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Pro-Poor Electricity Provision

Maximisation of Benefits for the Poor of Investments in Renewable Electricity: A Policy Tool for Project Planning

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July 2014

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MAXIMISATION OF BENEFITS FOR THE POOR OF INVESTMENTS IN RENEWABLE ELECTRICITY: A POLICY TOOL FOR PROJECT PLANNING

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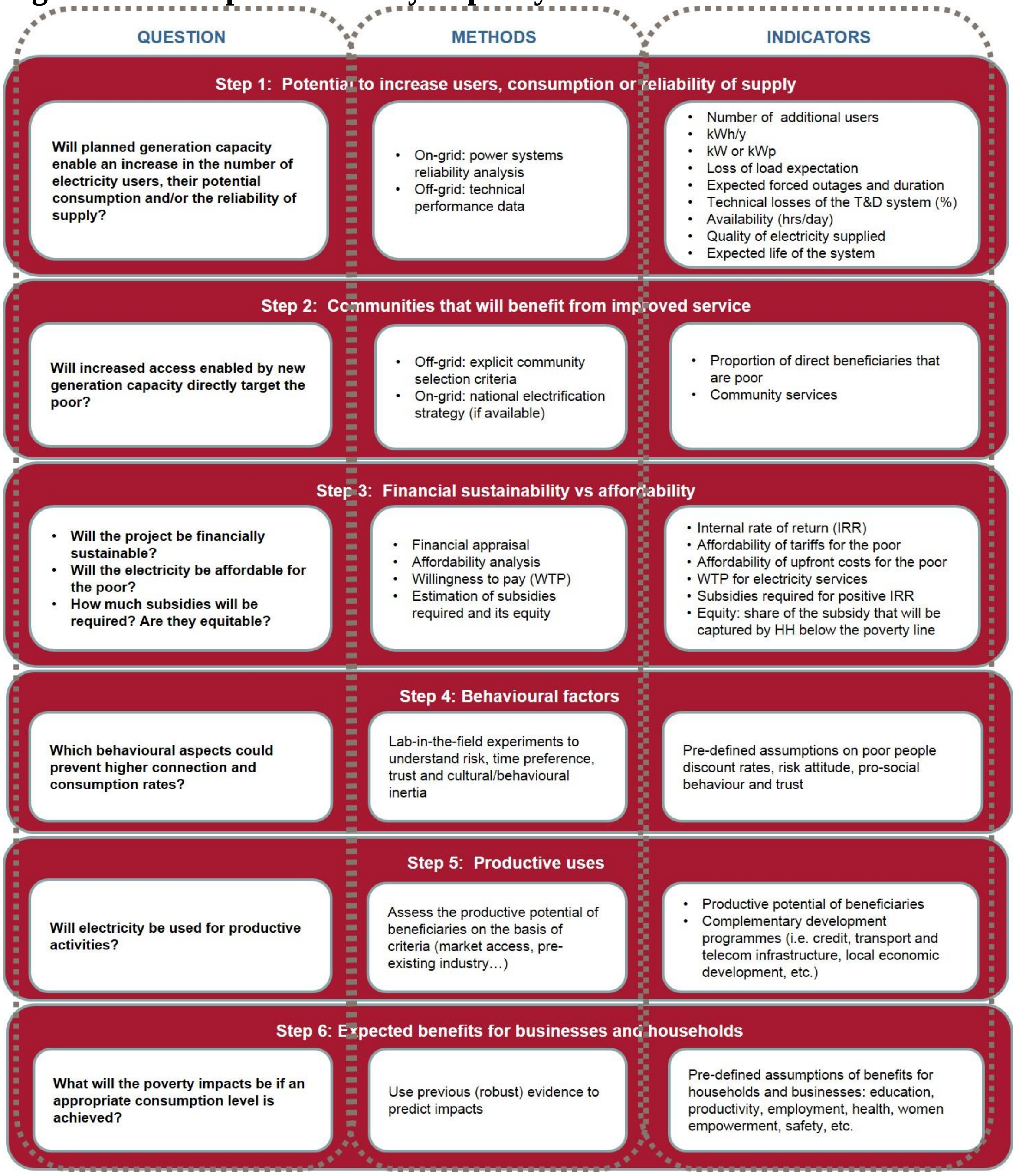
Executive Summary

Drawing on the results of a robust review of the evidence, we propose a policy tool to integrate poverty concerns into renewable electricity investment projects. A graphic summary is presented below. For each of the steps required to achieve poverty reduction through electrification, questions are posed, methods to answer them are proposed, and indicators are defined to appraise the project performance related to each specific issue.

Figure 0.1 Graphic summary of policy tool



QUESTION	METHODS	INDICATORS
Step 1: Potential to increase users, consumption or reliability of supply		
Will planned generation capacity enable an increase in the number of electricity users, their potential consumption and/or the reliability of supply?	• On-grid: power systems reliability analysis • Off-grid: technical performance data	• Number of additional users • kWh/y • kW or kWp • Loss of load expectation • Expected forced outages and duration • Technical losses of the T&D system (%) • Availability (hrs/day) • Quality of electricity supplied • Expected life of the system
Step 2: Communities that will benefit from improved service		
Will increased access enabled by new generation capacity directly target the poor?	• Off-grid: explicit community selection criteria • On-grid: national electrification strategy (if available)	• Proportion of direct beneficiaries that are poor • Community services
Step 3: Financial sustainability vs affordability		
• **Will the project be financially sustainable?** • **Will the electricity be affordable for the poor?** • **How much subsidies will be required? Are they equitable?**	• Financial appraisal • Affordability analysis • Willingness to pay (WTP) • Estimation of subsidies required and its equity	• Internal rate of return (IRR) • Affordability of tariffs for the poor • Affordability of upfront costs for the poor • WTP for electricity services • Subsidies required for positive IRR • Equity: share of the subsidy that will be captured by HH below the poverty line
Step 4: Behavioural factors		
Which behavioural aspects could prevent higher connection and consumption rates?	Lab-in-the-field experiments to understand risk, time preference, trust and cultural/behavioural inertia	Pre-defined assumptions on poor people discount rates, risk attitude, pro-social behaviour and trust
Step 5: Productive uses		
Will electricity be used for productive activities?	Assess the productive potential of beneficiaries on the basis of criteria (market access, pre-existing industry…)	• Productive potential of beneficiaries • Complementary development programmes (i.e. credit, transport and telecom infrastructure, local economic development, etc.)
Step 6: Expected benefits for businesses and households		
What will the poverty impacts be if an appropriate consumption level is achieved?	Use previous (robust) evidence to predict impacts	Pre-defined assumptions of benefits for households and businesses: education, productivity, employment, health, women empowerment, safety, etc.

1 Introduction

Energy poverty is a major development issue: nearly 1.2 billion people, or close to one-fifth of the world's population, have no access to electricity. Close to 85 per cent of them live in rural areas (Banerjee *et al.* 2013).

After falling out of favour in the 1980s, electrification is again seen as central to poverty reduction efforts. Electricity improves users' quality of life and can enable income generation when used for productive activities, hence supporting an escape from the poverty trap. Where generation comes from renewable sources, it also makes a positive contribution to low-carbon development; for many, this is a classic 'win-win' situation.

While increasing the supply of electricity can create significant effects on poverty, these are not automatic. Firstly, once electricity is generated, it needs to be reliably fed into the system. Off-grid solutions need to provide a durable and sufficient level of access to electricity. Secondly, this additional supply must be made accessible and affordable for the poor. With on-grid energy, this is a matter of grid connections and grid capacity and reliability. For off-grid energy, this is a question of situating the generating capacity in the right places. Thirdly, increased electricity consumption then needs to be used in ways that translate into poverty reduction. Fourthly and finally, increased electricity supply can also indirectly reduce poverty by boosting economic growth.

When planning electrification projects, decisions can be taken at each of these four steps that should lead to greater impacts on poverty. However, it is far from inevitable that these decisions will be taken.

This report uses the evidence collected through a comprehensive literature review to develop a policy tool to maximise the poverty impact of electrification projects. It can be of use for development and climate finance institutions funding renewable energy projects in developing countries, and keen to enhance the poverty impacts of these projects. Organised into six steps, for each step the proposed framework starts by posing a question for policymakers: for example, 'Will the additional energy supply be affordable for poor people'? Drawing on the evidence gathered in the literature review, it then proposes methods to answer these questions, and mechanisms to ensure that project design features are supportive. In the example given, this means explicitly assessing affordability thresholds and structuring the financial aspects of the project so that these thresholds are not breached.

While not always the case, it is important to understand the tensions that exist in some cases, for example: affordability versus financial sustainability; maximising the productive potential versus reaching the poorest communities. In such cases, the best outcomes will result from the best balance being struck. The tools developed in this report are explicitly designed to help get this balance right.

The fact that we are talking about renewable energy is both a challenge and an opportunity. It is a challenge in that it creates some technical difficulties (e.g. intermittent supply) and can be more expensive than fossil fuel alternatives, potentially compounding affordability concerns. There are also opportunities, however. Firstly, renewable energy offers a wider range of off-grid solutions, which are particularly well suited to rural areas in developing countries. Secondly, cost concerns can potentially be addressed through the access to climate finance that renewable energy offers.

