Towards a Locally Adapted Rural Electrification Assessment Framework: A Case Study of the Lao PDR

Julius Susanto[1,*] and Mattijs Smits[2,*]

[1] Lao Institute of Renewable Energy,
Vientiane, Lao PDR
[2] School of Geosciences, University of Sydney,
Sydney, Australia
*Corresponding author: julius@lao-ire.org

Abstract

Off-grid rural electrification is and will remain important in the Lao PDR, due to its difficult geography and low population density. The relative success of different off-grid rural electrification technologies, however, has often been disproportionate to the level of external financing and support received. Some technologies, such as solar home systems, receive significant financing and policy support, yet fail or perform at subpar levels. On the other hand, technologies such as pico-hydropower flourish without any external support whatsoever. This article assesses the different off-grid rural electrification technologies used in the Lao PDR and tries to identify the factors that lead to success (or failure). On the basis of a short literature review of existing frameworks, an existing rural electrification assessment framework is used and adapted to the Lao context. The main conclusions of the assessment suggest that while economic and institutional factors are important, consideration must also be given to the frequently neglected technical, supply chain and local capacity factors, which are crucial for appropriate rural electrification development and long-term sustainability. This also requires a more fundamental understanding of the way energy transitions relates to rural development at the local level.

Keywords: Lao PDR, rural electrification, assessment frameworks, off-grid

1. INTRODUCTION

Off-grid rural electrification (RE) is still an important alternative to grid extension, especially for remote communities where grid extension is often impractical and not cost-effective. Moreover, off-grid rural electrification can often make use of locally available renewable energy sources and thereby reduce the pressure on expensive and increasingly scarce fossil fuels, and reliance on controversial large hydropower developments.

In the Lao PDR (as in many other developing countries), there have been a number of off-grid RE programs and promotional activities initiated and funded by public and private agencies. Policy makers and program implementers typically view the success of RE projects through the prism of short term financial and / or technical success factors. However ongoing sustainability after implementation is often overlooked. At the same time, market-based initiatives have continued to develop independently of externally-funded programs.

Assessment of off-grid RE technologies has been fragmented, using different scoping, scaling and time frames. Moreover, assessment frameworks are often designed very generally and for single RE technologies, with little space to include local conditions. Finally, assessment frameworks are often produced by donor organisations, who are themselves also involved in the implementation of RE projects. Therefore, biases can arise towards project-based initiatives as opposed to autonomous or market-based developments, in particular when limited reliable data is available.

This paper investigates the assessment of off-grid RE technologies (e.g. solar, hydro, diesel, etc), with specific attention drawn to the Lao PDR. By focusing on off-grid RE technologies as a whole rather than individual projects, this paper addresses implementations driven by both external interventions ("top-down") and the market ("bottom-up"), with the aim of answering four key questions:

1. What are the existing frameworks to assess off-grid RE systems and what dimensions do these frameworks consider?
2. What are some of the shortcomings of these assessment frameworks and how can they be addressed with a locally adapted framework?
3. What are the results of applying the framework in the Lao PDR?
4. What are the policy recommendations for the Lao PDR as well as for the adaptation and use of RE assessment frameworks?

Section 2 reviews existing frameworks for evaluating off-grid RE technologies and develops the case for a locally adapted framework. Section 3 describes in detail the locally adapted framework that builds upon (and adapts) an existing assessment framework for the GMS region. Section 4 is the application of the locally adapted framework to off-grid RE technologies used in the Lao PDR. Section 5 offers conclusions from the application of the framework in the previous section. Section 6 outlines some policy implications as a result of applying the framework, and reflections on the use of assessment frameworks.

2. OFF-GRID RURAL ELECTRIFICATION ASSESSMENT FRAMEWORKS

2.1 Review of Existing Assessment Frameworks

There are various ways to assess off-grid rural electrification implementations, each having specific qualities and focusing on specific issues. Assessment frameworks tend to differ across three dimensions.
The first dimension is the *scale* of the assessment, varying

from project level to international strategic level. Assessments on project or field level are useful to evaluate the impact of specific projects, such as demonstration sites before they are scaled up, for example the mini-hybrid systems in [1]. On the other hand, assessments on national strategic level can identify broad patterns of development. An example from the Lao PDR of such an assessment can be found in Annex 9 (Economic and Financial Analysis) of the Rural Electrification Program phase 1 and 2 [5, 6].

