the project by carrying out assessments, at least one year after delivery, then a few years later.	X		X
	▸ Measure project social, technical, environmental and economic impacts.	X		X

DATE

SIGNATURE

The practical recommendations process.

The following chapters report the problems identified throughout stand-alone solar lighting projects and recommendations by the Alliance to overcome them. The following chapters trace the project's chronology:

1. **Chapter I** 'Preliminary Design' focuses on needs assessment and economic analysis
2. **Chapter II** 'Project Setup' highlights the methodology used to mobilize financing and to define the associated economic models.
3. **Chapter III** 'Design' explains how to write a call for tenders then how to rank offers.
4. **Chapter IV** 'Implementation' covers recommendations from installation to maintenance and recycling of the lighting infrastructure.
5. **Chapter V** 'Assessment' reviews the project's assessment criteria and impact measurements.

CHAPTER I : PRELIMINARY DESIGN

A. Needs assessment : what tools for an on-site identification ?

Before designing the lighting infrastructure, it is essential to clearly define what infrastructure needs to meet. This needs assessment seems to be obvious, however it is not always easy to clearly identify the stakeholders of the evaluation, to prioritize the uses and places of need, and to transcribe the needs for technical specifications. The technical recommendations «Needs Assessment» provide suggestions for answering this problem.

1. Integration of the project into local programs: how to ensure coherence?

Coherence involves integrating access to electricity and modern energy services, including solar street lighting, into the municipal or local development plan document, taking if needed the lead onto energy action planning.
In general, this approach aims to verify the coherence of the project with those already committed or to come at different local and national scales by the public policies on the scale of the territory.
▸ **Conduct a study of the existing** with the electrification agencies, national companies or agencies dedicated to rural electrification to be part of a dynamics of spatial planning and energy planning, avoid any duplication with an existing program and respect overall priorities in terms of resource allocations.

2. Identifying needs on the ground with local actors: which stakeholders and methods to identify local needs and the purchasing power of populations?

The first crucial step when assessing needs is the mobilization of local stakeholders who are able to adequately identify local needs.

This step is necessary to prevent a "top-down" approach to the definition of needs based on preconceived ideas rather than conditions in the field. Several recommendations apply when carrying out local identification.

▸ **Go local:** Instead of working solely from a remote city-centre office to understand the needs of the project, it is essential for project managers to visit the places where needs arise in order to assess conditions in the field by meeting with neighborhood committees and village leaders. This helps improve understanding of the needs and priorities defined under the guidance of the local project owner. At this stage, it is important to associate with local intermediaries (design offices, project managers, NGOs, associations) who know the field and will be able to converse in the local language with the right people.

▸ **Consult with the population:** To avoid relying on the perspective of a single stakeholder, often the mayor, it is important to consult with the population concerned in coordination with the local project owner. This consultation may take the form of a survey. It is even more effective when it involves existing consultation groups, such as users' committees or community lighting infrastructures.

▸ **Involve local authorities:** In addition to identifying needs, consultation ensures local authorities are involved in the project. As a forum for discussion, consultation helps highlight the advantages of public lighting and underline security benefits, as well as launching debate on the need to plan maintenance activities, draw up a post-investment budget and understand beneficiaries' ability to pay and give rise to their interests guaranteeing protection from vandalism.

3. Defining and prioritizing uses : how to establish a need-specific framework?

Once the relevant stakeholders and forums have been identified, discussion must focus on defining a framework and hierarchy of needs.

▸ **Define one or two objectives for the project:** Rather than wanting to address the needs in all directions, it is advisable to identify one or two specific objectives that seem to meet the most urgent needs of the concerted parties, even if the project produces positive effects that are not initially discounted. Among the key objectives, project leaders can for example focus on:
o Securing neighborhoods, especially for vulnerable people & their assets.
o Frequentation of roads, major axes or development of additional axes.
o Revitalization of economic or social places, for example the market or community infrastructures thanks to the increase in working hours.
o Schooling of children

This prioritization also paves the way for impact measurement, which is completed at the end of the project, by clearly defining and quantifying the project's expected impacts.

▸ **Identify strategic locations to be lit:** the definition of priority needs necessarily follows the identification of the strategic places to be illuminated. It will indeed identify, not symbolic places such as the street of a person influential in the community, but places that allow to achieve the objectives of the project. In this choice, particular attention must be paid to local characteristics through the prism of vulnerability.

Indeed, it may be strategic to illuminate places that seem trivial at first glance, such as public toilets, bus stops, railway stations, because these places are proving to be a source of strong insecurity for vulnerable people.

It is recommended to formalize this identification of places by a typology to facilitate quantitative pre-design, as shown in Table 1.

4. Quantitative preliminary design: which technical specifications help optimize lighting infrastructure use?

The last step of the needs assessment involves translating the needs expressed in terms of priorities, objectives and strategic locations into the technical language used in the quantitative pre-design. For 3 types of path, the specifications summarized in Table 1 below can be used for this process.