Several funds have emerged or are under development to provide finance and catalyse private investment for the goals of sustainable energy for all and climate change mitigation. These include bilateral funds, such as the UK's International Climate Fund (ICF); multilateral funds under the United Nations Framework Convention on Climate Change (UNFCCC) umbrella, mainly the newly created Green Climate Fund (GCF); or outside the UNFCCC, such as the Climate Investment Funds (CIF) administered by the World Bank. These funds can be designed to address both greenhouse gas (GHG) emission reductions and poverty reduction. This has not happened with market mechanisms – mainly the clean development mechanism, that has instead focused on the technologies and the regions with the higher emission reduction potential, namely large scale and in emerging economies.

The proposed policy tool can support investors and donors to assess the poverty reduction potential of the electrification projects or programmes they fund through a set of performance indicators. The tool can also support ex post evaluations. Some of the proposed indicators are easy to gather; some others would require a significant effort. Practitioners may wish to apply each step of the framework in full. While this would be likely to lead to the greatest poverty impacts, there are also costs in terms of time and resources that need to be balanced against this. In other cases, there may be a more selective focus on a few of the elements that seem most important. In all cases, however, thinking through the issues set out in this report is likely to lead to better project design. By 'better', we mean projects that both increase the supply of renewable energy, and achieve the maximum possible poverty impacts in the process. The more that this can be mainstreamed into the standard practices of key agencies, the greater these developmental and environmental impacts will be.

2 STEP 1: Potential to increase users, consumption or reliability of supply

2.1 Description of the problem

The addition of renewable generation capacity will only achieve poverty impacts if it increases the number of people with improved access to electricity. A comprehensive definition of 'access to electricity' is provided in the *Global Tracking Framework* of the Sustainable Energy for All (SE4ALL) initiative (Banerjee *et al.* 2013), and includes both the quantity and quality of the supply and the use of electricity services based on ownership of appliances.

The relationship between additional capacity and improved access is relatively straightforward in off-grid systems. However, continuous maintenance is often forgotten in off-grid business models, which results in short-lived electricity supply and users' mistrust. The relationship between capacity and access is more complex for grid-connected generation units, as it depends on a number of factors such as: the type of low-carbon generation (e.g. intermittent vs. dispatchable); the location of the plant in relation to centres of demand; the layout, capacity and reliability properties of any network which links the new generation project to centres of demand; the distribution of demand through the day/week/year; the statistics of available renewable resource at different times of the day/week/year; and changes in the number of consumers, including not only legal network extension but also illegal connections (which are common in developing countries).

The first questions project planners need to answer are therefore:

1. Will planned generation capacity enable an increase in the number of electricity users, their potential consumption and/or the reliability of supply?
2. For how long will initial levels of generation and potential consumption be maintained?

2.2 Proposed method

Technical performance indicators are required to assess the expected improvement in supply of electricity attributable to on-grid and off-grid generation projects. Supply attributes that define different levels of access to electricity include quantity (peak available capacity), duration (hours per day), availability of evening supply (hours) and quality (voltage adequacy) (Banerjee *et al.* 2013).

These attributes can be directly ascertained in off-grid projects. Power system reliability analysis can predict the impact of additional on-grid capacity on the quantity and reliability of supply and final consumption. It also helps identify the weak links in the system.
A typical analysis for a given system would consist of the following stages (Dent *et al*. 2012):

1. Estimate probabilistic representations inputs such as demand, available generating capacity and network component availability at all relevant locations;
2. define model outputs, for example loss of load expectation (the mean number of periods in a year in which the system cannot meet all demand), or indices based on the frequency and mean duration of indices of a given severity;
3. specify a mathematical model linking the outputs to inputs;

4. either write computer code, or use commercial software, to evaluate the outputs for given input data.

As an example, in a system with both renewable and conventional generation, a standard reliability of supply index would be the loss of load probability (LOLP – the probability that not all demand can be met) at a snapshot in time. Assuming the network places no restriction on demand security, the snapshot margin of available supply over demand may be expressed as

$$Z = X + Y - D$$

where X is available conventional capacity, Y is available renewable capacity and D is demand (all random variables). The LOLP is then

$$[\mathrm{LOLP}] = P(Z < 0)$$

and it is possible also to define (e.g.) metrics for the capacity value of the renewable resource, such as the equivalent firm capacity (EFC – the perfectly reliable generating capacity that would give the same risk level if it replaced the renewable resource):

$$P(X + Y < D) = P(X + [\mathrm{EFC}] < D)$$

These basic principles of how to perform reliability assessments are universal. However, there are two key differences which must be considered in designing methodologies in developing countries:

- **Data availability.** Most developed country electricity industries have well-established systems for collecting reliability data, and hence have substantial information with which to estimate the relevant probability distributions for system reliability analysis. They have also put considerable investment into renewable resource data assessment. Good data on the state of networks, reliability and number of consumers may not be available in developing countries[1] – and in particular data availability to donors on individual systems may be poor. These data issues may require more extensive uncertainty analysis, and may also affect judgements as to the appropriate probability model structure (e.g. it might not be worth including very fine detail if the data simply do not exist).
- **Design of reliability indices.** Reliability indices in developed countries are based on the premise that all customers receive all of their demand almost all of the time – this is expressed in concepts such as the loss of load probability, or the value of lost load. In developing country systems, there may be no times at which all demand may be supplied, and hence the question turns around into the value of having supply at all at a particular time (not the cost of interruptions). Different model outputs will therefore have to be developed, along with different methods of evaluation. In particular, it might be necessary to include some consideration in the outputs of how a limited supply is shared between customers or between classes of use.

When there is not enough time or budget in the investment planning process to undertake a power system reliability analysis, we recommend using World Bank indicators on

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[1] For example, for many countries the only source of data on the reliability of electricity supply are the World Bank's *Enterprise Surveys.*

technical losses of the national electricity grid to estimate the actual amount of electricity that will reach final consumers.

Off-grid electrification business models should consider how to deal systematically with battery replacement costs, repairs and maintenance, and replacement of electronic regulatory devices and appliances in a sustainable and affordable way for the target population.

2.3 Key performance indicators

The new project should be able to address the mismatch between demand for and supply of generation, transmission, and distribution capacity in its host country. Some output indicators to show this include:

- Additional number of users/households fed by the new project;[2]
- nominal power (kilowatt – kW) or peak power availability (kilowatt peak – kWp);
- additional final electricity consumption (kilowatt hour – kWh) enabled by the project;
- loss of load expectation;[3]
- number of forced outages and outage duration;
- availability of electricity (number of hours per day);
- quality of the electricity supplied (voltage and frequency fluctuation);
- technical losses of the national grid;
- expected life of the system and maintenance plan.

2.4 Policy levers

Funders of renewable generation capacity can influence projects’ abilities to provide access to a large number of poor people by:

- Favouring locations for grid-connected renewable generation capacity that are close to low-income centres of demand;
- conditioning investment in grid-connected renewable generation capacity to a reduction in electric power transmission and distribution losses (in per cent);[4]
- requesting a sufficient capacity and reliability of the transmission and distribution network linking the new generation project to centres of demand;
- requesting off-grid electrification project developers to implement maintenance plans that consider battery replacement, repairs and maintenance, as well as replacement of electronic regulatory devices and appliances.

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[2] Included in the Department for International Development’s (DFID), International Climate Fund’s key performance 'indicators (KPI), but only for off-grid systems.

[3] Expected number of periods (hours or days) in a year in which the system cannot meet all demand because of a generation capacity deficiency.

[4] Indicator available at the World Bank Databank – http://data.worldbank.org/indicator/EG.ELC.LOSS.ZS.

3 STEP 2: Communities that will benefit from improved service

3.1 Description of the problem

Predicting the effect of increased renewable generation capacity for the poor in a specific country requires an understanding of how choices are made about which communities get increased access.

The decision as to which communities to electrify has strong economic and political elements. Public utilities traditionally have been highly politicised and have concentrated their services on urban elites or other powerful voting blocs, often neglecting the poorest populations (Watson *et al*. 2012; Victor 2005). International donors, following the World Bank approach, often chose the communities that provided the highest chances of cost recovery: close to the existing grid, densely populated, with high average income and productive potential (World Bank 2008). Evidence from the World Bank (*ibid.*) shows that only a minority of projects use a social allocation rule that gives preference to deprived areas or looks for geographical balance, regardless of economic criteria. For mini-grids, large and densely populated communities, where there is a pre-existing ‘anchor load’ to purchase a good share of the electricity from the outset, have the higher potential to reach financial viability.

The potential to reach the poor increases in those communities with social services, such as schools and health centres.

This section will support project planners to answer the following question:

1. Will increased access enabled by new generation capacity directly target the poor?

Provision of electricity to the most dynamic and better-off communities can also have a positive indirect effect on the poor if it generates growth, employment and an increase in average incomes. But these indirect effects may only happen if a number of factors are in place, as described in Step 5 about productive uses.

3.2 Proposed method

The potential for renewable electricity generation to directly improve poor people’s quality of life is higher when poor people are explicitly targeted as final consumers.

