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Pro-Poor Electricity Provision

The Evidence of Benefits for Poor People of Increased Renewable Electricity Capacity: Literature Review

Ana Pueyo, Francisco Gonzalez, Chris Dent and Samantha DeMartino
September 2013

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THE EVIDENCE OF BENEFITS FOR POOR PEOPLE OF INCREASED RENEWABLE ELECTRICITY CAPACITY: LITERATURE REVIEW

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List of Abbreviations

AC	air conditioning
ADB	Asian Development Bank
AHREC	Andhikhola Hydroelectric and Rural Electrification Centre
ARDL	Autoregressive Distributed Lag
ASEAN	Association of Southeast Asian Nations
BLDS	British Library of Development Studies
CEE	Collaboration for Environmental Evidence
CEPE	Centre for Energy Policy and Economics
CEPR	Centre for Economic Policy Research
CIC	Customer interruption cost
CI	confidence interval
CRGGE	Collaborative Research Group on Gender and Energy
DECC	Department of Energy & Climate Change
DEFRA	Department for Environment, Food & Rural Affairs
DES	descriptive
DFID	Department for International Development
DID	Difference-in-Differences
dl	DerSimonian-Laird random effects model
EFC	Equivalent Firm Capacity
EPSRC	Engineering and Physical Sciences Research Council
ESMAP	Energy Sector Management Assistance Program
EXP	experimental
FCO	Foreign & Commonwealth Office
fe	fixed effects
FMOLS	Fully Modified Ordinary Least Squares
FRw	Rwandan franc
GDP	Gross Domestic Product
GHG	greenhouse gas
GIZ	German Society for International Cooperation
GNP	Gross National Product
HH	household
ICF	International Climate Fund
ICT	Information and Communications Technology
IDS	Institute of Development Studies
IEA	International Energy Agency
IEG	Independent Evaluation Group
IIA	Independence of Irrelevant Alternatives
ISSER	Institute of Statistical, Social and Economic Research (Ghana)
ITT	Intention-to-treat
IV	Instrumental Variable
JOLIS	Journal of Librarianship and Information Science
KIPPRA	Kenya Institute for Public Policy Research and Analysis
kWh	kilowatt-hour
LIC	Low-income country
LOLP	Loss of Load Probability
LPG	liquefied petroleum gas
LSMS	Living Standards Measurement Survey
MDB	Multilateral Development Bank
MDG	Millennium Development Goal
MHSP	Fund for the Promotion of Micro Hydro Power Stations
MJ	mega joules

MWT	Modified Wald Test
NPDP	Nepal Power Development Project
O&M	Operation and Management
OBS	observational
OLS	ordinary least squares
OPEC	Organization of the Petroleum Exporting Countries
P&E	Primary and empirical
pc	per capita
PDR	People's Democratic Republic
PMAPS	Probabilistic Methods Applied to Power Systems
PPER	Project Performance Evaluation Report
PSM	Propensity Score matching
PV	photovoltaic
RCT	Randomised control trial
RDD	Regression discontinuity design
REAP	Rural Electricity Access Project
REDP	Renewable Energy Development Project
Rs	rupees
S	secondary
SHS	Solar Home Systems
SME	small and medium-sized enterprises
SPRU	Science and Technology Policy Research
T&D	Transmission and Distribution
TC	Theoretical or conceptual
TFP	total factor productivity
TOT	Treatment-on-the-treated
UNDP	United Nations Development Programme
UNFCCC	United Nations Framework Convention on Climate Change
VECM	Vector Error Correction Model
WTP	Willingness to Pay

Executive Summary

Background

Lack of access to electricity is seen as a major constraint to economic growth and increased welfare in developing countries. The latest update by the IEA (2012) shows that in 2010 nearly 1.3 billion people did not have access to electricity, which is close to one-fifth of the global population. This deficit is due to a combination of political and institutional problems and the economics of expanding grid infrastructure or providing off-grid solutions to remote, poor and sparsely populated areas.

After an intense activity during the 70s and early 80s, electricity provision slipped down the list of priorities for donors and governments, following the World Bank's position. This change in direction was largely due to the disappointing results of many electrification programmes that had delivered low economic returns, low-cost recovery and little evidence of an impact on income generation and poverty eradication. However, since the late 90s until today electrification has come back to the development agenda as a key element of poverty reduction strategies and low-carbon development. Many rural electrification projects use the Millennium Development Goals as their main justification, although often without robust evidence to back it up.