	Route principale	Traversée de village ou petite voie péri-urbaine (largeur 7m)	Lieux/places publics
Eclairement recommandé (fourchette en lux)	15 à 20	10 à 15	5 à 10
Uniformité	0.4	0.4	0.4
Durée d'allumage à pleine puissance	5h minimum	4h minimum	4h minimum
Niveau minimum d'éclairement en gradation (dimming)	60% du recommandé	50% du recommandé	20% du recommandé
Options de gestion à étudier	Gestion simultanée du parc de lampadaires	Extinction Détection de présence collective/communiquante (par groupe) peut être envisagée	Détection de présence
Hauteur de feu (en m)	8	6	4
Température de couleur (fourchette en K)	3000-5000		
Cette typologie est seulement indicative, la technologie LED évoluant très vite et les projets étant ensuite définis au cas par cas.			

Table 1. Technical specifications depending on road typology

▸ **Avoid copying European standards:** In Europe, public lighting is steered by the standard EN 13201, which defines lighting typologies based on location, performance requirements and related calculations and measurements. Although this standard can be used as a reference, it does not seem suitable for the local contexts of Alliance projects. It should therefore be used as a maximum, while keeping in mind security at stake.

▸ **Illumination level:** the level of illumination is expressed in lux. It gives information on the amount of light on the ground.

▸ **Uniformity of lighting:** The uniformity of lighting is a key factor as it ensures constant visibility throughout the area to be lit.

▸ **Lightning variations:** Depending on the needs expressed, the lighting system may not need to function at 100 % power all night long. Therefore, the times when lighting must function must be clearly defined, as well as variations in lighting levels.
Smart lighting device and the induced-use of a regulator add to the complexity of the system, making maintenance and repair more difficult. However these tools are extremely relevant for energy savings, for tailored to real use system sizing and lighting, and for decreasing production and storage costs.

▸ **Fire height:** the fire height is determined so that the uniformity and the level of illumination are sufficient for the illumination on the ground. It is also necessary to take into account the needs according to the places on height of the mast.

▸ **Colour temperature** Although the choice of color temperature is based in part on the tastes and habits of the beneficiaries, the need to respect biodiversity and optimize the sizing and cost of the system must be taken into account. A cold white, above 5000K, may have a better lumen / watt ratio because the LED contains less phosphorus, although the evolution of the yields is less related to the color temperature than before. However, this cold white is proving to be a disruptive for biodiversity, for example in Africa.

▸ **Light pollution:** It is also a question of taking into account the light pollution induced by the installation. The recommendations produced by the Dark Sky Association may guide the process. For example, it is recommended to minimize the waste of light by illuminating the right place, especially by not emitting light above the luminaire. To limit the impact on fauna, flora and the human being, a maximum color temperature of 3000 Kelvin is required for sensitive areas (isolated places, natural parks ...).

B. Economic analysis: why opting for a solar streetlight project?

Once the needs expressed have been translated into technical specifications, project initiators have all the information they need to decide which infrastructure will best meet the project's objectives. Is an stand-alone solar streetlight project appropriate, or should the streetlight system be connected to the electricity grid?
The aim is to draw up a comparative analysis of the costs and savings generated by the two situations in order to identify under which conditions the solar energy is more competitive than the conventional one. Thus, the available means - financial, human and infrastructure - to install and maintain the project will be decisive.

1. Investment costs according to the state of the network

Because solar lighting has a higher initial investment cost than grid-connected LED lighting, situations in which solar LED lighting is usually the best option follow:

▸ • Limited, unstable or non-existent electricity production capacity: In most emerging markets, energy demand exceeds supply and it can be difficult to increase production capacity in time to meet the growing demand for public lighting. This is especially true in many markets in Africa and South America.

▸ Off-grid locations: In areas of low population density, it is often faster and more economical to provide solar street lighting and similar off-grid solutions for other energy needs.

▸ Renovations of facilities: When energy costs are high and when it is decided to light an already existing road, it may be worthwhile to opt for a solar solution. It is possible to save on the wiring network between the poles (cables, landfill, electrical connection box) and even reduce the number of poles needed per kilometer thanks to an intelligent design.

The following questions may further refine the understanding of investment costs related to the state of the network:

▸ Does the country's electric power generation provide continuous service all night long?

▸ Is the place to be illuminated covered by the network?

▸ Does the network connection require expensive work?

▸ Is the electricity grid in good condition?

▸ What is the share of renewable energy in the energy mix?

▸ What is the financial situation of the network management company?

2. Operating and maintenance costs

Solar street lights are synonymous with greater energy savings: solar streetlights can save 100% of energy compared to conventional streetlights and thus reduce energy bill.
In addition, the following questions must be asked to estimate their operating costs in comparison with conventional streetlights:

- What local skills and resources are available?

- What is the level of availability of spare parts and maintenance equipment?

- Cost of maintenance, eg cleaning panels at least once a year

- Cost of maintenance: In addition to the cost of the parts to be replaced, the maintenance and transport of parts is an expensive operation, to be taken into account in the total estimate of the cost of the project.

3. Recycling stream

- What are the options for recycling, with particular attention to photovoltaic batteries and modules?

- Is it necessary to set up a recycling network dedicated to the project?

► **In order to illustrate the analyzes proposed in the points above, the following photo shows that even with an existing electrical network, a solar street lamp may be relevant.**

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CHAPTER II : FINANCIAL SETUP

This part intends to give elements to the carriers of projects so that they are able to provide:
1- Explanation of an overall cost assessment
2- Study of the profitability of a project
3- Presentation of the meaning of a project to mobilize financiers
The International Solar Alliance programme "Affordable finance at scale" (AFAS) is focusing on creating tools necessary for mobilizing and sustaining funding. This chapter is thus restrained to introducing key concepts without trying to replicate the AFAS programme.