The second dimension is the *scope* of the assessment, ranging from a single aspect of energy technology to several or a multi-dimensional assessment. Assessments focusing on single aspects typically focus on technical or economic issues, for example the ESMAP assessment in [2]. Other methodologies try to employ more holistic perspectives, focusing on several dimensions, such as Ilskog [4], who identifies five sustainability 'dimensions' of energy projects: technical, economical, social/ethical, environmental and institutional sustainability. Another example of a multi-dimensional type of assessment is the joint Winrock International and World Bank monitoring and evaluation tool, although that one has a specific focus on gender issues [3].

Finally, assessment frameworks differ in *time horizon*, from before the project (ex ante) assessments, to after the implementation (ex post). Alternatively, assessments can be done over a certain period of time or through the implementation of a project or a program. This is mostly relevant when considering individual projects. When proposing an assessment framework on a more strategic level, the time horizon becomes less relevant, because RE technologies are seen as part of the energy landscapes, not comprised of individual projects.

2.2 Selecting a Base Assessment Framework

Two comments need to be made that are of particular relevance for the adapted framework proposed in this paper. First of all, most of the above mentioned methodologies focus on projects, implemented by the government or external donor agencies. However, not all off-grid RE implementations are project based. For example, in the Lao PDR, many people implement their own off-grid RE systems using materials available on the open market. Adopting assessment methodologies that only focus on projects is likely to result in a negative bias towards non-project based technologies.

Related to this point is the tendency to look at projects in isolation, rather than looking at how the technologies fit into the local skill base and previous energy and electrification means. This is again especially relevant when looking at off-grid rural electrification, with the prospect of local ownership, maintenance and repair.

So in terms of scale, the framework proposed in this paper will focus more on the strategic level rather than that of individual projects. The scope will be multi-dimensional and as we do not look at individual projects, the time horizon is not really relevant for the proposed framework.

Ilskog's assessment methodology [4] was selected as the basis for the proposed adapted framework. It is the most holistic and multi-dimensional of the existing frameworks reviewed and is also flexible enough for adaptation and extension to local conditions.

3. LOCAL ADAPTATION OF ASSESSMENT FRAMEWORK TO THE LAO PDR

3.1 Why Local Adaptation?

Having identified some features of RE assessment frameworks, we now start to construct a new one. This is because it is necessary to adapt the assessment framework to the local context in order to capture specific conditions that make every country unique. This also reflects the need to see energy as integral part of rural development in general. In other words, energy systems should ideally fit seamlessly with the local livelihood conditions, to minimise the potential friction and maximise the technical and economic viability, local acceptance and ownership, and long-term sustainability.

The proposed adapted framework for the Lao PDR should be able to capture some specific features of the Lao context, such as the low population density, low GDP per capita, availability of cheap grid electrification from large-scale hydropower and high incidence of private off-grid electrification technologies and related local skill bases and networks.

3.2 Features of the Proposed Locally Adapted Assessment Framework

Like Ilskog's assessment framework, the proposed locally adapted framework is qualitative and is based around a set of assessment indicators. However most of Ilskog's indicators are only relevant for the assessment of individual RE *projects* as opposed to the assessment of RE *technologies* as a whole, and as a result, many indicators are omitted or adapted in the proposed framework. We also focus mainly on the technical and economic development indicators.

The proposed locally adapted assessment framework for off-grid RE technologies has the five following indicators:

a) **Capital costs** – how much it costs to build an off-grid RE system using the technology, and the extent to which external capital financing is required (e.g. donor funds, soft loans).

   Off-grid RE projects are typically unprofitable and therefore not very attractive to investors. The capital costs of off-grid RE projects are also largely influenced by the technology. Consequently, the higher the technology's capital cost and level of external financing required, the less likely it will be implemented beyond small scale demonstration projects.

b) **Operating costs** – how much it costs to operate and maintain a system using a particular technology (e.g. cost of consumables, fuel, spare parts and specialised labour).

c) **Complexity of the technology** – level of technical competence required to understand the technology and the extent to which damaged equipment can be repaired locally using locally sourced materials. Technologies that require a high level of technical expertise to understand are often the first to fail and remain in disrepair.

d) **Local capacity** – availability of local knowledge and support networks for the technology. Off-grid RE systems are typically installed in remote rural areas where local capacity and support networks (which can include local government / institutions) are crucial to maintain systems in good working order over time.

e) **Strength of the supply chain** – the ease with which replacement equipment, consumables, spare parts and technical expertise can be procured and shipped to the site. As many off-grid RE systems are installed in remote areas, technologies with well-established supply chains will have a better likelihood of wider adoption.