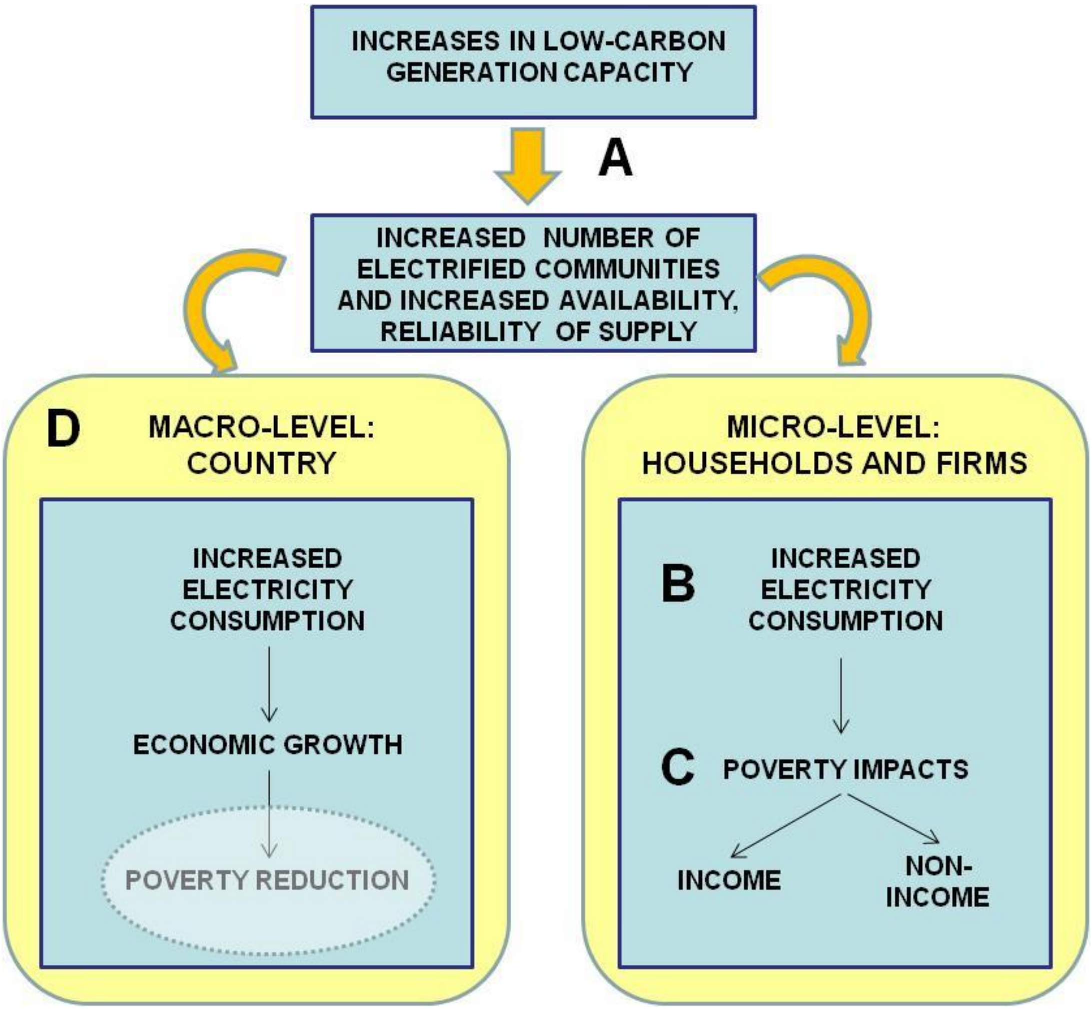
DFID is involved in this renewed interest in electrification as a means to poverty reduction through its participation in the International Climate Fund (ICF) and is particularly interested in maximising the poverty impact of investments in renewable electricity capacity. This review aims at supporting donors' planning of investments in renewable electricity capacity to maximise their impact for the poor. It identifies the evidence that links electricity generation capacity to benefits for the poor, as well as the policy interventions that can maximise this relationship.

Method

The review begins by elucidating a theory to break down the causal chain between additional renewable electricity generation capacity and poverty impacts in four stages or links, which can be formulated as four research questions: A. What is the link between increased renewable electricity capacity and higher availability and reliability of supply?; B. What is the link between increased availability and reliability of electricity and actual connection and use by the poor?; C. What is the link between electricity consumption and poverty impacts?; and D. What is the link between electricity consumption and economic growth at the macro level? The causal chain is illustrated in Figure 1.

A structured review, following the realist approach, focused on developing countries and covering academic and grey literature was conducted according to a detailed search protocol including five sets of search terms related to interventions, uses, poverty outcomes, geography and low-carbon technologies. Retrieved publications were systematically reviewed and included in the study according to a detailed set of criteria related to their relevance to the four research questions. Each paper was assessed in terms of the quality of the evidence provided on the basis of explicit quality evaluation criteria. A total of 143 papers were deemed relevant and of sufficient quality to respond to our research questions. Most reviewed literature concentrates on link C of the causal chain, whereas technical literature dealing with link A was particularly thin. The literature was synthesised into a single narrative giving a higher weight to the best quality publications.

Figure ES1 Causal chain of poverty impacts of electricity generation capacity



Results

Even though there is a large body of literature analysing links B, C and D of the causal chain, their quality and methodological approach is highly uneven (only 32 per cent of studies are considered as high quality). There are particularly significant gaps in the technical literature on link A of the causal chain and literature on link C that can demonstrate causality from electricity consumption to income-related impacts. The literature has been thoroughly classified according to transparent quality criteria, with the main conclusions derived from high-quality literature, reinforced with evidence presented by moderate and low-quality literature. The main outcomes of the review for each of the links of the causal chain are summarised below:

A. What is the relationship between increased renewable electricity capacity and higher availability and reliability of supply?

The potential additional generation capacity in a grid electricity system to increase the number of electricity consumers, the consumption of existing consumers or to improve the reliability of their supply depends on a number of factors, including:

- 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 resources at different times of day/week/year
- Changes in the number of consumers, including not only legal network extension but also illegal connections (which are common in developing countries).

Power system reliability analysis in developing countries can predict the expected impact of additional capacity on reliability of supply and final consumption taking these data into account. The literature in international journals and conferences on power system reliability analysis methods specialised to developing countries is very limited. It points at data availability as a main difficulty to undertake power systems analysis in developing countries.

Even if additional renewable generation capacity improves quantity and reliability of electricity supply, this may still not reach the poor. Increases in connection rates can either come from intensification (increase the percentage of electrified population inside electrified communities) or extensification (increase the percentage of population living in electrified communities) strategies. The final impact of these strategies on the poor depends on whether they are mostly located in electrified or unelectrified communities. If extensification strategies are followed, the selection of communities to be provided with increased access usually follows economic imperatives, prioritising the more densely populated, closer to the grid, with a high average community income and productive potential and access to roads. A minority of rural electrification projects have explicitly targeted the most deprived areas or rolled out electrification following geographical balance criteria. Political and institutional barriers also play an important role in determining who gets access to electricity. In some cases, corruption and the behaviour of vested interests, as well as a lack of political will to extending energy services to sparsely populated rural areas are behind low access rates for the poor.

B. What is the relationship between increased availability and reliability of electricity and actual connection and use by the poor?