A. Mobilization of financing: towards a mapping of stakeholders?

Once the project has been defined by assessing needs and available implementation resources, financing must be mobilized as part of the project setup. This involves identifying key stakeholders who will support the initiative and building arguments that will help these stakeholders.

1. Mapping of actors: which stakeholders should be involved?

In the midst of the many funding counters , it can get arduous to steer in between the piles of funding proposals files, templates and induced conditions, especially when a substantial number of banks and asset managers have little knowledge and much distorted perception of international investment in renewables, all the more in African countries. To gain visibility with such multiple stakeholders, can be highlighted the following tips:

- Get businesses interested in public-private partnerships
- Organise awareness workshops and trainings with financial stakeholders to create a climate of trust and reduce distorted perceptions
- Share experiences to the regional scale
- Set up a unique common platform to aggregate investments and projects based on standardized countries and common garantees

2. Bankability: which thresholds must be reached?

A second issue is to draft a convincing presentation which will appeal to investors. A first feasibility study, or at least prefeasibility study, is a key item to defend a project. Accessing the funds to lead such primary study can turn into the main bottlenecks for countries. Ways to overcome the obstacle can be found here:

▸ Gather internation common fund for multi-country prefeasibility study implementation for showing technical and socio-economic arguments on the side of project bankability
▸ Adapt to the various requests and conditions coming from financial stakeholders : donors, investors, International Financial Institutions (IFIs)
▸ Depending on the financial stakeholders involved: donors, investors, international financial institutes, etc.

Moreover, criteria used by banks to determine interest rates are often cryptic and spur inequality among countries. It would therefore be useful to :
▸ Normalise a list of criteria to be used in interest rate assessment, based on concrete examples and case studies
▸ Share information on asset financial performance in order to constitute a "track record" to be used as a reference for future projects

B. Contracts & business models: how to ensure investment over the long term?

The practical recommendations below are intended to help formalize the project's contractual setup. They involve drawing up a business plan prior to the project design phase to balance initial capital expenditure (CAPEX) and operating and maintenance expenses (OPEX), as well as to identify the lighting project's financial partners.

1. OPEX and CAPEX: what balance for minimizing costs?

A solar streetlight project can be designed in two ways. The first way involves investing in a qualitative system, which will last overtime, and will require very little in terms of maintenance and component replacement. This first option entails high investment costs (CAPEX) but low operational costs (OPEX). The second option consists in reducing initial investment costs by choosing a poorer quality system, but then also in increasing downstream costs for frequent repairs and out-of-order components to be replaced. The goal is to optimize the quality-cost ratio taking into account both investment and operation costs, as follows:

▸ **CAPEX :** Transaction and due diligence costs account for a high share of the initial investment. The goal is therefore to pull down this share by simplifying and aggregating the procedure on both the supply and demand sides with standardized contracts and common guarantees. Regarding the technical installation phase, the equipment used must be affordable enough to allow the project owner to place or help pay for new orders when replacement becomes necessary.

▸ **OPEX** : The business plan should be drawn up in such a way as to raise the project owner's awareness of maintenance issues and costs (maintenance costs staggered over time, the replacement of batteries and LEDs, etc.). This helps the project owner choose equipment that it can afford to maintain and replace after a certain number of years.

Draw up a Business Plan for the client who raises awareness of the maintenance issues and their costs (time-phased costs for maintenance, battery change, then LED ...), allows the client to choose equipment that he will actually be able to maintain and replace after x years of operation, considering his financial capabilities.

2. 1. Who pays for the lighting service?

Identifying stakeholders responsible for the lighting service can get down to two main questions. What must be paid for? The local authority must be able to pay for:

▸ The maintenance of equipment by a private company or municipal service (provided that they have received training) during and after the guarantee period,
▸ The replacement (or at least a financial contribution towards the replacement) of equipment at the end of its lifespan.


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▸ **How should it be paid?** There are two options, which may be combined:
- Management by the local authority : The local authority's existing budgetary mechanisms are examined in order to mobilize a budget item that can be ring-fenced for public lighting (State budget set aside for infrastructure renewals, user participation through the collection of a local tax, etc.).
- Community management on a volunteer basis: Basic maintenance (dusting) is performed directly by populations on a volunteer basis. This management method does not address the issue of provisions to replace streetlights and can therefore be combined with the local authority method (for example, the population carries out basic maintenance on a volunteer basis; the local authority ring-fences savings to help replace components).

CHAPTER III : DESIGN

A. Writing the Tender: How to guarantee the organizational quality of the device?

The drafting of the Invitation to Tender (AO) is decisive in the conduct of the project downstream. This is the time to formally register the quality commitments to be implemented during implementation and operation, then to select the service provider or best able to respond systematically to the call for tenders.