Targeted communities are easy to identify in off-grid generation projects. Community selection criteria should be made explicit for *ex ante* evaluations of poverty impacts. Project beneficiaries’ income level data as compared to the national poverty line could be obtained as part of project reporting, or from household survey data available for the targeted communities.

For on-grid generation, the final beneficiaries of new renewable capacity cannot be ascertained. Power system analysis (as per Step 1) can give an indication of the expected number of beneficiaries and the quality and reliability of supply. Who actually gets access depends on each country’s strategy to improve connection rates and on the politicisation of energy service delivery, which may cause politically powerful groups to set the agenda.

Communities that are likely to gain improved access to electricity can be identified in coordination with the national utilities providing transmission and distribution services. Many countries have developed rural electrification strategies and plans showing their approach to improve electrification rates and the way communities are prioritised. Such a strategy will show if increases in connection rates are expected to come through intensification of access or grid extension. Intensification of access involves providing an improved service to existing customers or enabling further connections in already electrified communities. Grid extension plans involve increasing the number of electrified communities and can follow different criteria, mainly cost-effectiveness and social allocation. Grid extension plans following a cost-effectiveness approach target communities where costs are lower; these communities are typically close to the grid, densely populated and with high average income. A social allocation approach would instead explicitly target deprived or remote communities.

The final impact of these strategies on the poor depends on whether they are mostly located in electrified or un-electrified communities. Extensification will achieve maximum impact in countries where most poor people live outside the range of the transmission and distribution network. For countries where the grid is available for most of the rural population but connection rates are still low, intensive growth could be more appropriate to target the poor through, for example, a lower connection fee for late connectors and increasing and diversifying patterns of electricity use. Finally, there will be areas beyond the reach of the grid for which only off-grid connections are financially viable (World Bank 2008).

Countries that do not adhere to a transparent rural electrification strategy may require a political economy analysis to disentangle the power struggles and vested interests that determine the communities that gain access to the grid. A political economy analysis will identify the alignments of interest or alliances that define priorities in providing access to electricity by showing actors involved, the levels at which they operate, their priorities and the policy processes that they influence. A good compilation of political economy tools available to development agencies for sectoral political analysis is provided in a Practice Paper produced by Department for International Development (2009).

A geographical analysis of poverty rates in the host country will reveal to what extent the new electricity generation project is expected to target the poor. Income levels of the communities that are planned to receive access to electricity according to the rural electrification strategy, can be obtained from national household surveys.

For off-grid projects where the final users can be easily identified, electricity is more likely to reach the poor even if they are not connected, in communities that have social services that will benefit from improved supply. A detail of existing or planned community services, such as health centres and schools, will provide valuable information about the potential reach of electricity supply.

3.3 Key performance indicators

- Proportion of users that are poor (using a country-specific poverty line);[5]
- detail of existing or planned community services that will get access to electricity.

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[5] Included among DFID's key performance indicators.

3.4 Policy levers

Funders of renewable generation capacity can influence projects' abilities to directly target poor people by:

- Requesting for off-grid project developers to introduce social requirements in the selection criteria for target communities. This could involve the specific targeting of populations below an income level or targeting communities with a high number of potential indirect beneficiaries below an income level;
- requesting that governments looking for funds for on-grid renewable energy generation projects have in place transparent rural electrification strategies that target the poor;
- having a coordinated approach for the provision of community services (mainly health and education) in addition to electricity.

4 STEP 3: Financial sustainability versus affordability

4.1 Description of the problem

The poverty impacts of access to electricity are cumulative, both in terms of the level and range of benefits to individuals and households, and the number of people who receive these benefits. Creating new electricity generation capacity is the start of this process, not the end. For the long-term poverty benefits of this expanded supply to be realised, it needs to be reliably maintained and efficiently managed. This requires generation, transmission and distribution companies to be operating in a financially sustainable manner, avoiding unsustainable subsidised tariffs and poor management.

Financial sustainability is just one side of the equation, however. As well as being generated by a financially sustainable company, electricity needs to be affordable to the poor. If this is not the case, while we might see indirect impacts on poverty via economic growth, the direct poverty impacts that this policy tool focuses on will be severely constrained.

The literature strongly and consistently reports the problem of financial barriers to increased connection and use. Key barriers are the low incomes of users and upfront costs of electricity, including unaffordable connection fees or the price of home systems, internal wiring and electrical equipment. Electricity tariffs are less frequently reported as a barrier to initial connection costs and increased use, because poor people are usually already spending a significant share of their income in alternative energy sources such as kerosene. Some evidence suggests a willingness to pay for high-quality and affordable electricity services at prices that can cover operation and maintenance costs, even in the poorer and more rural communities. However, willingness to pay does not mean capacity to pay, which is related to affordability of upfront costs and service tariffs.

There is a trade-off here: the lower the level of tariffs and fees the more affordable the electricity, but the generating company may be less financially sustainable. We are therefore faced with a delicate balancing act.

This section will support project planners to answer the following questions:

1. Will the project be financially sustainable?
2. Will the electricity provided be affordable for the poor?
3. How much in subsidies will be required to reconcile financial sustainability and affordability? Are they equitable?

This is not just a straightforward commercial question of market size, revenues and costs, although these elements are very important. As we shall see, the planner may have additional tools in her toolkit, which may be deployed to adjust the balance in favour of maximising poverty impacts.

4.2 Proposed methods

4.2.1 Financial sustainability

In many respects the financial sustainability of electricity generation projects is no different from any other financial appraisal. Different institutions will have their own particular approach, but these largely cover the same ground. Here we outline a generic format.

The first step is to assess the **economic and political context** within which the project will take place. On the economic side, key factors to consider are current and projected rates of inflation, and macroeconomic stability more generally. Politically, it is important to assess the breadth and depth of political support for the project. For on-grid generation, the viability of the project will be strongly influenced by the power purchase agreement (PPA). As well as being set at a sufficient level in terms of revenue, the credibility of the PPA is also important.

The second step is to assess the **project and financial management**. For the former, planners should undertake standard due diligence on the experience and capacity of the developers to manage the project successfully. For the latter, the planner should, using relevant benchmarks, assess the quality and appropriateness of financial management systems, accounting and bookkeeping systems, data and IT systems, and internal and external controls and checks on these systems. In practice, this will require the assessment of a range of systems and processes.[6]

The third step is to **forecast annual costs** over the lifetime of the project. Relevant variables are: fixed capital costs (distinguishing between foreign and domestic currency expenditures); operating and maintenance (O&M) costs; the cost of capital (annual interest payments and scheduled loan repayments); and depreciation.

The fourth step is to **forecast annual revenues**. Here we need to distinguish between off- and on-grid generation. In both cases we start with estimates of the total electricity production per year. For off-grid production, we then estimate customer numbers, proposed connection fees and tariff rates, estimated usage, and total revenues. For on-grid production it is not possible to identify end users, and revenues largely depend on the national tariff system and the particular terms of the PPA, as well as the solvency of final consumers. When estimating both costs and revenues, it is essential to incorporate the degree of uncertainty into the forecasts.

The fifth step is to use cost and revenue estimates to construct **income and cash flow statements,** and calculate the project's **internal rate of return (IRR).** To be financially viable, a project must have a positive IRR. A positive IRR requires tariffs that allow recovery of capital and operational costs.

Thus far, this is similar to the financial appraisal of any infrastructure project. The goal is not just to generate electricity, however, but to maximise the impacts on poverty of this increased supply. As a result of relatively high capital costs of renewable energy production, low density of demand and difficulties of access to rural populations, rural electrification projects with renewable energies usually require high connection fees and

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[6] For example: planning and budgeting records; payroll records; accounts payable; accounts receivable; taxes and duties; inventories; project accounting records; ledger systems; bank accounts and reconciliations; equity records; subsidies received; loans received and payments made; loans advanced; cash management; asset records; internal controls and audit procedures; periodic and annual financial statements; and external auditors' reports.

consumption tariffs which may be unaffordable for the poorest populations. Subsidies, of one kind or another, are therefore usually required to produce a positive IRR for the project.

4.2.2 Affordability

Affordability of infrastructure services can be measured as the share of payments for utilities, such as electricity, district heating and water, in total household expenditures. Affordability of electricity not only concerns the consumption bill, but also upfront costs including connection fees and the investments in internal wiring and basic appliances necessary to turn electricity into energy services. In regard to upfront costs, transaction costs and delayed revenues as a result of the long process to get a connection should be taken into account in addition to the actual fees.

Affordability of consumption tariffs

Affordability can be measured as the percentage of households that are able to purchase a subsistence level of consumption at the prevailing average effective tariff, without spending more than a given threshold of their household budgets (Briceño-Garmendia and Shkaratan 2010). Alternatively, we can define ‘affordable’ as a tariff that allows the poorest quintile of the population to purchase a subsistence level of consumption with less than a given threshold of their household budget.

Four key figures are needed to define the affordability of electricity tariffs: household budget, proposed tariff, the subsistence level of electricity consumption, and the threshold of electricity payments as a percentage of the household budget above which electricity is considered unaffordable.