Evidence shows that even once households and businesses are given the opportunity to connect to the grid or purchase off-grid systems, connection rates and final use may remain disappointingly low.

The literature strongly and consistently reports financial barriers to increased connection and use, and in particular barriers related to income of users and upfront costs of electricity, including unaffordable connection fees or purchase price of home systems, house wiring and electrical appliances. Electricity tariffs are less frequently reported as a barrier to initial connection and increased use. Electricity is price inelastic, even if the own price elasticity is consistently negative and significant, as expected. Besides, several papers find good evidence of willingness to pay for an improved service, suggesting that heavily subsidised tariffs that make utilities unviable are often unnecessary. Evidence also suggests that subsidised tariffs often benefit the better off, who are able to connect and purchase appliances, therefore perverting public service solidarity mechanisms.

The quality and reliability of supply and the capacity of the utility to cope with subscription applications are also widely and consistently reported factors facilitating increased connection rates and use. Particularly for productive activities, availability and reliability are more important than price as energy costs are usually only a small percentage of total production costs and industry could face high costs as a result of voltage drops or blackouts. Bad quality of service is often linked to the financial weakness of utilities or managing cooperatives caused by unsustainable subsidised tariffs or poor management. In the case of SHS it is often due to poor maintenance of the systems, due to lack of training or to maintenance not being a priority in electrification programmes.

Lack of productive uses is frequently reported as the reason for low electricity consumption. Electricity is still mainly used for lighting, which is concentrated in a few hours of the early evening, instead of productive uses more evenly spread throughout the day. On one side, this jeopardises the financial sustainability of electrification projects and on another side it limits the income generation effect expected.

Behavioural barriers are less frequently reported by the literature and are mostly included in qualitative research. These include the lack of control over monthly electricity bills, as opposed to kerosene, where 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. Other behavioural barriers refer to insufficient knowledge about the usage and operation of electrical equipment in businesses and households and about the economic and productive benefits of electricity, as well as deeply engrained habits of using specific energy sources for cooking and lighting. As a result, poor households tend to keep on using traditional sources of energy such as firewood, kerosene and candles after they have been connected to the grid.

C. What is the relationship between electricity consumption and poverty impacts?

The benefits of electricity for the poor depend on how much and what for it is used. Direct and short-term non-income benefits for households are more strongly and consistently reported than income-related outcomes that depend not only on electricity but also on a number of factors jointly enabling its productive use. A compilation of quantitative estimates of several income and non-income impacts of electricity for households is provided in Table 3 of the main text.

Electricity use outcomes are consistent for employment and time allocation, particularly for women. Several authors report increases in women's employment, total hours of paid work, and probability of participating in non-farm or non-household work. This impact is caused by an increase in household productivity through the use of electricity, which releases female time from domestic tasks such as collecting fuel, fetching water and cooking, to market work and also to education and entertainment. There is also robust evidence of positive impacts for women's empowerment, understood as their participation in household decisions, independence and intolerance of male abuse. Men's employment does not consistently increase.

Improvements in education are widely and consistently reported, with homogeneous measurements, mainly: years of schooling completed, study time and school enrolment. Impacts are generally higher for girls than boys, probably as they need to perform less household tasks with the introduction of electricity.

Evidence is weak regarding health and environmental improvements facilitated by the use of electricity.

Evidence shows that richer households benefit more than poorer ones from the use of electricity. This is explained because electrification benefits happen through multiple channels and poorer households can only benefit from lighting, while richer households can use more diverse energy services.

Even though productive uses are seen as those having the highest potential to reduce poverty, robust evidence is scarce as regards impacts of electricity on the creation of enterprises or the improved performance of existing ones. Rural electrification projects on their own rarely deliver income generation activities because lighting and TV are the most widespread uses. Most authors agree that electricity is a necessary but not sufficient condition for income generation and poverty reduction. The pre-existing conditions in the area to be electrified play a big role in the number and magnitude of positive impacts to be expected. Areas most 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 resources and skilled entrepreneurs capable of innovating and reaching new markets. Additionally, businesses not only need access to electricity to improve their performance, but a sufficient and reliable service. Where these preconditions do not exist, integrated development programmes should address the existing gaps through, for example, improved roads and telecommunications, access to credit to purchase end-use technologies, business services, training programmes and professional support for enterprise creation, business promotion and development, demonstration projects of the use of electricity appliances for irrigation and for industries, and technical assistance in converting enterprises to electricity.

Some authors have estimated the monetary benefits of electricity consumption on the basis of willingness to pay for the services it provides and cost of labour for the time it saves in domestic tasks. The World Bank (2008b) in particular has estimated benefits that would allow to break even supply costs within one to three years, hence justifying investments in rural electrification. However, this justification is provided with the caveat that estimated benefits are not cashable and hence do not contribute to the user's ability to repay connection costs.

D. What is the relationship between electricity consumption and economic growth at the macro level?

The empirical literature about the relationship between electricity consumption and economic growth has focused on two main related questions. A large number of studies analyse the direction of causality between economic growth and electricity consumption. A smaller number of studies measure the size of the potential impact of electrification on economic growth, based on the assumption that causality runs from electricity consumption to economic growth.

Four possible hypotheses on causality are found in the literature:

1. No causality or '*neutrality hypothesis*': The analysis cannot find causality in any direction between economic growth and electricity consumption
2. Causality from economic growth to electricity consumption or '*conservation hypothesis*'
3. Causality from electricity consumption and economic growth or '*growth hypothesis*'
4. Bidirectional causality or '*feedback hypothesis*', economic growth leads to electricity consumption and vice versa.

The finding of the report is that the evidence regarding the causal direction is extremely mixed. Most studies suggest that there is some causality; only around 14 per cent of estimates support no causality or 'neutrality hypothesis'. However, the direction of causality is less clear. Around one third of estimates support the 'growth hypothesis' where electricity consumption increases growth. Around 53 per cent of observations suggest other types of causality; bidirectional causality (30.38 per cent) or causality running from economic growth to electricity consumption (22.78 per cent). This heterogeneity of outcomes is not only explained by the country of study but also by the study design, including variable definitions, sample period or methodology used.