The writing of the AO frequently focuses on a technical description of the products to be supplied and installed. The overall quality of the project is largely due to initial organization. It comes in three major angles to secure the quality of the project.
It is important for the buyer to specify in his specifications:

1. Redirect the Call of Tenders : How can the project's organizational quality be guanranteed?

The writing of calls for tenders often focuses on the technical description of products to be supplied and installed. However, the overall quality of the project often depends on its organizational structure. For optimal quality, the project should incorporate three major features.
It is important for the buyer to specify in his specifications:
1. The needs it seeks to satisfy such as the type of places to be lit, the required light intensity and uniformity, and the duration (all night, a predetermined number of hours, with or without a presence detector, etc.). He must indicate if he wishes possibilities of adjustments of the sought profile, to keep a relative flexibility of use of the products or not. It must also say if these needs can be automatically reduced during a certain number of days (during the difficult season) or not, so as to avoid a period of total blackout. He may also wish to have access to monitoring functions to monitor the operation of the installed park. With regard to the infrastructure management and operation phase, with a view to transferring and strengthening local capacities, the AO may stipulate the provision of simple maintenance equipment, for example LED systems for rapid diagnosis of possible malfunctions, as well as monitoring tools and remote warnings.

The dimensioning of the photovoltaic part must remain the responsibility of the supplier, since it directly impacts the notions of service rate, operation and maintenance, and component lifetime.
The mast height must also be determined by the supplier, especially for road use. Is it necessary to have lower and closer luminous points, or higher and more distant

streetlights: this optimization must be the responsibility of the supplier. Optionally, the beneficiary may need to impose a minimum or maximum height for issues of height above the tracks or safety.

2. The services expected

- **Delivery services :** this involves integrating and planning a set of services around the delivery of equipment. Actions to raise the awareness of decision-makers on the issues of maintenance and renewal of equipment can be put in place with local authorities and building owners. It is also recommended to include in the offer an operator training component, which could be a maintenance company or a local company.

- **Warranty conditions and After Sales Service (SAV):** it is the responsibility of the AO to define the framework for the sustainability of the infrastructure, through the terms of guarantees and After Sales Service (SAV). The aim is to realistically define the duration and conditions of the after-sales service, in particular the procedures for diagnosing faults that may be done in situ on the basis of photographs, but also the procedures for dismantling, repatriating, and replacing defective / worn parts. These tasks would ideally be handled by a local partner of the manufacturer who installed the equipment. The warranty period of the parts by the supplier is recommended at least 10 years, the challenge is to consider the system as a whole, and to make the guarantee on the service as a whole, and not on the operation of a component (ex: battery all alone). The client should pay particular attention to obtaining the following answers from the suppliers: what does the guarantee cover? Who is in charge of these different operations? Who pays for it? Under what conditions? For how long?

- **Practical maintenance training materials**, including robust and simple comprehension labels, as well as a user guide and instructional maintenance manual. This ancillary equipment may be essential in the event of changes to the maintenance teams, particularly the municipal board that may change after the elections. A complementary option to consider is that of «remote monitoring». This tool makes it possible to recover all the daily log of a product on a server, and to carry out a very precise diagnosis by the supplier. This option must be determined by the context and the ability of the owner to appropriate the tool.

- **Finally, an information and user awareness campaign** helps to prepare the ground for collective ownership. To this end, the ideal is to be grafted on existing community devices, emphasizing the functioning of public lighting and the challenges of sustainability.

3. Must provide information

▸ **The technical characteristics of the main components:**
- The photovoltaic generator: Power in Wc, voltage, etc.
- The luminaire and its matt: P Led in W, efficiency, T color, height of the mat …. as well as the duration of lighting, and the maximum energy consumption on a nocturnal cycle in Wh (cf the longest night).
- Battery: technology, voltage, C10 and / or C100 capacity, regulation, etc.
- The energy manager: adjustment of lighting automatisms or not, management of the charge / discharge battery, possibility of monitoring, etc.

▸ **A calculation note detailing the assumptions taken into account for simulations of multi-year operations, and the results obtained:**
- The «nominal service rate»: number of days or hours of nominal operation / number of days or annual hours
- Possibly, the «degraded service rate», by a reduction of the luminosity or the daily operating duration, intended to avoid a more complete rupture of the service.
- Possibly, the number of annual days of non-functioning
- The cycling and temperature conditions used to estimate the expected life of the batteries, and in fine the estimation of the life of the battery.

▸ **Prices, including all items:**
- supply of products, transport, customs, installation, operation and maintenance (availability of spare parts, response time), training of local staff, etc.

▸ **Equipment acceptance protocols:**
- Any substantial order must plan out a sampling for investing more specifically some streetlights. Lighting level, at different times in the night, will be part of features to be investigated thoroughly.
- Out-of-factory checks, delivery checks, acceptance tests in specialised test centers, acceptance conditions after installation, or even a certain time after receipt.

B. Decrypting bids: How can the technical quality of the lighting infrastructure be guaranteed?

The technical elements appearing below and the use of simple rules - as proposed in this document - are necessary to evaluate acutely the proposals of the manufacturers. Decision makers can entrust this technical analysis to a trusted third party expert organization.

Sizing consists of optimizing the system (characteristics of the different components, electricity management modes) taking into account the needs of users and local weather conditions. It allows to «guarantee» its proper functioning, ensuring:

- **In the short term**, the right energy balance (production / consumption), whatever the variations of the electrical need (lighting times vary according to the duration of the nights) and the solar resource according to the seasonal variations.

- **In the medium and long term**, the minimization of the irreversible aging of the battery.

The word «to guarantee» is in quotation marks, because this notion can only be statistical, considering the uncertainties related to the difficult meteorological sequences (number of consecutive days with weak sunshine), or periods of exceptional fouling.
Several combinations of components may be suitable.
Lighting and battery management strategies are very important. An example of lighting management is shown below.