3.2 Limitations of the Proposed Framework

In this framework, the emphasis is on the technical and economic dimensions of the electrification options, but also some issues related to ownership and existing skills. This does not imply that we do not consider other dimensions, such as environmental sustainability, but these are not the main focal points addressed in this paper.

Moreover, the proposed framework does not address some of the major methodological and data collection issues related to the application of any framework. In general, any model or framework depends on what data is being used and how this is interpreted. In countries like the Lao PDR, good and reliable data is difficult to obtain and any kind of aggregated or secondary data should be treated with a healthy dose of scepticism.

Furthermore, some of the major ideological choices behind any kind of assessment framework are not addressed. Criteria such as sustainability can have different meaning for different actors. Even relatively straightforward indicators such as economic viability can show a very different outcome if one uses price per kWh, investment costs only, full load factor, real load factor, etc. These ideological choices necessarily involve a reduction of reality and reflect the priorities of the people / organisation, and are therefore intrinsically political.

4. APPLICATION TO OFF-GRID RURAL ELECTRIFICATION IN THE LAO PDR

4.1 Off-Grid Rural Electrification in the Lao PDR

Before applying the locally adapted assessment framework to the Lao PDR, some context regarding the local energy and off-grid RE situation is provided.

Despite having an abundance of hydropower resources and exporting over 2,315 GWh of electricity in 2008, only 63% of the Lao population have access to electricity (as at June 2009) [7]. The mountainous topography that makes for ideal hydropower conditions also makes it difficult to install power transmission and distribution lines. Moreover, the rural parts of the country are sparsely populated (less than 24 persons/km^2) and the rural population are on average economically poor.

The combination of difficult terrain, low population density and a poor target market also suggests that it is not economically feasible to build a fully comprehensive electricity network in the near or mid-term future. Therefore, to reach the Government of Laos (GoL) goal of 90% electrification rate by 2020, a significant number of households will need to be supplied electricity via off-grid sources (the GoL itself has stipulated a target of 10% by off-grid sources). Lao legislation defines off-grid sources as all electricity supplies that are either 1) below 2MW, 2) not administered by the state-owned domestic electricity supplier Electricite du Laos (EdL), or 3) have no interconnections to international grids.

4.2 Off-Grid Technologies Used in the Lao PDR

A number of off-grid rural electrification technologies are present in the Lao PDR, and there have been attempts in the past to harness these technologies with varying degrees of success.

a) Solar Photovoltaic
Solar PV for off-grid RE comes in three main forms:

1. Solar Home Systems (SHS): are household level systems and make up the majority of solar PV installations in the Lao PDR. A typical SHS consists of a solar panel connected to a rechargeable battery (via a charge controller) and then connected directly to DC loads. There are over 15,000 SHS installed throughout the country, mainly by the World Bank as part of its Rural Electrification Project Phase I [5] and Southern Provinces Rural Electrification Project [8]. The World Bank plans to implement another 10,000 SHS in phase 2 of the Rural Electrification Program [6]

2. Solar PV Mini-Grids: are larger scale solar PV systems designed to supply one or more villages. Solar PV mini-grids tend to be part of hybrid systems (either diesel or hydro). There are three solar PV mini-grids in the Lao PDR located in Oudomxay, Luang Prabang and Xiengkhouang provinces, all of which were funded by official development assistance grants.

3. Community PV: are typically used to provide standalone electricity for medical supplies and vaccine storage, schools, community lighting, etc. There are over 1,000 community PV systems throughout the country, mainly installed as part of larger rural development projects.