We look also at the size of the impact of electricity consumption on growth for those studies that estimate or assume a direct causality, and that report elasticities that can be compared across studies. The random effects estimate of the overall effect is positive and statistically significant, suggesting that a 1 per cent increase on electricity consumption leads to an increase of 0.17 per cent of the GDP. This is a substantial effect, however, subject to the caveat about the direction of causality.

Overall and looking at the reviewed evidence, the answer to the link between electricity consumption and economic growth remains largely inconclusive.

Policy implications

Policies to increase the quantity and reliability of electricity available for final users as a result of increased renewable generation capacity

Our review of the technical evidence of impacts on final consumption of increased renewable generation capacity in developing countries was rather limited. However, some relevant recommendations for the design of policies to increase access for the poor point at the need to consider the host country's electricity systems as a whole when planning investments in on-grid renewable energy capacity, as these will not have a significant impact for the poor if they are located far from poor people's centres of demand, are linked to them through low capacity and unreliable transmission and distribution networks or if the availability of renewable energy resource does not match the distribution of demand through the day/week/year. It is recommended that power system reliability analysis is undertaken in developing countries as part of investments planning to predict the expected impact of additional capacity.

In addition to technical aspects, the political economy of access to electricity in the host country should be well understood to better plan which communities are more likely to gain access as a result of donors' investments in additional generation capacity.

Policies to increase electricity connection rates and use

- Subsidies or liberal credit should be provided to cover upfront costs (including connection costs, house wiring and electrical equipment), which are considered as very important barriers to connection and use. These subsidies should be specifically designed to target the poor, for example through subsidised connection rates for late connectors, which usually include the poorest.
- Electrification strategies based on intensification (increasing connection rates in already electrified communities) could be much more cost-effective than extensification strategies, involving extending the grid to reach additional communities.
- Subsidised tariffs are often not necessary, as evidence shows that there is willingness to pay and they have been found to benefit the better off (those who can connect and buy appliances). If required to lower project risks at the start, they could have a phase-out period, aiming at financial sustainability in the long term.
- Tariffs should guarantee the financial health of operation and maintenance activities of the utility. They should also cover the potential expansion of generation capacity. Capacity development for efficient management of utilities and local cooperatives is also necessary. Only then, utilities will be able to provide a high-quality service to a large number of consumers in the long term.
- The effects of privatisation of the power sector for the poor are not conclusive. It may increase tariffs and not expand the grid to rural areas, but it may also improve quality

and reliability, expand networks and liberate public finances to support rural electrification.

- Interventions are required to increase the control of consumers over their monthly bill, as evidence shows that poorly understood payment schemes are a barrier to higher consumption by the poor. This can be done through individual meters and pre-payment schemes.
- Interventions that promote productive uses of electricity are likely to deliver higher consumption rates.
- Consumer education can stimulate demand, ensure that consumers derive maximum benefit at least cost and increase the lifetime of individual off-grid systems.

Policies to improve the poverty impacts of electricity use

Several estimates of the expected household benefits from the use of electricity are provided in Tables 3 and 4. They could be used by policymakers to undertake cost benefit analysis of their investments in access to electricity. Other policy recommendations to improve the poverty impact of electricity for households include:

- Policies that facilitate increased access to electricity appliances through microcredits, free distribution or favourable payment conditions.
- Gender-targeted policies to promote 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.

Two main policies can be put in place to encourage productive uses for electricity.

- A set of criteria could be developed to prioritise rural areas with the highest potential to use electricity for income-generating activities. These would include communities with a large internal market and easy access to external markets; a pre-existing diverse and growing productive sector including agriculture, manufacture and services; a set of infrastructures conducive for business development, such as road and telecommunications networks; and easy and reliable access to exploitable resources such as agriculture and tourism.
- Alternatively, more deprived areas with lower economic potential can be targeted but electrification should be integrated with other development programmes that contribute to create the appropriate environment for productive activities. This could include support to purchase productive equipment and to develop the skills to efficiently use it; infrastructures (particularly roads and telecommunications) and social skills to access external markets; or support for the creation of businesses.

The diversity of impacts of electricity for income generation, depending on productive activity and location of the businesses implies that a one-size-fits-all methodology that would try to predict the productive impact of electricity would be likely to deliver misleading results.

Policies to improve the macro-impact of electricity consumption on economic growth

The policy implications resulting from a review of the impact of electricity consumption on economic growth are not obvious and do not facilitate the adoption of specific electrification policies. Perhaps the most important element that transpires from our results is the need for electrification projects to not assume the ‘growth’ hypothesis that electricity consumption causes growth, and consider that some reverse causality is also possible.