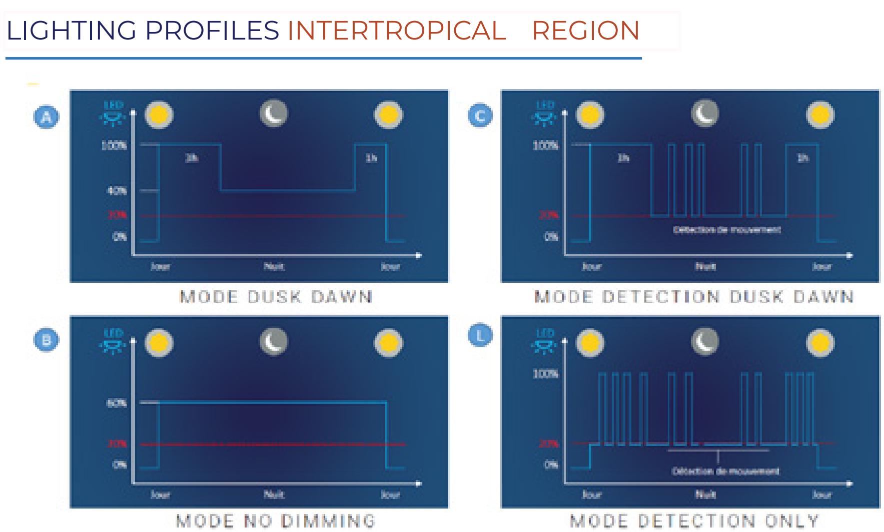


Figure 1 Lighting Profiles with Dimming and Detection Tools

The proposed solution must remain the responsibility of the supplier.
Some recommendations for the evaluation of tenders received:
Some criteria can be given to rule out the least relevant sizing for the intertropical zones on the basis of the information indicated by the supplier.

▸ **Criterion 1: Power of Modules / Luminaire Power:** The power of the modules must be greater than the power of the luminaire:
P module in Wc> P led in W.

This ratio «P module in Wc» / «P led in W» can be represented on the next graduated arrow

Sizing in the red zone should be avoided, the green zone is favorable, the yellow zone remains a risk zone.

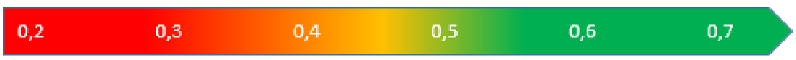
Since this first criterion does not take into account the intended use program, mainly the lighting duration, there is no other option but completing it by the following other criteria:

▸ **Criterion 2: Module Power / Daily Reference Consumption**
The ability to function during periods of low sunlight, in other words, for a few consecutive days with little sun, is an important criterion. For this, it is necessary to know the reference daily consumption, taken into account by the supplier to make the sizing of his product. It is calculated from the power of the led, and the operating program during the longest nights (12h or 13h), which correspond often in the least sunny periods and is expressed in Wh.

If the power of the modules divided by this reference daily energy consumption is less than 0.25, the luminaire will have difficulty in providing service during periods of low sunlight.

In equatorial zone, a ratio inferior to 0.2 is prohibited (red zone below)

In tropical zone, where seasons get worse, a ratio inferior to 0.3 is prohibited (red zone below).



▸ Criterion 3: Daily Reference Consumption / Nominal Capacity of the Battery :
The daily reference consumption divided by the nominal capacity (C5 or C10) of the battery will give an indication of the daily cycling rate, and therefore the lifetime potential of the battery.

For a given technology, a cycled battery daily at 30% discharge depth will last much longer than a 50% cycle battery.

The number of cycles, and therefore the service life, depends on the technologies chosen and the temperature conditions encountered. The strategies of management of the charges and discharges as well as their quality of manufacture are other influential parameters (see box, to know more about the batteries):

The battery will likely change in less than 3 years	Increased surveillance is expected beyond 3 years	The battery could last beyond 8 years, if the temperature conditions are not too severe, see box

* The only way to run a lead-acid battery is to limit the rate of cycling to 15%, which de facto condemns its economic interest

▸ The lifetime potential of the battery

Forecasting exactly battery lifetime is challenging. The degradation of the batteries varies according to their qualities according to their technological differences and their operating conditions which depend on the strategies of management of the charges and the discharges: the number and the duration of the cycles of discharge, the intensity of the currents of charge and discharge, temperature, are all parameters that affect the life of batteries.
As a whole it can be mentioned that lead technologies have been the first ever used technologies on a large scale, especially in the thermal powered car industry. Their technological dispersion is that wide that the way they cope with cycling can vary by 10. Nickel technologies have appeared later on with better cycling bore components. 10 years ago a yet new technology has appeared with lithium, invading mobile device and electrical vehicles.

In the context of solar streetlights, we can hardly be more perspective regarding the technology to use as many additional parameters have to be taken into account : maximum and minimum temperatures, device transportation, recycling.... The supplier is accountable for selecting the right components, for sizing, for deciding upon the energy management of the whole system, while aiming at the economically optimal service on the entire project lifetime.

Project managers must absolutely insist on the quality of selected batteries, as well as the management strategy, whatever the technology selected. These two parameters must be validated by preliminary tests, then tests in situ.
Given the diversity of contexts and possible solutions, it is not possible to specify more precisely a technology suitable for all scenarios. On the other hand, the vast majority of lead technologies will not be able to provide an interesting economic compromise for solar street lamp applications.