Household budgets are best estimated through monthly expenditure data, which can be gathered through annual household surveys. Expenditure data are considered more precise than income data because they can capture revenue from informal activity, which can be quite high in developing countries (Fankhauser and Tepic 2007).

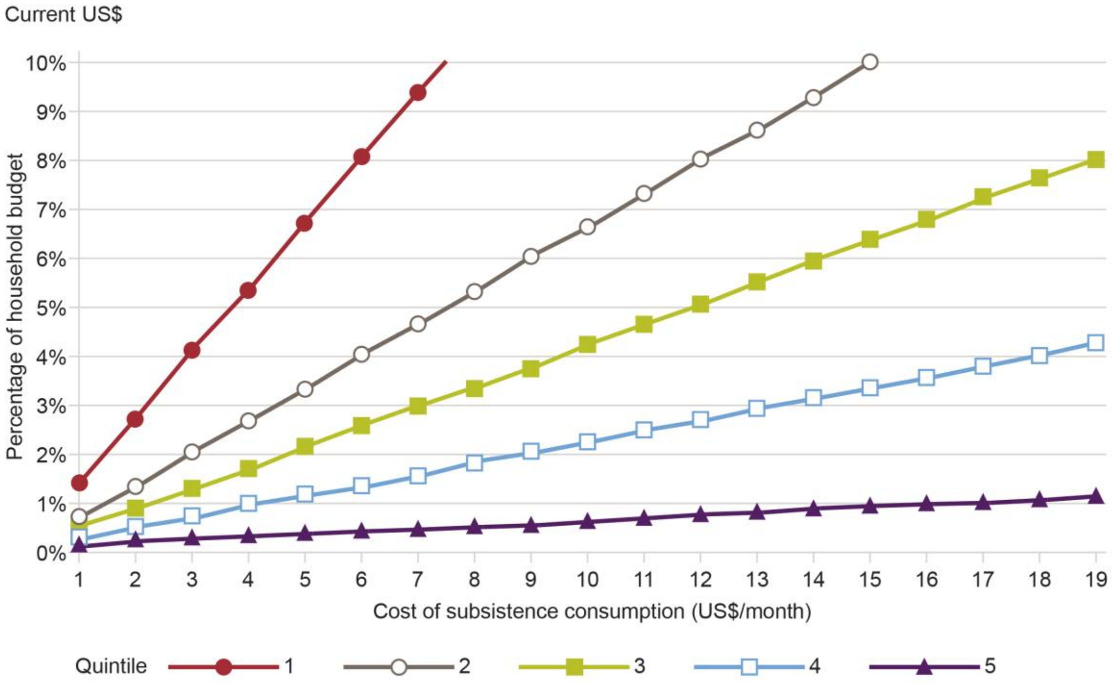
For proposed tariffs, off-grid projects have flexibility to determine tariffs that cover capital and operational costs. However, on-grid projects are typically limited by the national tariff system.

The definition of subsistence levels of electricity consumption and an acceptable threshold for utility expenditures ultimately require a value of judgement, and thus it is crucial to understand the context of the project to define the threshold. We suggest values often used in the literature but these can be adapted to the project context.

Subsistence consumption of electricity ranges from 25 kWh per month (supporting use of two 100-watt light bulbs for four hours each day) to 50 kWh per month (supporting limited use of an additional appliance, such as a radio) (Banerjee *et al*. 2008).

Governments and international financial institutions generally set ten per cent as an acceptable threshold of electricity expenditure as a percentage of total expenditure (Fankhauser and Tepic 2007). Banerjee *et al.* (2008) and Briceño-Garmendia and Shkaratan (2010) refer to a five per cent threshold based on historic trends of household expenditure patterns and results of willingness to pay surveys in Africa. Figure 4.1, taken from Banerjee *et al*. (2008), demonstrates the relationship between actual expenditure on infrastructure services and the proportion of total household expenditure this represents for a given income quintile across the African continent.

Figure 4.1 Share of average urban household budget required to purchase subsistence amounts of piped water and electricity, by continental income quintiles



Source: Banerjee *et al.* (2008).

For example, for the poorest quintile (1), infrastructure services would remain affordable (below the five per cent expenditure threshold) if they are priced below US$4. The study found that between one-third and two-thirds of the urban population would face difficulties in paying tariffs to cover the cost of electricity. According to best estimates, most households should be able to afford monthly charges of around US$2 (based on a low-cost tariff of US$0.08 per kWh and absolute minimum consumption of 25 kWh) for any given infrastructure service, but charges of US$10 per month are prohibitive for the majority. Thus, it is likely that governments would have to subsidise part of the costs to service providers.

Affordability of upfront costs

A number of studies have highlighted upfront costs as a more significant barrier to accessing electricity than monthly bills. However, affordability thresholds for one-off upfront costs are less clearly defined than for tariffs. The evidence tends to be fairly localised and anecdotal. For example, in a rural electrification project in the Philippines, connection fees at 70–150 per cent of average monthly incomes were prohibitively expensive (Asian Development Bank 2005). Even when subsidised in Benin, fees were still too high at 50 per cent of average monthly incomes (African Development Bank 2011). Winkler (2011) reports that in the case of South Africa, a connection fee of US$50 was not widely affordable and in Bangladesh close to half of households considered a US$40 connection fee to be high. Existing literature often does not take into account the costs of wiring and appliances when assessing affordability of upfront costs.

We suggest that estimations of upfront costs include connection costs, internal wiring, and a number of appliances consistent with subsistence consumption of electricity as defined above for monthly bill affordability: two light bulbs and an additional appliance such as a radio or mobile phone. For off-grid solar home systems, upfront costs would consist of the initial purchase price of the whole system, including lighting, and an additional appliance chargeable with the system. These can be expressed as a percentage of monthly expenditure to assess affordability. However, setting a single affordability threshold for upfront costs is difficult, because the ability to pay might vary dramatically between different communities due to, for example, the presence or absence of access to finance or any safe place to save money. Therefore, it would seem prudent to determine the ability to pay for the connection fee and appliances on a case-by-case basis.

In addition to these, the transaction costs and the lost revenue for businesses that result from long and cumbersome application processes for an electricity connection should be taken into account for on-grid generation projects. A good estimation of these is provided by the World Bank *Doing Business* indicators on the process a private business must go through to obtain an electricity connection. They include the number of days and procedures required to obtain a connection, in addition to connection fees and installation costs (World Bank 2010).

Willingness to pay

Willingness to pay methods can also measure affordability by calculating the levels of tariff increases that would be acceptable for the final consumers.

Willingness to pay can be measured in various ways, one of which being a survey that reveals stated preferences through questions on willingness to pay for levels and types of service. Households are asked a number of questions regarding their preferences, such as whether they would agree to a specified monthly increase in their electricity bill in exchange for improved service reliability. Stated preferences are often not ideal because respondents may be reluctant to reveal their actual willingness to pay higher prices if they believe it may result in a future raise in tariffs. This outcome can be avoided by analysing actual energy expenditure data from household surveys, which details revealed preferences. A quick survey on energy use including questions on fuel sources, appliances and end uses, hours of use and time of the day used, will provide the current expenditures on energy and may provide a proxy for willingness to pay. As it is likely that electricity will not be used for cooking, the surveys should not focus on cooking fuels.

4.2.3 Subsidies required to balance financial sustainability and affordability

Balancing affordability and financial sustainability of renewable electricity generation projects often requires some kind of capital or tariff subsidies. In particular, figures shown in the literature suggest that connection fees at commercial rates are unlikely to be compatible with affordability, and a subsidy for these and for electrical appliances will be required, particularly for the poorest.

For off-grid projects, the literature shows that capital subsidies and tariffs that allow cost recovery are the most effective way to achieve financial sustainability and affordability, as there is a willingness to pay for good quality energy services.

On-grid projects may also require capital subsidies, loans or grants from international development institutions to break even. The projects usually have less flexibility in determining tariffs that allow cost recovery, as they are subject to national tariff systems and the specific terms of their PPA. National tariffs should be designed to ensure economic sustainability or revenue sufficiency, but this is not always the case. In defining national tariff structures, regulators face a conflict between promoting economic efficiency and equity of access. Besides, electricity ratemaking can be used as a very valuable political tool (Pérez-Arriaga 2013).

The regulator may implement subsidies to enable low-income consumers to access electric power, which is considered as a basic need. Two forms of subsidies are implemented in standard international practice (Pérez-Arriaga 2013):

- Subsidies integrated in the tariff or cross-subsidies, often progressive, with higher consumption brackets paying a higher price and hence subsidising the low prices of the lowest consumption brackets. This is unadvisable from the standpoint of economic efficiency. Very often these subsidies are not equitable as power connections are highly skewed toward more affluent households (Briceño-Garmendia and Shkaratan 2010). However, when connection rates are high at the country level, cross-subsidies can be useful to cover for the higher distribution and maintenance costs of isolated areas (Acciona Microenergia 2013).
- Tariff independent, explicit subsidies, identifying the beneficiary communities and establishing direct payments to cover the cost of their electricity. They can be designed to cover upfront costs instead of the electricity bill, as the former are considered a more significant barrier to connection than the latter. These types of subsidies are more efficient and equitable than cross-subsidies, but carry the cost of identifying and reaching the beneficiaries.