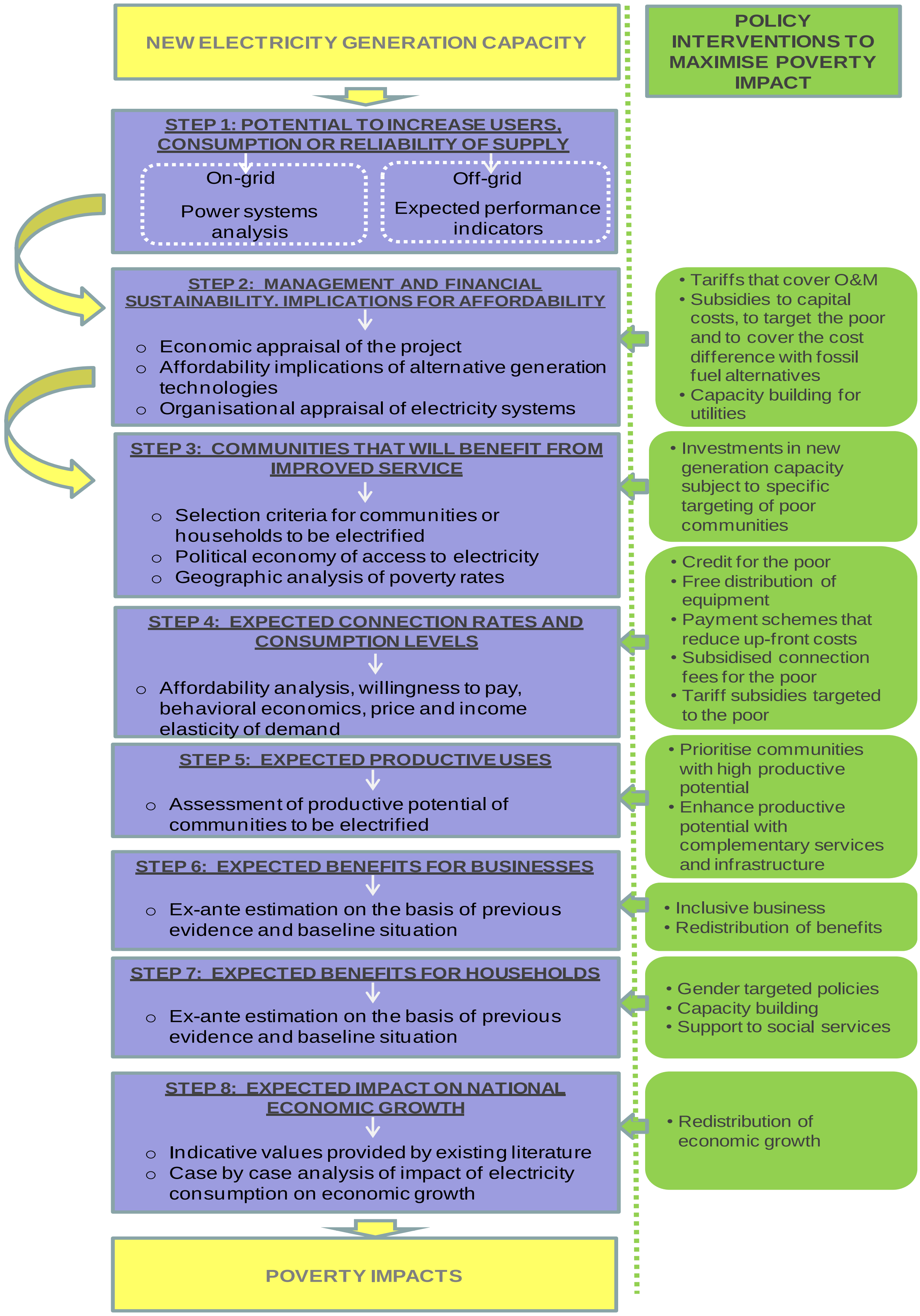
Recommendations

This review has identified the links of the causal chain that determine the occurrence and size of poverty impacts from increased renewable electricity capacity. We recommend that these elements are taken into account by donors when planning investments in generation capacity that maximise their poverty impact. To facilitate the introduction of poverty considerations in planning exercises we propose the use of a methodology for ex-ante evaluation based on the results of our review, which is summarised in Figure 2.

Our results can also contribute to improving the design of ex-post impact evaluations of the poverty impacts of electrification projects. We suggest contributions at three stages of the impact evaluation: posing the right research question; developing a robust evaluation strategy through selection of treatment and control groups; and designing the baseline and endline surveys to include all the appropriate criteria and indicators for the selection of treatment and control groups and the assessment of impacts.

Both the ex-ante and ex-post evaluation methodologies will be further developed as part of IDS work on pro-poor access to electricity funded by DFID's Accountable Grant to the programme on Strengthening Evidence-based Policy.

Figure ES2 Methodology for ex-ante evaluation of poverty impacts of generation capacity



1 Introduction and objectives

As part of a larger Accountable Grant from the UK Government's Department for International Development (DFID), the Institute of Development Studies (IDS) has conducted a review of the evidence that investments in electricity-generating capacity have benefits for poor people, and what factors influence that relationship.

Lack of access to electricity is seen as a major constraint to economic growth and increased welfare in developing countries. The latest update by the IEA (2012) shows that in 2010 nearly 1.3 billion people did not have access to electricity.[1] This is close to one-fifth of the global population, with most of them in India, South East Asia and sub-Saharan Africa. This deficit is due to a combination of institutional problems and the economics of expanding grid infrastructure or providing off-grid solutions to remote, poor and sparsely populated areas.

After a number of years in which electricity provision slipped down the list of priorities for donors and governments (especially in Africa and South Asia), it is now receiving more attention. A 2009 World Bank assessment of infrastructure needs in Africa, for example, called for investment of $930 billion over ten years, of which nearly half should be in the power sector (World Bank 2009). This renewed interest is in part because of the emergence of climate change as a major problem, and interest in forms of low-carbon development, in which low-carbon energy plays a major role. There is now considerable interest in catalysing investment in low-carbon electricity generation, especially through renewable technologies, to help developing countries avoid 'lock-in' to high-carbon growth paths (IEA 2011; Unruh 2006).

The combination of objectives of achieving universal access to modern forms of energy (which includes electricity), and increasing low-carbon energy capacity and greater energy efficiency in developing countries come together in the call for Sustainable Energy for All, with 2012 being the UN's Year of Sustainable Energy for All.[2] As a result, bilateral donors and multilateral development banks are now seeking to put an increasing amount of resources (both directly and indirectly through leveraging private finance) into investment in electricity generation and access in low income countries. This includes DFID, which has been increasingly involved in electrification interventions through its participation in the UK's International Climate Fund (ICF). The ICF became operational in 2011 and is expected to disburse £2.9 billion over the period 2011–14, with 30 per cent (£870 million) of that amount allocated to low-carbon development, of which a significant share may be spent on low-carbon electricity infrastructure.[3] The ICF is run jointly by DFID, DECC, DEFRA and the FCO.