CHAPTER IV : IMPLEMENTATION

A. Installation: How to guarantee the quality of the service over time?

The infrastructure realization phase represents the first milestone in the implementation of quality criteria defined in the design of the IT. Three elements are to be promoted as a priority:

1. Local assembly
In order to strengthen local capacities, the local assembly of lampposts is highly recommended. Local assembly can be very beneficial if companies bring quality material, and they transfer their editing skills.

However, this step can be halted by the lack of matching between the inclinations of local companies and those of project promoters. It is necessary to choose the technicians who will participate in the assembly, making sure that they master the prerequisites.

It is important to qualify - in coordination with the client - the local operators in charge of the installation to justify his skills in public lighting on the following criteria:
- Experience
- CVs and Diplomas of employees
- Inventory of equipment available to installers
- Registration at the local Chamber of Commerce
-References

Setting up a school site with 3 phases - explain, show and then reproduce - upstream of the assembly allows the project to be carried out more efficiently. To ensure the success of the project, it is best to stay on a simple assembly: maximum 4 pieces - module, luminaire, mast, battery - basic electrical connections.

2. Quality Control

Immediate control
As pointed out in the specifications bill, five streetlights must be tested more specifically by a third independent technical centre after 15 days of use, to make sure streetlights have gone through several cycles. The test will control :
- Lighting levels to insure that the service complies all night long
- Compliance with the expected lighting programme

Documentation for long-term quality control
Following the installation, it is necessary to carry out a control and to formalize it by the production of a control documentation. This documented synthesis will allow monitoring throughout the project and will serve as a support for the project evaluation.

The portfolio of documents certifies the level of installation and details the performance of the installations in terms of level of illumination, uniformity, characteristics of the mast, the battery, etc. He presents the technical description of the equipment that has been installed in a clear and precise format, for example in the form of a control sheet per mast.
To facilitate this documentation, it may be wise to think about a system of referencing the masts, by GPS position numbering or barcode. This referencing could serve as a database gradually enriched by the description of each product, the control sheets after installation, the contacts of the installer and the controller, as well as monitoring the number of visits.

3. Phased-out installation stages

To guarantee the commitment over time, it is recommended to plan several phases of installation. This sequencing makes it possible to re-balance operating and maintenance costs, but also to learn from its mistakes during the project and to transmit a long-term training to the teams. Thus, a first pilot phase focuses on the gradual formation and evaluation of teams through demonstration and example. The second phase focuses on practice and reproduction. A third phase can even be considered for a complete empowerment of the actors. The sequencing of training in two stages, a first part without pre-requisites on the cleaning of the panel PB and the verrine protecting the LEDs, a second part with prerequisites on the diagnosis and the intervention in case of problem.

4. Payment terms

In the same way that the sequencing of the installation makes it possible to perpetuate the quality of the implementation, the payment deadlines encourage the sustainability of the projects and the implication of all the actors over the duration.
It is therefore recommended to put in place a 5% holdback, paid to the supplier only after at least one year of operation.
The guarantee must also cover the rate of service at the end of the guarantee or life, commonly known as «State of health».

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B. Maintenance: how to train Operation & Maintenance (O & M) technicians?

The knowledge, know-how and interpersonal skills essential to the maintenance of solar lighting equipment and services are only partially present among workers in sub-Saharan countries, so there is a need to ensure a transfer of skills to local workers to contribute to the sustainability of the equipment. Local labor must not only be trained but also sustained.

Tackling needs for local skills will require from social companies and project entrepreneurs as a whole to either build their own internal vocational training strategy or to partner up with local training centres, while participating to training content design where expertise is lacking. Following a careful methodology is key in both scenarii, from training need assessment to training design to skill transfer evaluation.

1. Training design

▸ **Assessing training needs :** The identification of training needs is a diligent but essential phase that helps setting out training objectives. It involves both qualifying and quantifying the gap between local skills (supply) and maintenance needs (demand). This phase is either based on past experiences from comparable projects or on an audit of necessary skills carried out in the field. Both approaches involve obtaining a list of skills needed to successfully carry out maintenance tasks. The simplest tool is a TTS (tasks, tools and skills) table, which is applied systematically to each task performed by maintenance technicians.

For innovative projects – projects mobilizing unique skills for which technicians have not received adequate training – this survey must be carried out in the field, and on an iterative basis. In other words, a technical expert must develop maintenance processes (tasks and tools), then observe how these processes are actually completed by technicians. By observing the tasks performed and skills mobilized, experts can adapt processes and pinpoint missing skills, thus identifying training needs.

A common pitfall is the “top-down” assessment of training needs – in other words, identifying needs on a theoretical basis, and often remotely. Failing to observe the skills available (or unavailable) among trainees (here, technicians) and making prior judgements about their skills can result in irrelevant training that produces incompetent trainees. This gives rise to technicians who are incapable of performing maintenance tasks, and managers who believe the contrary.
These considerations also apply to the identification of trainee target audience. Are technicians the only stakeholders likely to benefit when transferring the skills needed to correctly maintain lighting equipment? Would political decision-makers and investors also benefit from learning about maintenance issues and other factors in the lighting infrastructure to truly impact long-term performance?