The equity of subsidies to power consumption can be measured as the share of the subsidy captured by households living under the poverty line divided by the percentage of households in the population that live under the poverty line. A value greater than one implies that the subsidy distribution is progressive (pro-poor), because the share of benefits allocated to the poor is larger than their share of the total population. A value less than one implies that the distribution is regressive (pro-rich) (Briceño-Garmendia and Shkaratan 2010).

In addition to these subsidies, renewable energy technologies also tend to require an extra payment for the energy generated through price instruments, mainly feed-in tariffs (FITs) and premiums. FITs provide renewable energy generators with a fixed long-term price for power, potentially above market price to cover the higher costs of renewable energy generation, and allow them guaranteed access to the electricity grid. In many developed countries, these are funded with a small charge on general electricity bills. Increasing the general tariff level in this way would clearly have negative impacts for affordability. In some developing countries, however, FITs have been fully or partially funded by donors and/or multilateral climate finance institutions, in which case negative impacts on affordability can be avoided. In these circumstances, the credibility of the FIT becomes crucial, and it is likely that this will be enhanced by some degree of donor involvement. [7]

The amount of subsidies required to make affordable electricity supply financially viable should be estimated. Renewable energy generation has potential access to climate finance, which can be used either to reduce the cost of capital (e.g. by providing ‘patient’, blended or concessional finance models) or to provide direct assistance to low-income households (e.g. ‘viability gap’ funding).

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[7] Spratt *et al*. (2013) argue that donor support for FITs in low-income countries (LICs) is desirable for two reasons. First, it does not seem reasonable to expect poor people in LICs to pay additional costs relating to climate change when they have little or no responsibility for creating the problem. Second, the credibility of policy mechanisms such as FITs is crucial to leveraging private investment. In many cases, international investors will consider a mechanism with some level of donor input as more sustainable and credible than one which does not have this component.

4.3 Key performance indicators

- **Internal rate of return of project –** the rate of growth that the project is expected to generate, calculated as the discount rate that makes the net present value of all cash flows equal to zero.
- **Affordability of tariffs for the poor** – measured as the percentage of households that are able to purchase a subsistence level of consumption (50kWh) without spending more than five per cent of their household budgets (Briceño-Garmendia and Shkaratan 2010).
- **Affordability of upfront costs for the poor.** We propose adding the costs of connection fees, wiring, two light bulbs and an additional appliance such as a radio or mobile phone and expressing these costs as a percentage of the median annual income and the annual income of the poorest quintile of the population. For solar home systems we would consider the purchase price of the system.
- **Transaction costs of getting an electricity connection for business** – can be proxied through the World Bank's *Doing Business* electricity indicators at the country level on the number of procedures and the number of days required to obtain an electricity connection.
- **Willingness to pay for electricity services.** This can be estimated through revealed preferences by carrying out surveys that allow the estimation of current costs of energy services similar to those that could be provided by the improved electricity supply (i.e. lighting, heating, mobile charging, radio, TV).
- **Amount of subsidies required to reconcile financial sustainability and affordability** – estimated as the amount of capital and/or tariff subsidies required to provide a positive IRR for electricity generation projects charging affordable tariffs and connection fees.
- **Equity of subsidies.** Equity is measured as the share of the subsidy captured by households living under the poverty line divided by the percentage of households in the population that live under the poverty line. A value greater than one implies that the subsidy distribution is progressive (pro-poor), because the share of benefits allocated to the poor is larger than their share of the total population. A value less than one implies that the distribution is regressive (pro-rich) (Briceño-Garmendia and Shkaratan 2010).

4.4 Policy levers

Donors can potentially assist project developers to maintain affordability within the limits of financial sustainability by:

- Advocating transparent, stable and consistent electricity tariff systems that guarantee economic sustainability in host countries;
- co-funding subsidy systems to cover upfront costs of access to electricity for the poor;
- co-funding and enhancing the credibility of feed-in tariffs that improve the financial viability of renewable energy generation in host countries;
- funding the provision of electrical appliances for the poor;
- supporting best practice financial structuring and management of utilities;
- facilitating access to capital subsidies where developers are required to ensure positive project IRR;
- initiating research into affordability thresholds in target countries and communities.

5 STEP 4: Behavioural factors affecting connection rates and consumption levels

5.1 Description of the problem

Behavioural barriers have not been frequently reported by the literature, but are believed to play a significant role in preventing higher connection and consumption rates. Some behavioural causes for low consumption include deeply engrained habits of using specific energy sources for cooking or manual work for productive tasks.

The lack of control over the monthly bill is also believed to be hindering electricity consumption, whereas with kerosene, households can pay as they consume and quickly react to price changes. Often households want to avoid large monthly bills and consume less than their optimal amount. In some other cases, lack of understanding of flat tariffs makes them consume less than what they are actually paying for.

Individual and household preferences including risk preferences, time preferences, trust, and pro-social attitudes may have a significant effect on the decision to connect or the decision to consume electricity once connected, and thus understanding these preferences is key to elicit reasons for or against connecting to the grid and level of consumption once connected.

Project planners should be able to address behavioural issues behind low levels of connection and consumption by answering the following question:

1. Which behavioural traits could prevent or promote higher connection and consumption rates?

5.2 Proposed methods

Behavioural analysis aims to understand the behaviour of individuals with regards to their decision to connect to a grid (or purchase off-grid systems) and consume electricity. Individual and household preferences that can influence electricity connection and consumption decisions include:

- **Risk.** Risk perception may be a factor in decision-making if the household is unsure about the size of the monthly bill, and the reliability and availability of electricity. The lack of control over the monthly bill can be perceived as a risk. As opposed to kerosene, where households can pay as they consume and quickly react to price changes, electricity billing procedures are sometimes unclear to them. Households also have experienced a higher control over the accessibility and reliability of firewood, briquettes, or kerosene, but may well have heard or experienced that electricity access can be unreliable and unpredictable and therefore is perceived as riskier.
- **Time preferences.** The poor often exhibit a higher discount rate than wealthier individuals. This could make them reluctant to invest in connection fees or electrical appliances even where this enables cost reductions as compared to current energy sources, or the potential to generate income in the longer term. Discount rates for poor people should be measured and taken into account in order to design optimal subsidies to compensate for the lower discount rates.
- **Trust.** Trust in the quality and reliability of supply and the capacity of the utility to cope with subscription applications may be an important factor in household

decision-making. Although not directly measured as a trust indicator, availability and reliability are seen as even more important than price for productive activities, as energy costs are usually only a small percentage of total production costs, yet unreliable electricity supply can stop production entirely.

- **Behavioural/cultural inertia.** The lack of knowledge and familiarity with the economic and productive benefits of electricity often lead to low consumption rates. Low consumption levels often give way to higher consumption after a few years, as users learn about the different services it can provide and buy the required appliances (Obermaier *et al*. 2012; Khandker, Barnes and Samad 2009a; Khandker *et al*. 2009b; Thom 2000). Just as importantly, switching fuels requires learning new skills to use the new technology powered by the electricity, which often (especially in the case of cooking) requires changing traditional household chores and possibly the taste of food. Traditional household activities are often socially engrained and culturally significant and changing them fully may take as long as several generations.
- **Pro-social attitudes.** Evidence shows that neighbours' connection behaviour has a large effect on a household's connection decision, which is explained by a 'keeping up with the neighbour' type of mechanism (Bernard and Torero 2013). This calls for policies aimed at generating the type of critical mass necessary to trigger social interactions effects.

Lab-in-the-field experiments can be a useful tool to understand prevailing norms of behaviour and preferences of community members in a particular society, which will help target electrification projects and give insight on how to encourage changes in behaviour to increase adoption and usage. This method typically involves several roundtable experiments where participants play a game – such as Ultimatum, Dictator, Trust, Prisoner's Dilemma, Coordination, market games, and time and risk preference games. A few suggested games as well as a summary of the benefits of all the games can be found in Annex 1. Annex 1 also details the conceptual framework and sampling frame to be defined for the implementation of lab-in-the-field experiments, as well as the different reward mechanisms. Behavioural games tend to be complemented with a survey instrument that collects data on observable characteristics, such as demographic data, to reveal stated preferences, ensure internal validity, and ideally enhance external validity.

Although it would be interesting to elicit this information in the field for each particular project, we understand that in practical terms it could be difficult and expensive to do this. Given that many behaviour 'heuristics and biases' are well understood, it may not be necessary to measure these in every instance. As an alternative, we recommend that known behavioural biases are taken into account and designed into projects to increase levels of connection and consumption.

5.3 Key performance indicators

Indicators of behavioural traits vary according to the games that are used in the analysis. For the purpose of this policy tool, we recommend that known behavioural traits are taken into account, even if they are not measured in every instance. These include:

- Lack of control over the monthly bill is perceived as a risk;
- high discount rates of poor people as compared to wealthier individuals;
- low quality and reliability lead to lack of trust and low consumption;
- low consumption rates in the first years after connection, due to cultural and behavioural inertia;
- higher connection rates when neighbours connect.