One major issue for DFID is to ensure that its investments in renewable energy generation capacity are effective not only in mitigating climate change but also in benefiting poor people. Accordingly, this review aims at responding to two main questions: what is the evidence of the impact of investments in renewable electricity capacity on poverty reduction? And what conclusions can be drawn from this evidence to help donors better target their investments to maximise their impact on poverty reduction? This review will inform the subsequent development of indicators and methodologies to be used in the business case for DFID's investments in renewable electricity capacity.

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[1] The OECD/IEA define access to electricity as: 'more than a first supply connection to the household; our definition of access also involves consumption of a specified minimum level of electricity, the amount varies based on whether the household is in a rural or an urban area. The initial threshold level of electricity consumption for rural households is assumed to be 250 kilowatt-hours (kWh) per year and for urban households it is 500 kWh per year.'
[2] www.sustainableenergyforall.org
[3] *ICF Implementation Plan 2011/12–2014/15*.

2 Background

2.1 The evolving understanding of electricity–poverty links

Several authors provide good reviews of the evolving rationale for donor support to electrification in developing countries, on the basis of its poverty impacts (see, for example, Cook 2011; Bernard 2010 and IDS 2003). Three main stages can be differentiated, with a clear influence of the World Bank's approach.

During the first stage, until the early 80s, electricity was seen as a catalyst of economic growth, considered the engine of development. It was taken for granted that growth in output would deliver development and poverty reduction and that this growth required growth in energy consumption. Electricity was seen as an essential element of modernisation that would contribute to limit rural migration to the cities and to reduce deforestation. It was expected to deliver high political returns. Large-scale generation projects had a political symbolism, marking strategic political alliances in the context of the Cold War. Electrification projects were expected to deliver high returns as connection and consumption rates increased and as they fuelled economic growth across the country. All this made investments in rural electrification worthwhile, even if initial capital investments were high and benefits had not been corroborated with evidence. As a result, investments in infrastructure and particularly in generation capacity were given a central role in development policies.

A second stage from the early 80s until the mid-90s saw energy falling off the agenda of mainstream development thinking and action. The World Bank's lending to the electricity sector declined rapidly as did support from other donors and there was a stronger focus on cost recovery and profitability. The change in direction was due to the disappointing results of many electrification programmes. Evidence from the World Bank (IEG 1994) showed low economic returns, low-cost recovery and little evidence of an impact on industrial development. Connection rates and consumption remained low despite improved availability and electricity was rarely used for productive activities. It was instead mostly used for lighting in the early evening hours, not inducing the expected outcome of industrial growth and keeping load factors low and unit costs high.

Electrification had therefore contributed to the unsustainable debt burden of many countries without delivering evident development benefits. Besides, it had not particularly benefited the poor as usually only the wealthier households could connect to the grid and have a significant consumption. Hence the large subsidies to rural electrification were not justified. International donors then moved to finance what were considered more basic needs for the poor, such as health, nutrition or water, and the private sector was expected to provide the bulk of financing for electrification. The high costs of electrifying remote, sparsely populated and poor rural communities in developing countries meant that private companies tended to focus on the more profitable urban areas.

The third stage from the late 90s until today has seen a shift by the World Bank and other international institutions from a focus on growth to a focus on poverty reduction as a priority for development. Electrification has come back to the top of international donors' agendas as a key element of poverty reduction strategies. It is seen as a necessary condition to achieve the MDGs (DFID 2002a, 2002b; IEA 2002) and many rural electrification projects use the MDGs as their main justification, although without robust evidence to back it up. The World Bank has claimed that the economic case for investment in rural electrification is proven on the basis of high willingness to pay exceeding the long-run marginal cost of supply (World Bank 2008b), but points at the need of cost-recovery tariff levels and least-cost supply to achieve financial sustainability. This increased interest in energy (including electricity) culminated with the initiative Sustainable Energy for All, with 2012 being the UN's Year of

Sustainable Energy for All.[4] However, the lessons learnt since the 1980s still hold during this renovated interest in financing electrification. New interventions need to be designed to maximise their impact for the poor, avoiding previous failures, mainly: low connection rates; limited productive use; and poorly designed subsidies that benefit the better off, put utilities under financial stress and jeopardise service quality and reliability.

2.2 Electricity generation capacity and poverty reduction: key channels

Expanded generation capacity can have an impact on poverty reduction through several channels. A first distinction can be made between impacts at a macro and a micro level.

At a macro level, electricity capacity can stimulate economic growth and hence indirectly achieve poverty outcomes. At a more micro level, generation capacity can directly improve the income and non-income aspects of poverty through several channels. The magnitude of impacts is determined by the accessibility, reliability, quality and affordability for the poor of the services provided by electricity. Besides, the relationship is complex and is mediated by a number of other factors. Also, causality between electrification and income per capita is not clear. Electricity infrastructures can cause growth, but growth also causes greater demand for electricity, so-called reverse causality or endogeneity. This problem may lead to an overestimation of the impact of electricity on income generation and it should be minimised by using appropriate techniques in macro-level econometric models or impact evaluations at the micro level.

Our literature review will explore the evidence that links electricity generation capacity to poverty reduction by questioning each of the links in the causal chain as illustrated in Figure 1. The figure shows two levels of analysis, one at the macro level and another at the micro level involving households and firms. The poverty impact of economic growth promoted by electricity at the macro or at the firm level depends upon the extent to which proceeds are equitably distributed. The literature on the relationship between economic growth, distribution and poverty reduction is very large and it is beyond the scope of this study, although for comprehensiveness it is included as part of the causal chain that will guide our review.