▸ **Writing training content :** Training content is necessarily developed to meet the needs identified and must respect conditions observed in the field. This phase is crucial in producing well-written and appropriate deliverables, without which trainers may deviate or stick too closely to the programme, to the detriment of trainees. A key tool could be programme worksheets outlining the training themes, objectives and detailed outline. In this vein, several considerations should be kept in mind:

▸ **Content creation is more difficult than it appears:** Writing training content is very time-consuming. Content must also be updated regularly to take into account constantly evolving needs.

▸ **Content creation requires expert knowledge:** Writing training content requires knowledge of the design and delivery of educational material, which local operation teams may not have, despite their other areas of expertise.

▸ **Content creation is collaborative :** "We only transmit what we are." Experts master the relevant skills but do not know how to transmit their knowledge; educators know how to transmit knowledge but not specifically the relevant skills. They must work together to produce informative and transmissible content.

▸ o **Content creation requires human resources:** Training design – identifying training needs, writing content and implementing training sessions – requires dedicated human, material and temporal resources.

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2. Training implementation

▸ **Applicant sourcing:** Identifying the right profiles of candidates calls for three key elements.

It first falls down to avoiding typical restrictions regarding gender issues. Indeed, O&M technician training often targets a male audience, having therefore blinders on half of the potential labor market. Several tools can be put in place to encourage the widening of the target audience for the training, for example indicators of female participation in training, or minimum rates of gender diversity.

In a second step, it is important to match each type of training with a typical profile defined by skills, locality and linguistic items. This typical profile makes it possible to list predictive characteristics of a successful training. For example, in rural areas, it is necessary for the O&M technician to speak the local language to interact with the end-users.
Finally, the sourcing of candidates requires the identification of adequate distribution channels, designed specifically to rural area conditions. Depending on the location of the project, the search for candidates may go through local influential elites, or rather though the radio.

▸ **Training attractiveness :** Gathering motivated and willing candidates for training is not obvious. Membership in the training project is not given. Direct attractiveness lies in the cost of training. Compensating future technicians for transport, housing, food and equipment during training can be considered to overcome their low purchasing power c. Indirect attractiveness lies in the quality of content and interventions, in the potential certification to be obtained, and in the promise of a job.

▸ **Selective training :** Since it is extremely difficult to forejudge the skills of a candidate, the best way to retain only the most able to-be technicians and benefit from training to both train all applicants and use the training as an in-situ job interview. It is therefore recommended to train more individuals than necessary, and to keep only part of them to carry out the maintenance of the project. This method also makes it possible to spread training beyond the scope of the project.

▸ **The material and human resources of training :** to guarantee the quality of training, it is essential to invest in adequate equipment, ranging from training rooms to training courseware as well as dedicated technical platforms and housing for trainees. It is also essential to ensure the quality of the trainers by merging the roles of teachers and expert. The combination should rely on dedicated trainings of trainers in the aim to increase the technical skills of teachers, and the teaching skills of experts.

3. Sustain the trained workforce

The turnover is a failure resulting from three bad practices:

▸ The wrong selection of candidates during the phase of selective training
▸ The weak attractiveness of the job (direct remuneration and indirect remunerations)
▸ The non-adequate follow-up with people along the time (management and continuous training)leading to loss in both motivation and capacity to make sense of one's taks

To ensure the sustainability of the projects, it is necessary to first create a management committee who can supervise the continuity of the training and the effectiveness of the people trained over time.

How to ensure that trained technical people stay on site? Often they leave because, thanks to the short training undertaken, they easily find job elsewhere. The turnover can be seen as natural, liable to elections, and various hazards. One solution can be not to fight against the turnover, but adapt to it through an agile methodology. It is therefore essential to have teaching memos and simple maintenance equipment so that the transfer is done without problems, for example through a logbook to keep track of their progress.

If however one proejct's strategy is to train teams as a long-term investment, the allegiance of O&M teams relies on the guarantee of a stable job at the end of the training, and by the management of dedicated teams – hiring a manager could be a fruitful option. It may be beneficial to also offer a comprehensive career management based on continuous training and development prospects. Finally, the creation of a group of alumni in which circulate advice, training offers and job offers facilitate keeping track of trainees.

3 axes can be developed to keep the technical team loyal to the project.

1. Management and in-service training
▸ Involving stakeholders from the territory (municipality, county) to monitor the technical group;
▸ Making available a folder with all the contacts, belonging to the public body, of trained technicians
▸ Offering this document with all the contacts to project developers who act in the locality

a. Possibility for a trained technician by a company dedicated to installations in order to monitor streetlights from another company
b. Possibility for a technician to complement their competences of streetlight installation by acquiring knowledge about PV roofs
c. Two advantages for the technicians: development of additional skills, regular temporary work in a given locality
d. Three advantages for project developers: recruitment facilitated by the list, skilled technicians, work force immediately available for mid-term maintenance

- If the team is substantial and the logistics becomes important, it will be necessary to involve a manager- in the public body- in charge of monitoring and dispatching the technicians.

2- Direct remuneration: ensuring the salary meets the expectations of the local job market

3-Indirect payments

▸ Working material, social status, regularity and reliability of the salary, legality of the working conditions (this element can be a profoundly attractive matter in multiple African countries), compatibility between work and the personal activities (workplace, working timetable, etc.), motorbike license.