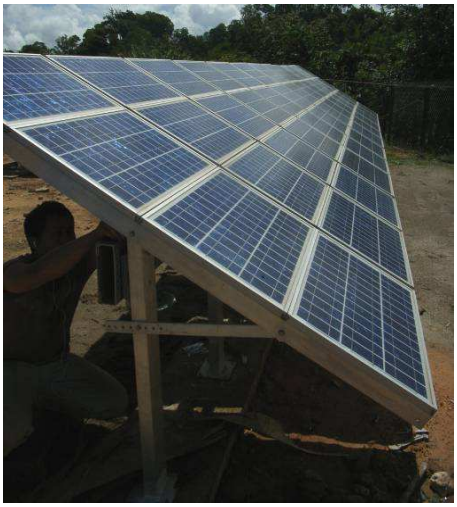

Fig. 1 Solar PV Mini-Grid in Luang Prabang

b) Micro-Hydropower

Micro-hydropower is defined as hydro-electricity generation with a rated capacity of between 5kW and 100kW. There have been a total of 31 micro hydropower facilities constructed in the Lao PDR, of which only 9 are currently operational (with a total installed capacity of 454kW) [7].

Most of these facilities operate isolated grids serving a village or a small collection of villages, although some facilities are or will be grid connected.

c) Pico-Hydropower

Pico-hydropower is defined as hydro-electricity generation with a rated capacity of under 5kW. It is typically used at the individual household level and is primarily market driven, with little external support from both public and private sponsors / investors.

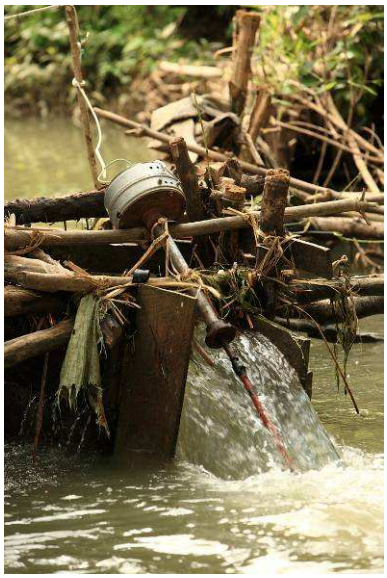

Fig. 2 Pico-hydropower turbine

Traders, typically from neighbouring China and Vietnam travel across the borders and sell cheap pico-hydropower turbines to shopkeepers at the major provincial markets. The shopkeepers then sell the units directly to the end-users. There are no official statistics on pico-hydropower in Lao PDR, but it is estimated that over 60,000 pico-hydro units are installed throughout the country [9]. The majority of these are installed in the mountainous and hilly northern provinces (Phongsaly, Houaphan, Xiengkhouang, Bokeo, Luangnamtha, Oudomxay and Sayaboulli).

d) Diesel Generators

Diesel generators for off-grid RE come in two main forms:

1. Medium-Large scale (>5kW): these are larger scale diesel generator sets that supply one or more villages. There are around 12 such systems still operating in the Lao PDR, all of them installed in the northern provinces.

2. Personal scale (<5kW): There are very few statistics on the use of small / personal scale diesel generators in Lao PDR. Anecdotal evidence suggests that diesel generator ownership is widespread (i.e. there are typically several generator sets in each village). However these generators may not be used particularly often due to the high cost of fuel. Diesel engines with alternators, such as those found in motor vehicles and agricultural machines (e.g. iron buffalo), can also be used as an electricity source.

e) Rechargeable Batteries

While households using automotive (or other rechargeable) batteries are not officially recognised as being “electrified”, it is a source of electricity that has widespread use. Car batteries are used typically to provide DC power for several hours of lighting at night and also for small portable appliances (e.g. radios). The use of smaller portable rechargeable batteries for the same purposes is also popular.

The batteries are normally recharged for a small fee at commercial battery charging enterprises, which either make use of small generator sets or are located at the end of a grid supply. Personal recharging is also known to be done, as is recharging using alternative sources, such as solar PV and pico-hydropower.

4.3 Applying the Locally Adapted Assessment Framework

The locally adapted assessment framework for off-grid RE technologies is applied to the Lao PDR, with a summary of the results shown in Table 1 below.