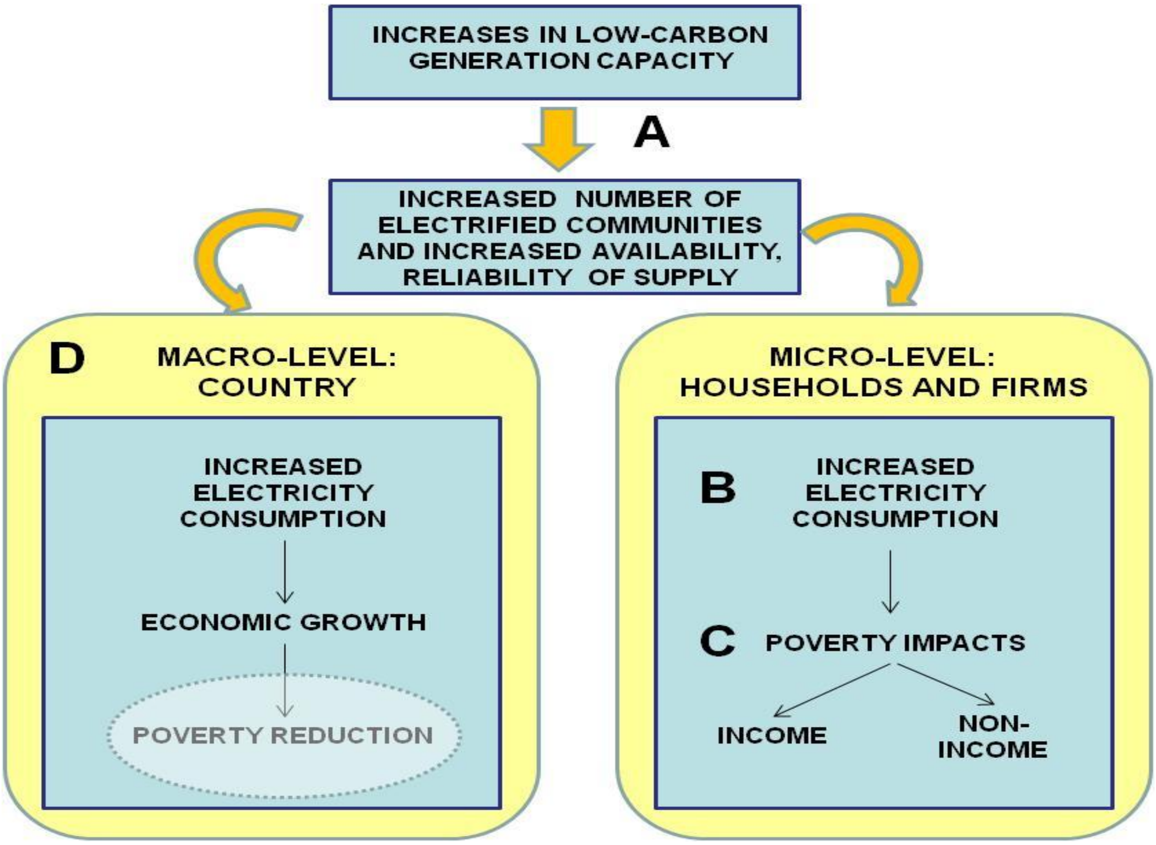
The actual impact of electricity generation capacity provision on poverty reduction therefore depends on several links, according to which our review can be broken down into four main questions:

A. What is the relationship between increased renewable energy generation capacity and higher availability and reliability of supply?
B. What is the relationship between higher availability and reliability of electricity and increased connection rates and actual consumption by households and firms?
C. Once households and firms get a connection and start consuming electricity, what is the evidence of the impacts of this consumption for the poor?
D. What is the relationship between electricity capacity or consumption and economic growth at a macro level?

A brief description of each of these elements of the causal chain is presented below.

[4] www.sustainableenergyforall.org

Figure 1 Causal chain of poverty impacts of electricity generation capacity



A. Relationship between increased renewable energy generation capacity and higher availability and reliability of supply

When additional generation capacity is provided through off-grid systems it is fairly straightforward to link investments in capacity to electricity consumption by end-users. However, the relationship between grid-connected generation units and the number of people with improved access to clean energy is a more complex issue.

Electricity is a system rather than a fuel. Supply of electrical power to an end user requires generation, transmission and distribution.[5] A reliable supply of power requires generating capacity to match demand at all times, including at times of peak demand. In this context, peak capacity means capacity that is reliably available. In a large system (i.e. regional or national grid), to ensure reliability an excess of available unused capacity over expected peak demand is required. This is something that does not always happen in developing country systems. Some types of power generation, including fossil-fuel generation using gas, oil or coal fired thermal plants as well as hydro, are known as 'dispatchable' as they can be ramped up and down to follow daily or seasonal changes in demand. The power output of nuclear plants can also be varied,[6] but this is costly, so nuclear is often run at base load (i.e. at a constant output). Dispatchable power sources may not always be available, because of planned maintenance downtime or faults, and in large grid systems their contribution to the peak capacity of the system is 'de-rated' by a small proportion to reflect this.

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[5] In very small-scale technologies (such as solar photovoltaic products or on-site systems) these elements are collapsed into one.

[6] In France, the output of nuclear plants are to an extent varied over the course of a few days, but this practice requires greater maintenance of the reactor cores.

Renewable electricity technologies vary in whether they are dispatchable. Biomass, hydro and geothermal are dispatchable, but solar PV and wind vary with the strength of the wind and sun, and are known as 'intermittent' power sources. Without storage (which remains prohibitively costly at grid scale), they cannot be dispatched at peak times and so they cannot be regarded as adding their rated (i.e. maximum output) capacity to the peak capacity of the system. They are thus also de-rated, but to a greater extent than dispatchable power sources.[7] In conventional, demand-following grid electricity systems, a large proportion (i.e. above 20 per cent) of intermittent renewable generation starts to pose problems in terms of the use of dispatchable power plants to balance supply and demand. Few developed countries[8] and no developing countries yet approach this level of grid-connected intermittent sources at present, however.