5.4 Policy levers

Some activities that can contribute to reduce behavioural barriers to electricity consumption include:

- Delivery models adapted to poor people’s risk perception and time preferences. For example, pay-as-you-go or lease-to-buy schemes are popular business models for solar home systems. Metering devices to charge consumers for their actual consumption in place of a flat tariff have been successful in grid systems.
- information campaigns on the benefits and potential uses of electricity in the community;
- involvement of communities in the electrification process to build trust;
- policies that create a critical mass of connections to electricity that can trigger social interaction effects.

6 STEP 5: Expected productive uses

6.1 Description of the problem

The lack of productive uses of electricity[8] is one of the reasons why consumption levels and income generation remain low, and rural electrification projects are financially unsustainable. Without additional income generation, the poor are often left unable to afford access to electricity. Low electricity demand in rural regions and its concentration in just a few hours of the early evening for lighting keep load factors low and unit costs high, making power generation and distribution unprofitable. Productive uses could spread electricity consumption more evenly throughout the day, hence making electrification projects viable in rural areas.

Evidence has shown that the provision of electricity is not enough to trigger productive uses. Electricity supply is a necessary, but not sufficient condition for growth, and other significant enablers need to be promoted jointly to improve business performance.

The pre-existing conditions in the areas to be electrified play a big role in the number and magnitude of positive income-related impacts. Areas more likely to benefit are those more economically developed, with access to new markets or a large local purchasing market, a solid pre-existing industry, access to finance, skilled local entrepreneurs, access to exploitable resources and infrastructures. There is a trade-off as in these areas electricity has the highest potential to deliver income generation and hence poverty reduction, but by focusing on them, the poorest communities would be neglected. Electrification projects addressed to communities with low productive potential should be part of a coordinated approach to development to create the enabling conditions for productive uses.

The promotion of productive uses will also require a sufficient and reliable supply of electricity.

This section aims at supporting project planners to address the following question:

1. Is the electricity provided likely to be used for productive activities?

6.2 Proposed methods

Different levels of electricity access enable different intensities of productive use. The technical information about the project delivered by Step 1 will inform the types of productive uses enabled by the relevant level of electricity supply. However, an appropriate level of electricity supply is only one part of making possible its productive use and related income generation.

A framework for measuring the productive potential of different levels of electricity access is currently being developed as part of the *Global Tracking Framework* of the SE4ALL initiative (Banerjee *et al.* 2013).

Establishing the types of use enabled by different levels of electricity supply is the first step to make possible its productive use and related income generation.

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[8] Productive uses of electricity are those that increase income or productivity (see Brüderle, Attigah and Bodenbender 2011).

The income generation potential of off-grid systems can be maximised by targeting communities with high productive potential; however, this would involve not targeting directly the poorest. The alternative is to increase the productive potential of communities at the same time as new electricity is supplied through local economic development (LED) or integrated development.

The assessment of the productive potential of communities can draw from the guidelines provided by local economic development programmes, which usually start with an analysis of the local economy using socioeconomic and political information (World Bank 2006). Other significant studies referring to selection criteria to maximise productive use of electricity are Brüderle *et al.* (2011) and InWEnt (2008). Criteria used to determine the productive potential of a community include:

- Market access. The community has roads that allow all-weather transportation of goods, or other transport infrastructures, good telecommunications and knowledge of how to access external markets. The current share of local production that is currently sold outside the communities is also a good indicator of accessibility to external markets.
- size of the local economy. A growing local economy with demand for non-basic goods can provide an exit to increased production.
- inventory of existing productive activities and their potential to be upgraded through electricity use;
- partners' interest in productive use promotion;
- current power/energy consumption and what it is used for;
- access to natural or touristic resources;
- local private sector development and management capacity;
- availability of finance and experience with businesses being exposed to formal loans;
- human resources and skills;
- availability of electrical equipment;
- technical know-how of purchasing and using electrical equipment.

Alternatively or in addition to pre-existing conditions, the existence of integrated development plans for the region should be taken into account to anticipate the productive potential of electricity. These include programmes for the promotion of small and medium enterprises, capacity building, business services, infrastructure development and access to credit.

For on-grid programmes: identify which regions/communities are more likely to benefit from improved access according to Step 3 and assess their productive potential.

6.3 Key performance indicators

Data collection to assess the productive potential of target communities:

- Productive potential of target communities (high/medium/low, on the basis of criteria listed in the methodology section);
- Indicate if any of the following are in place in the target communities:
    - local economic development programmes;
    - infrastructure development programmes;
    - programmes for the promotion of small and medium enterprises;
    - business services;
    - training programmes;
    - microfinance programmes;
    - agricultural extension.

6.4 Policy levers

Request the following as a precondition for investments in renewable generation capacity:

- Access to credit for the purchase of end use technologies by local entrepreneurs;
- training programmes and professional support for enterprise creation, business promotion and development;
- demonstration of the use of electrical appliances for irrigation and industry;
- technical assistance in converting enterprises to electricity;
- integrated development projects complementing access to electricity with access to roads and telecommunications, business services, etc.
- channel resources and effort to boost the productive potential of poor areas.

7 STEP 6: Expected benefits for businesses and households

7.1 Description of the problem

Electricity can realise its potential to reduce poverty once it is consumed and transformed into services by different appliances, particularly if these services can generate income. Existing evidence of benefits of electricity consumption for households and businesses could therefore inform donors about the potential poverty impact of their electricity generation projects.

Evidence of direct and short-term non-income benefits for households and businesses is widely and consistently reported. Quantitative evidence of the income generation impact of electricity is instead thin, weak and inconclusive, providing a questionable predictive value. This is due to the challenges of quantifying income impacts of electricity and attributing causality. Income generation is an indirect effect of electricity taking place through long causal chains with interactions with many other external factors, which makes it difficult to differentiate the part of the impacts attributable solely to electricity.

Many effects only become evident after long periods of time, but as time passes they are more difficult to attribute to electricity. Comparisons of units with and without electricity raise the problem of different initial conditions, so that impact measures may in fact capture the impact of these initial differences and not that of electrification. Wealthier households and communities, with better growth prospects, located close to the existing grid, are more likely to get a connection and to have higher consumption than in more deprived communities. This can lead to the so-called placement bias or selection-bias if appropriate counterfactuals and adequate controls are not used.

Even with these caveats, existing evidence can support donors and other investors to provide an answer to the following question:

1. What are the potential poverty impacts of increased electricity consumption by households and businesses?

7.2 Proposed methods

Multiple benefits are attributable to electricity consumption. The more straightforward and short-term benefits are directly related to the energy services provided by electricity. In the residential sector these include: reading, indoor and outdoor space lights; image and sound through radio and TV; communications through mobile phones; food preservation through refrigerators; space cooling through fans and air conditioning; heat for cooking and boiling water through stoves, ovens or boilers; laundry washing and ironing through washing machines and irons; and water pumping. The most frequently reported uses of electricity in the residential sector are household lighting, radio and TV, which are therefore the main sources of benefit for the poor.

Direct benefits related to these services include:

- Improved education as a result of more hours in the evening in which children and adults can read, and teachers can prepare lectures; also as a consequence of the provision of information through radio and TV and the release of children’s time due to the increased productivity of the household;

- increased productivity of household tasks through the use of several electrical appliances and time savings for tasks such as buying or collecting fuels and water, or charging mobile phones. Also, increased flexibility to perform domestic tasks through the day instead of concentrating them during daylight hours.
- improved comfort in the household as a result of better lighting and refrigeration;
- improved safety as a result of a lower risk of fires caused by burning kerosene, and outdoor safety through street lights;
- improved health as a result of better food preservation, improved indoor air quality and improved health services in communities with clinics possessing electricity supplies;
- improved possibilities for entertainment, thanks to the use of TV;
- improved communications through the use of mobile phones;
- energy cost savings.

Productive uses have been less widely reported in the literature. The most extensively observed productive uses of electricity include: lighting the workspace, manufacturing, agriculture processing, food processing, irrigation, welding and carpentry. Even though lighting is at the top of the list, it is not expected to have a significant productive impact as compared to other electrical equipment.

Benefits allowed by these productive uses of electricity include:

- Increased productivity of agricultural and industrial activities and services through the use of electrical equipment;
- the possibility to produce new products and services or improve the quality of existing products and services through the use of electrical equipment;
- the possibility to extend opening hours of businesses;
- better quality workspace as a result of improved lighting, cooling or heating;
- lower cost of energy as compared to kerosene or other alternative energy sources.

These outcomes are directly linked to how the use of electrical appliances can facilitate additional indirect benefits. These are more difficult to directly attribute to electricity consumption, as they depend heavily on the interaction of other external factors. They include:

- **Employment.** This can increase as a result of the improved productivity of household tasks – which releases time, especially for women – and the potential to use electricity for new productive activities or extend the scope of existing ones. The literature is consistent in showing positive impacts on employment for women. The results by Dinkelman (2011) are particularly robust, which estimates the impact of electrification on gender-differentiated employment growth in South Africa. She relies on a quasi-experimental approach, using the community's land gradient as an instrumental variable to correct for initial placement biases of electricity, assuming that gradient is not related to employment. New employment comes mostly from self-employment and micro enterprises, as electricity releases time and lowers the cost of new home-based products and services.
- **Income and business profits.** The literature is not conclusive about the impact of electrification on income generation. Income increases are heavily dependent on the use of electricity for productive activities, but also require the interaction of other factors. Electricity has a higher potential to generate income and hence reduce poverty in the more economically developed areas, where it is more likely to be used in productive activities. In very poor areas the impacts are small because even if electricity is used for income generation, there is a limited market

for the additional production, which would crowd out un-electrified businesses (Obeng and Evers 2010; Peters *et al*. 2011; Yang 2003).