Table 1 Application of the locally adapted off-grid RE assessment framework to the Lao PDR

Technology	Capital Cost	Oper. Cost	Com-plexity	Local Capacity	Strength of Supply Chain
Solar SHS	Med	Low - Med	Med – High	Low	Low
Solar PV Mini-Grid	High	Med	High	Low	Low
Community Solar PV	Med	Low - Med	Med – High	Low	Low
Micro Hydropower	High	Low - Med	Med – High	Low	Low
Pico Hydropower	Low	Low	Low	Med - High	Med – High
Diesel Med-Large	Med – High	High	Med	High	High
Diesel (Small)	Low – Med	High	Med	High	High
Recharge-able Batteries	Low	Low	Low – Med	Med	Med – High

Solar photovoltaic (PV) RE technologies (solar home systems, mini-grids and community PV) tend to be relatively complex technologies comprising solid-state electronic components that are packaged into "black boxes" (e.g. charge controllers, inverters, etc). The idea behind this is that the potential for local, on-site repair of faulty equipment is minimal. However, local capacity is therefore also low and there are weak or sometimes non-existent support networks (both official and informal). SHS field evidence suggests that faulty components often remain unrepaired and batteries are poorly maintained and incorrectly charged [8]. Moreover, there is a weak supply chain for solar PV spare parts and equipment. The spare parts tend to be expensive and manufactured abroad. Spare parts are also typically stored in Vientiane Capital and shipping to remote areas is expensive and time consuming. Lastly, even if a rural community could access the supply chain, the capital cost of solar PV systems is high relative to its power output [2]. Despite these issues, solar PV remains a popular technology for off-grid RE, although it is driven entirely through external interventions (e.g. World Bank or other ODA).

Micro-hydropower suffers many of the same problems as solar PV. A modern village-scale run-of-the-river installation can be very complex inside the powerhouse, which typically contains a turbine, alternator, governor control system and unit control panel. Many installations will also have step-up / down transformers for power transmission. All of these components are single points of failure and can be difficult (if not impossible) to repair locally, especially some of the power system equipment. Furthermore, the technical expertise required to undertake major repairs or maintenance is high. Like solar PV, there is also no supply chain for spare parts and equipment and the availability of local capacity and support networks is low. These problems are illustrated in the following statistic – of the 31 micro-hydropower facilities built in the Lao PDR in the last 30 years (mainly off-grid), only 9 are still operational (a 71% failure rate).

Pico-hydropower is a low complexity technology with a local market and accompanying support networks that have developed over the last 20 years in the Lao PDR. Local capacity is high (especially in the northern provinces) because of its ubiquity and low complexity. Even in rural areas, the supply chain is strong with spare parts and equipment available at nearly all major provincial markets. The capital costs are affordable enough for many individual households to install their own system (or share with neighbours) and the operational costs are also low, although the turbines typically need to be replaced every 3-4 years. These advantageous features have seen pico-hydropower become a very popular off-grid RE technology, despite the absence of any external support or intervention.

Diesel generators, despite being of medium complexity, are nonetheless familiar to rural people due to the widespread use of diesel engines in motor vehicles and agricultural machines. In 2008, over 51% of the Lao population owned a motorcycle or car, suggesting that there is at least one motor vehicle per household. Local capacity is therefore high for motor vehicles and so is the strength of the supply chain. This translates directly to diesel generator capacity as the skills and spare parts required for repairing and maintaining motor vehicles and diesel generators are often interchangeable. Larger scale diesel generators are less popular due to their capital cost, but smaller scale generators, especially those that can serve multiple purposes (e.g. iron buffalo), remain popular. The high cost of diesel fuel limits the use of diesel generators for prolonged electricity generation, as do the noise and smoke emissions.

Rechargeable batteries are low to medium complexity technologies. The rechargeable batteries used are typically automotive lead-acid batteries, and the high level of local capacity and strong supply chain for motor vehicles in the Lao PDR also applies for the batteries. The capital cost for batteries are low and so are the recharging costs. This has led to the high incidence of battery ownership amongst un-electrified rural households.

5. CONCLUSION

In light of the continuing significance of off-grid rural electrification in places like the Lao PDR, this paper has discussed the elements of off-grid RE assessment frameworks. It also proposes a locally adapted framework, based on the framework of Ilskog [4], which focuses on capital costs, operating costs, complexity, local capacity, and strength of the supply chain. This framework has subsequently been applied to the main rural electrification technologies in the Lao PDR. The outcomes show that complexity of the technology and local capacity are important to understand the widespread adoption of pico-hydropower, rechargeable batteries and small diesel generators. Solar photovoltaic and micro-hydropower score much lower on these points, making these technologies vulnerable to failure. Indeed, this is a frequent problem with any kind of donor-funded rural electrification project.