C. Recycling channels

The responsibility for recycling must be clearly established. Is the manufacturer responsible for material recycling? Is it the community? A recycling scheme must be planned at the very least for the collection and storage of batteries as well as other used equipment.
All four components of solar streetlights – PV module, battery, LED light, metal structure – need to be taken into account while assessing life cycle and end-of-life processes, keeping in mind chemicals likely to be harmful. Battery cells are a key issue of such recycling assessment, as they contain chemical elements for storing and distributing energy, and thus can be toxic.
Environmental charters and practical guidebooks dedicated to recycling exist and can be found on Recylum website. Project managers can get inspired from them to ensure both the supplier and the contracting authority commit jointly to virtuous recycling measures.


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CHAPTER V : EVALUATION

A. Project evaluation : how to assess projects' so¬cial and technicaland economic sustainability?

Project evaluation makes it possible to review and take stock of the progress of the project, from both a technical and a social angle. It comes down to checking the rightful respect of the specifications required by the technical pre-design then by the call for tenders, as well as the relevant implementation of devices to make the lighting infrastructure work. Two schemes are to be assessed: the technical schemes that guarantees the proper functioning of the streetlights, and the social scheme that measures the level of collective appropriation and the proper functioning of the organizational tools for maintenance. The evaluation points out a different consultation to ensure independence and objectivity of the stakeholders involved in the realization of the project and strives to work through local intermediaries.

1. The evaluation content

A project is evaluated under three aspects: : **(1)** whether the project deliverables meet the populations' expectations, **(2)** whether the project succeeded effectively in achieving all features of the preliminary design, and **(3)** whether the project has been led in an efficient and sustainable fashion.

(1) ▸ **Meeting the needs and expectations of the populations:** it is a question of ensuring that all the milestones of the project are coherent from the expression of needs to the delivery of the lighting infrastructure, as well as the design of the project through the call for tenders. If the set of stand-alone solar streetlights do not meet the needs of the beneficiaries, the performance of the set will not even be relevant. On the contrary, a project that matches the needs of the population will facilitate collective ownership, and therefore foster respect or defense of the lighting infrastructure project by the users, for example against attempted theft.

(2) ▸ **Project effectiveness:** this aspect aims at checking if all features of the preliminary design have been achieved. On the tracking and monitoring aspects, it is a question of verifying that all the documents necessary for the follow-up have been produced, ranging from the delivery report during commissioning to the completed control forms. It must be verified that the deadlines have been respected as well. As for the content, the assessment determines whether the skill transfer and the functioning of the lighting infrastructure are effective.

(3) ▸ **Efficiency and sustainability of the project:** there is nothing worse than meeting the needs of the populations but failing to have a working set of streetlights after one year. This situation creates counter-references and disappointed sun energy-averse stakeholders. It is therefore a question of verifying that the organizational and technical engineering of the streetlights lasts in time. Thus the three technical, social and economic aspects are to be assessed :

- On the social aspect, ensure the persistence of the training delivered, as well as its behavioral impact regarding work methodology and equipment choice
- On the technical side, check if the performance is consistent and stable with commissioning data
- On the economic side, draw up the financial balance sheet of the operation including the analysis of the various stages.

2. Evaluation methodology

▸ **Resource-persons :** the evaluation needs to be done by independent and objective intermediaries, no matter the evaluation is performed in the field or remotely. Beside not judging and being judged simultaneously, the evaluators require skills in social sciences and both quantitative and qualitative analysis of data, not necessarily mastered by project developers.

However, the evaluation needs to be done in the field and in cooperation with the different stakeholders involved, above all project developers, local governments involved and the project managers, aiming to ensure a complete immersion of the evaluators in the field context of the project.

▸ **Evaluation support:** Depending on the selected evaluation officer, a template to be completed as an evaluation campaign, or on the other hand a series of interviews. It should be noted that the evaluation requires a considerable upstream work of tracking and monitoring processes on which the evaluation has to be based, particularly the writing at the moment of the realization of material briefs.

▸ **Evaluation schedule:** several evaluation stages are ideally to be set up. The first stage focuses on verifying early technical results and on releasing the holdback. A second stage must be scheduled 3 years following the commissioning date to thoroughly qualify the technical and social sustainability of the project. A third evaluation 4 or 5 years after the commissioning date would be optimal in refining technical measurements, especially regarding battery performance and lifespan, and the social fabric of collective appropriation.

B. Impact measurement: how to measure the socio-economic impacts of the project in face of initial objectives?

Beyond the good progress of the project, it is also necessary to qualify and quantify to what extent the project fulfills its initial objectives, identified in the needs assessment stage. Impact measurement assesses the long-term footprint that the project will leave behind. This last step focuses on the social, environmental, and economic impacts of the project.

1. **Enact of the reference situation at the beginning of the project :** entrust an external consultant with conducting field surveys to assess the socio-economic situation in the project intervention areas. To this end, it is necessary to define a series of indicators such as:

▸ For security objectives, the number of thefts in the locality.
▸ For economic objectives, the number of income generating activities.
▸ For revitalizing and boosting objectives, the visit figures of the main places.
▸ Number of fossil fuel powered generators in use
▸ Perception of the involvement of local authorities

The consultant can be more or less directed for these studies: from providing him with a list of indicators, to entrusting him with questionnaires already elaborated.

2. **Measuring impacts at the very end of a project:** in this final stage, the same consultant is entrusted with carrying out similar surveys to measure the evolution of the indicators and therefore to draw up a report on the positive, neutral or negative impacts of the project in the locality.

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PRACTICAL RECOMMENDATIONS

solar streetlights

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