- **Creation of enterprises.** Electricity may facilitate the emergence of new businesses, which would have beneficial effects for income and employment generation. Even though this is the impact most widely covered in the literature, there is no consensus on whether or not it takes place.
- **Gender equality.** Better access to information through reading, radio and TV; the reduction or drudgery in the household; and time release through increased productivity can have a beneficial effect for gender relations.
- **Educational achievement.** In addition to the direct, short-term benefits of extended hours for reading and doing homework, access to electricity can have more long-term effects in educational achievement.

7.3 Indicators

A summary of quantified benefits of electrification to businesses and households according to several indicators is presented in Annex 2. The table shows aggregated results to provide practitioners with an indication of evidence to date, but should be used with a great deal of caution. There is no external validity in the estimates (i.e. estimates obtained in one village in Vietnam do not hold for elsewhere) and the analyses were all conducted in very different ways with different measurements and different statistical methods.

7.4 Policy levers

The benefits of electricity for the poor depend on how much and for what it is used. The previous steps have already highlighted how policy can facilitate higher consumption levels by the poor and in particular, productive uses. In addition to those, gender-targeted policies are important for the promotion of uses that improve the quality of life of women and girls, by reducing the drudgery of household tasks and the time spent on domestic activities. Household dynamics need to be taken into account as purchase and use of appliances is influenced by the decision-making power of the different family members.

8 Next steps

The proposed policy tool is based on a thorough review of the evidence on the factors that influence the poverty impact of electrification. It is addressed to renewable electricity projects, but it can be applied to any type of electrification project.

Our expectation is that this tool will be used by investors and funders of renewable electricity projects that consider poverty reduction as a key aspiration. We believe that it comes at a timely moment, when many climate and SE4ALL-related funds are in their infancy and can still be guided in a pro-poor direction.

The next step of our work will involve testing the tool in real renewable energy project/programme portfolios to assess their poverty reduction potential. Its application will show the actual level of effort required to collect indicators,[9] issues around data availability and the potential trade-offs between the different indicators. We expect to deliver an improved version of the tool once the testing phase finalises.

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[9] A list of indicators proposed is included in Annex 3.

Annex 1: Games, conceptual framework, sampling frame and rewards for behaviour analysis

Some games that can be used to elicit behaviours that are pro or against electricity connection and consumption include:

1. Risk experiments. Lotteries, or choices where the outcome is presented on paper to the players, are used to understand risk preferences, risk aversion, and loss aversion. If the experimenters are interested in understanding low consumption and hypothesise that lack of control over the monthly bill may be preventing the optimisation of consumption, and then observe risk aversion through the risk experiments, the project could install prepaid electricity meters or use fee-for-service models where consumers pay a flat fee for connection with a limited capacity.

2. Time preference games. These games usually present the player with the concept of discounting, whereby the player can choose an amount of money to receive today or in the future. If a high discount rate is observed it is clear that the player places a higher value on the present, which would be typical in a subsistence environment where people cannot afford to plan far ahead or save money.

3. Trust games. Player 1 has a specified amount of money (x) that she can keep for herself or send to Player 2. If she sends some of the money to Player 2, she keeps the difference. Player 2 decides how much of the received amount, which earns a return (1+ *r),* she will keep or share with Player 1. Player 1's actions are measured as *trust* because she does not know if Player 2 will send any money back. The amount sent back by Player 2 is measured as *reciprocity/trustworthiness* because the only motives for returning any money are altruism and establishing a trusting relationship. The subgame perfect Nash equilibrium (SPNE) for this game is that neither trust nor reciprocity can be measured because the trustee will maximise earnings and anticipate that a self-interested Player 2 will send nothing back, and hence Player 1 keeps it all. This game can be useful to infer behaviour in contracts where there is asymmetric information.

4. Ultimatum games. One player, called the 'proposer', divides money between herself and another player. The other player, the 'responder', either accepts it or rejects it. If the responder accepts the division, each receives the amount decided by the proposer, or otherwise they both receive nothing. The SPNE in this game is one in which the proposer offers the smallest non-negative amount and the responder accepts. In the experiments, however, people often behave differently – responders often reject low offers, and proposers sometimes offer close-to-even splits. While it is difficult to differentiate if the proposer who offers close-to-even splits is motivated out of altruism or fear of rejection, it is easier to understand that responders reject low offers if they feel it was an unfair offer. Therefore, ultimatum games are used to gain perspective on bargaining preferences – they can help inform policy by giving us a sense of cultural norms of fairness, especially in areas where institutions are weak or informal.

5. Dictator games. Dictator games are ultimatum games where the responder cannot reject the offer. The SPNE for this game is that the dictator maximises her earnings and takes all. The dictator game can be used to understand if the proposer in the ultimatum game offered close-to-even splits because of altruism or fear of rejection. Inferences on how people treat each other is relevant for policy in terms of how to design contribution schemes, or how to plan for or deal with other welfare-reducing activities such as crime and social exclusion.

6. Prisoner's dilemma or public goods game. This normally requires more than two players, and all players are given the same amount of money which they can decide to invest in their personal account or the group account. Contributions to the group account are multiplied and divided evenly to all players. The Nash equilibrium when all players play simultaneously is that no one contributes to the group fund with the intention of free-riding on others' contributions. Since free-riding poses a negative externality on the other players, as the optimal situation would be if everyone contributed to the group fund, the game has been used to understand collective action problems and negative externality issues in society. Common resource problems could be studied with a slight change to the public goods game, whereby if aggregate investment into the group account exceeds a given level, the return becomes less than the return on the personal account for not investing. Punishment, reward and leadership can be examined in this game in order to figure out what ways will increase cooperation prior to implementing the project.

7. Coordination games. Two players can choose risky or safe actions. If the two players make mutually consistent decisions, each will realise gains but if both make risky choices, they both earn more than if each played it safe. Camerer (2003 cited in Viceisza 2012) divides coordination games into three categories: matching games, games with asymmetric payoffs, and games with asymmetric equilibria. In matching games, all equilibria have the same payoffs for each player. In asymmetric payoffs, players disagree about which equilibrium is best due to the asymmetry. In games with asymmetric equilibrium, the players are symmetric but the equilibria are not (Viceisza 2012). It has been used in the context of farmer groups whereby a group enters into a single buyer contract wherein all group members need to deliver by a certain date.

8. Market experiments (auctions). A market environment is simulated whereby players are assigned to the role of buyer or seller in order to understand the role of markets in facilitating trade, establishing prices, etc. Convergence to market equilibrium, or failure to converge, is typically studied (*ibid.*). According to Viceisza, market experiments are used to understand bargaining and bidding behaviours, the role of information in impacting such behaviours, and those market or auction institutions that are most likely to function and be understood in rural areas.

Information on the games was obtained from Viceisza (*ibid.*); please refer to this report for more resources on developing games.

When designing lab-in-the-field experiments, it is necessary to define how the subjects are expected to behave and how they interact with each other. The target population should be determined and a sample drawn, taking into account sampling and non-sampling errors. The sample should also be sufficiently large to detect effects with high statistical significance which is measured through power calculations. In order to study everyone sampled to participate, which is necessary to ensure both internal and external validity, Viceisza (*ibid.*) recommends sending a formal letter endorsed by the local government or a respected NGO to the community which details only the most fundamental information so as not to introduce bias. Viceisza (*ibid.*) recommends that the typical invitation to attend an experiment should include: time, date, and place of study; a brief and general statement of the purpose of the study (i.e. 'remittances', 'insurance'); what will be expected of the participant (make decisions and answer questions); and what type of compensation can be expected. The report also recommends to plan for attrition by establishing an alternate list of participants that is also randomised *ex ante*.

Reward mechanisms also need to be determined. Subjects are usually paid for their time. It should also be noted that payments are often single-blind in lab-in-the-field experiments as this is most feasible when collecting data in the field (*ibid.*). Double-blind would require the experimenter to be unable to identify the subject, which prohibits them from gathering information on observables (*ibid.*). Aside from the show-up fee, additional earnings – whether hypothetical or real – are sometimes introduced during the game, depending on the game.

According to induced value theory (Friedman and Sunder 1994 cited in Viceisza 2012), rewards can be used to control the subjects' individual home grown preferences in order to study the characteristic of interest. However, three conditions must be met for individual preferences not of interest to be netted out: monotonicity (the subject prefers more of the reward to less), salience (reward is conditional on the subjects' actions as defined by institutional rules), and dominance (any change in utility of subject comes only from the reward medium).