This paper also points to crucial elements of assessment frameworks themselves. Firstly, it acknowledges that there are three main dimensions in which assessment networks differ: the scale, the scope and the time frame. Moreover, because assessment frameworks are abstractions from reality, they necessarily involve choices that emphasise certain aspects, and leave out others. In light of the highly politicised energy arena of the Lao PDR, it has to be recognised that every framework reflects certain ideologies, and can therefore be used politically. By drawing attention to these issues, while proposing a more symmetrical and less project / donor oriented assessment framework, this paper hopes to contribute to more equitable rural electrification development in the Lao PDR and elsewhere.

6. POLICY IMPLICATIONS

Address local capacity and supply chain issues for future off-grid solar photovoltaic and micro-hydropower RE projects
The assessment framework suggests that these technologies are susceptible to technical failure due to their complexity and a lack of local capacity and spare parts necessary for proper maintenance and repair. Off-grid solar PV and micro-hydropower projects are usually donor-driven and installed in a "fit and forget" manner, with minimal post-installation support and no access to spare parts. Care needs to be taken in designing a sustainable post-installation support programme and affordable supply chain for spare parts and equipment.

For micro-hydropower projects, commercial viability through grid connection should also be assessed, as this can provide incentives for professional level system maintenance.

Try to create conditions for the development of a market and capacity at the local level for off-grid rural electrification
The assessment framework points to the crucial importance of low complexity off-grid RE technologies and a high level of local capacity and a well-developed supply chain. Therefore, more effort should be made to the development of such conditions. For example, the import tax of solar home system components could be waived to improve the supply chain. Other market conditions are more complex to create, such as the creation of trust and standardisation of RE technologies. This is of particular importance in countries like the Lao PDR, where traders are often of non-Lao origin and RE equipment and manuals come in foreign (mostly Chinese) language.

Build upon the local skill base instead of focusing on technology transfer projects
The application of the locally adapted assessment framework shows that market-driven RE technologies are superior in terms of overall numbers and costs in the Lao PDR. It is therefore surprising that little effort has been made to use the favourable conditions and local knowledge and skill base as a starting point to provide rural electrification (for example, see the pico-hydropower initiatives in [10]). On the other hand, there have been various technology transfer projects, most of which have failed to live up to its promises.

Treat donor funded options and autonomous (market-based) developments symmetrically
One of the reasons for the discrepancy between the donor-funded and market-driven RE technologies in the Lao PDR has been the passive or active neglect of the latter group of electrification systems. The framework proposed in this paper tries to overcome this problem by treating all electrification systems symmetrically. In practice, this means that more effort has to be made to find out what systems are currently being used, as well as a field-based assessment of the economic and technical viability of systems, rather than factory- or laboratory-based figures.

Recognise local conditions when evaluating rural electrification options
The above mentioned policy recommendations all point to the fact that rural electrification systems cannot be seen outside of their geographical context, which includes the local economic, socio-cultural, meteorological, energy, and environmental conditions. Failing to recognise these circumstances will lead to skewed comparisons.

Link off-grid RE assessment frameworks to general energy and rural development assessments and strategies
To recognise the local conditions also implies that energy assessments cannot be seen in isolation from general rural development questions. Only when changes and choices in off-grid electrification are seen as part of the wider context of energy transitions and changing rural livelihoods, can their influence be understood in the right perspective. The danger of any assessment framework is that it oversimplifies local differences. We believe that the locally adapted RE assessment framework makes an important step in bridging the gap between a universal tool and its applications in unique local circumstances.

Recognise the intrinsic methodological choices and ideological choices in assessment frameworks
Although it is tempting to present any framework as objective or neutral, it would be better to recognise the intrinsic ideological and political motives which are hidden behind seemingly objective methodological choices in assessment frameworks. In addition, any kind of data should be scrutinised regarding the way the data was collected, as well as the scope of the research and the way the data is aggregated. Whereas these are general methodological insights, we believe that these issues are more pressing in the Lao PDR, because of its weak institutional developments and strong ideological drives of donor organisations as well as the government of Laos.

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