Viceisza (2012) stresses that the framing of how the game is presented to its participants is very important, as this needs to be neutralised in order to avoid bias. The participants should not know the purpose of the experiment. Bias could be introduced by something as simple as relating the task to their everyday life and must be avoided. It is often the case in lab-in-the-field experiments that the experimenter needs to research and test *ex ante* if the subjects can perform the necessary actions (i.e. simple arithmetic) and understand the task (*ibid.*).

Annex 2: Benefits of electrification

Benefits to businesses

Impact	Countries where data is available	Indicator	Quantification of impact (range in literature to date)	Variability of results
Employment	Bangladesh, Guatemala	Probability of participation in non-farm work	0.1 – 9%[10]	High
	India, Ghana, South Africa	Total hours worked growth (%); (hours)	0.21 – 1.5% (men); 0 – 17 (women)[11]	Low (men); medium (women)
Productivity	Kenya	Productivity per worker	100 – 200% for carpenters; 50 – 170% for tailors[12]	High
	India	Agricultural productivity	Qualitative: rural electrification had a direct impact through private investment in electric pumps[13]	N/A
	Indonesia	Technical efficiency	Qualitative: surveys on 2,250 small clothes producers show significant positive effects of energy consumption on technical efficiency[14]	N/A
Income	Bhutan, Vietnam, Bangladesh,	Non-farm income growth (%)	23 – 72%[15]	High
	Bhutan, Indonesia, Nepal	Farm income growth	0 – 52%[16]	High

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[10] Grogan and Sadanand (2011); Chowdhury (2010).
[11] Khandker *et al*. (2012); Dinkelman (2011); Costa *et al*. (2009).
[12] Kirubi *et al.* (2009).
[13] Barnes and Binswanger (1986).
[14] Hill and Kalirajan (1993).
[15] Banerjee, Singh and Samad (2011); Kumar and Rauniyar (2011); Asian Development Bank (2010); Gibson and Olivia (2010); Khandker *et al.* (2009a); Khandker *et al.* (2009b).
[16] Banerjee *et al.* (2011); Kumar and Rauniyar (2011); Asian Development Bank (2010); Gibson and Olivia (2010); Khandker *et al.* (2009a); Khandker *et al.* (2009b).

Benefits to businesses (cont’d.)

Income (cont’d.)	The Philippines, India, Vietnam, Bangladesh, Bhutan, Rwanda, South Africa	Total income	0 – 38.6%.[17] One study reported +174.9%[18]	High
Expenditures	Bangladesh, India, Nepal	Expenditure per capita growth (%)	8.2 – 18% (total), 14% (food), 30% (non-food)[19]	High
Creation of microenterprises	The Philippines, Bhutan	Number of enterprises	No significant impact.[20] Qualitative: increase in production of new products	Low

Benefits to households

Impact	**Countries where data is available**	**Indicator**	**Quantification of impact**	**Variability of results**
Health	Bhutan, Nepal	Cough incidence Respiratory ailments Eye irritation Headache	- 2.8% Girls: - 1.6% Boys: 6.1% - 13.5% - 4.2%[21]	Low (few studies)
	Nepal	Gastrointestinal problems	Girls: - 1.43%[22]	N/A
Education	Bhutan, Nepal, India, Bangladesh, Vietnam	Years of schooling completed (years)	All: 0.52 – 0.745 Girls: 0.24 – 0.64 Boys: 0.42[23]	Low
	Bhutan, Nepal, Rwanda, Senegal, The Philippines, India, Bangladesh	Study time (min./day)	0 – 60[24]	High (although most studies are 7– 12 min./day increase)

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[17] Khandker *et al.* (2012); Dinkelman (2011); Kumar and Rauniyar (2011); Bensch, Kluve and Peters (2010); Khandker *et al.* (2009a); Khandker *et al.* (2009b); Herrin (1983).

[18] The authors acknowledge that there may be a problem of selection bias, because electricity is not used for income generation, and the treatment is availability, not actual connection. Higher income may be due to pre-existing advantages in connected households.

[19] Khandker *et al.* (2012); Banerjee *et al*. (2011), Khandker *et al.* (2009a).

[20] Kumar and Rauniyar (2011); Asian Development Bank (2010); Herrin (1983).

[21] Banerjee *et al.* (2011); Asian Development Bank (2010).

[22] Banerjee *et al.* (2011).

[23] Khandker *et al.* (2012); Banerjee *et al.* (2011); Kumar and Rauniyar (2011); Asian Development Bank (2010); Khandker *et al.* (2009a); Khandker *et al.* (2009b).

[24] Bensch, Peters and Sievert (2012); Khandker *et al.* (2012); Banerjee *et al.* (2011); Kumar and Rauniyar (2011); Asian Development Bank (2010); Bensch *et al.* (2010); Khandker *et al.* (2009a); Herrin (1983).

Benefits to households (cont'd.)

Education (cont'd.)	India, Vietnam	School enrolment	Girls: 7.4 – 10% Boys: 6 – 11% [25]	Low
	India, Vietnam	Completed schooling	Girls: 0.12 – 0.5 Boys: 0.092 – 0.524[26]	High
Time allocation	Bhutan, India, Ghana	Time spent on fuel collection (hours) Water collection (hours)	All: - 3.3 – - 0.4 Women: - 0.28 Men: - 0.21 +0.182[27]	Medium
	Nepal	Women's time in income generation (hours)	0.19[28]	N/A
		Women's leisure time	0.21[29]	N/A
	Ghana, Bangladesh	Hours spent in unpaid work (women)	No impact (-0.016)[30]	Low
	Guatemala	Women's time cooking	- 34%[31]	N/A
Women's empowerment	Bhutan	Participation in decisions on education and health index	0.049[32]	N/A
	Nepal	Independent decision-making on fertility	0.042[33]	N/A
		Independent decision-making about children	0.027[34]	N/A
	Brazil	Share of women separated or divorced	Significant increase[35]	N/A

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[25] Khandker *et al.* (2012); Jensen and Oster (2009); Khandker *et al.* (2009b).
[26] Khandker *et al.* (2012); Khandker *et al.* (2009a); Khandker *et al.* (2009b).
[27] Khandker *et al.* (2012); Asian Development Bank (2010); Costa *et al.* (2009).
[28] Banerjee *et al.* (2011).
[29] Banerjee *et al.* (2011).
[30] Chowdhury (2010); Costa *et al.* (2009).
[31] Grogan and Sadanand (2011).
[32] Asian Development Bank (2010).
[33] Banerjee *et al.* (2011).
[34] Banerjee *et al.* (2011).
[35] Chong and Ferrara (2009).

Benefits to households (cont’d.)

Women’s empowerment (cont’d.)	India	Acceptability of spousal abuse, son preference, autonomy and fertility	Significant improvements[36]	N/A
Fertility	Bhutan, Guatemala	Number of children born in the last five years	- 28 – - 5%[37]	High
	Nepal	Contraceptive prevalence rate	0.038[38]	N/A
Deforestation	Bhutan, The Philippines	Yearly consumption of trees	- 0.41 – no impact[39]	High
Improved safety	Not studied (only assumed)	Number of fires; crime in village	Qualitative: lower risk of fires, outdoor safety street lights	N/A
Macro: Poverty Reduction	The Philippines, India, Thailand, China	Number of poor reduced per million peso/rupees/ bahts/yuans infrastructure investment	Qualitative: spending on roads and then on agricultural research showed highest impacts – not roads (India). Spending on roads had highest impacts (Thailand). Positive effects of infrastructure investment in rural electrification, but less impact than other investments such as roads (China)[40]	High

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[36] Jensen and Oster (2009).

[37] Grogan and Sadanand (2011); Asian Development Bank (2010).

[38] Banerjee *et al.* (2011).

[39] Asian Development Bank (2011); Herrin (1983).

[40] Fan, Jitsuchon and Methakunnavut (2004); Fan, Zhang and Zhang (2002); Fan, Hazell and Thorat (1999).

Annex 3: List of performance indicators to assess poverty impact

Issue	No	Indicator	Unit
Technical	1	Additional number of users	Number of users
	2	Additional final electricity consumption	kWh
	3	Nominal power or peak power availability	kW or kWp
	4	Quality of the electricity supplied (voltage and frequency fluctuation)	Volt
	5	Expected life of the system	Years
	6	Detailed maintenance plan	Detail
	7	Loss of load expectation	Hours or days
	8	Availability of electricity (hours per day)	Hours
	9	Technical losses of the national grid	%
Targeted communities	10	Proportion of users that are poor	%
	11	Health centres	Number
	12	Schools	Number
	13	Institutional buildings	Number
Financial/ affordability	14	IRR	%
	15	Affordability of tariffs for the poor	% HH expenditure
	16	Affordability of upfront costs for the poor	% annual income
	17	Current cost of energy services as a measurement of willingness to pay	US$ or local currency
	18	Amount of subsidies required for positive IRR	US$ or local currency
	19	Equity of subsidy	Equity indicator
Productive uses	20	Productive potential of target communities	High/medium/low
	21	Integrated development plans (infrastructure development, local economic development, promotion of SMEs, access to finance, etc.)	Yes/no
Behavioural	22	Pre-defined assumptions for behavioural traits	
Final poverty impacts	23	Pre-defined assumptions of benefits for businesses and households	

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