A conventional measure of the expected reliability of an electricity system is the excess of total de-rated generating capacity in a system over expected peak demand, known as the (planning) capacity margin. A full probabilistic assessment is required to define safe de-rated margin metrics. Generally, as the capacity margin in a system falls below around 10 per cent of peak demand, the reliability of supply begins to deteriorate.[9] To avoid system collapse supply must equal demand – and ways to do this include voltage reduction (brownouts) and planned customer disconnections (rolling blackouts). Unplanned blackouts are usually the immediate consequences of sudden faults. In many developing countries, reliability problems arising from insufficient capacity margins are common, and involve considerable costs for users of electricity.[10]

In principle, an addition to electricity generating capacity within a system should provide some combination of improvement to the reliability of electricity supply, a greater number of electricity consumers, or increased peak consumption of electricity per user, as long as that addition exceeds any increase in total peak demand.

However, a key factor affecting the contribution of new generating capacity to these outcomes is the state of transmission and distribution networks. Many T&D networks have points where the flow of power from regions of excess capacity to regions of excess demand is constrained by the capacity of the network. Thus the impact of adding new capacity on reliability, consumption and the number of potential consumers depends partly on its geographical location in relation to centres of demand and the ability of the existing network to deliver power from the new plant to those centres. The reliability of supply also depends more generally on the state of networks, especially distribution networks, how well maintained they are and how resilient to events like storms. Non-technical losses (i.e. theft) can also significantly reduce reliability of supply. Where blackouts are caused mainly by network faults, adding new generating capacity will not necessarily help.

Total demand, available capacity and grid extension in electricity systems in many developing countries are constantly changing, which means that it is not clear what would happen without upgrades, and comparisons have to be made with the state of the system before the intervention. It also means that the effects of an intervention may change over time.

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[7] For example, in assessing planning capacity margins in the UK, DECC de-rates on-shore wind to about 25-30 per cent of its peak capacity, and solar PV to about 10 per cent of its peak capacity.
[8] The exceptions are Denmark, Spain and Germany.
[9] There are a range of different commonly used measures of poor reliability of supply, including loss of load probability, loss of load expectation and expected unserved energy.
[10] The ability of system operators to manage load shedding spatially also means that users in politically or economically more marginal areas tend to a have more unreliable supply than, for example, the centre of large cities. In some places, poor reliability of national electricity systems has led many users, especially industrial and commercial users, to install on-site generation at their own expense as an alternative. For example, in India, where reliability is a chronic problem, such on-site 'captive power' constitutes almost 15 per cent of total capacity.

In addition to the technical aspects of improving access to and reliability of electricity through increased generation capacity, the decision of which communities to electrify has strong economic and political components. Public utilities traditionally have been highly politicised and have concentrated their services on urban elites, often neglecting the poorest populations (Victor 2005). Regarding international donors, evidence from World Bank projects shows that communities to be electrified are generally chosen on a cost-effectiveness basis. This involves selecting communities that are close to the existing grid, densely populated, with high average income and productive potential (World Bank 2008a, 2008b). In the case of the World Bank, since its 1995 report showing disappointing results for rural electrification projects, this has been a product of explicit policy aiming to maximise cost recovery. Evidence from the World Bank also shows a minority of projects (17 per cent) using a social allocation rule, giving preference to deprived areas or looking for geographical balance regardless of economic criteria. Some examples of this are Ghana, South Africa or Brazil, where the government has implemented special programmes to increase access to electricity for the poor.

B. Relationship between increased availability and reliability of electricity and actual connection and use by the poor

Even when investments in transmission and distribution provide the possibility of access to electricity to communities that did not have it before, evidence shows that this does not automatically translate into increased connections. And even when firms or households connect, their consumption is often too low to be a catalyst of significant poverty reduction impacts. It is important to clarify what is involved in the supply and use of electricity, because the commonly used term ‘access to electricity’ hides a number of distinct separate aspects of the consumption of modern energy services by households, firms and social services. Access to electricity involves not only the availability of supply (i.e. in the form of a home system, a mini-grid or a distribution network in the community), but also accessibility (i.e. poor households can physically connect and pay any costs of connection and supply). Besides, a simple measure of ‘access’ to electricity glosses over variation in the type and quality of supply. There can be large differences in the level of power being delivered, from maybe a 50 watt solar home system, up to a grid-connected source with unlimited power. There can also be widely varying experiences in the reliability of supply. In many cases, power may be available only for a few hours a day on a regular basis; in other situations supply may be interrupted in an unpredictable way.

Low connection rates and consumption were one of the main problems of rural electrification projects identified by the World Bank in the 1980s and continue to be a problem today. Low consumption levels are also documented in several studies. Once households or firms are connected, their actual use of electricity depends on the use of electricity-using appliances and equipment that provide energy services. These include lights, mobile phones, TVs, radios, fridges, water pumps, sewing machines and other agricultural and non-agricultural machinery. It is widely documented that most poor households with electricity access use it only for lighting, and as income levels increase wider uses are introduced, mostly mobile phone charging, TV and radio. The use of electricity for productive activities, in the agriculture, industrial or services sectors is still rare. As a result, the income-generating effect of electricity remains low, which in turn contributes to poor people’s inability to afford electricity.

The review will analyse evidence of the relationships between electricity availability, connection rates and consumption levels among households and businesses. It will particularly address the evidence of factors contributing to productive uses of electricity and hence having a direct impact on income levels. Low connection rates and consumption are particularly prevalent among poorer households in rural areas that cannot afford connection rates, electricity tariffs or the appliances required to turn electricity into useful energy services. These low connection rates and consumption are disappointing not only in terms of poverty outcomes but also in terms of cost recovery, as connection costs and electricity tariffs increase when there are a lower number of consumers to cover capital costs.

C. Relationship between electricity consumption and poverty impacts

The energy services provided by electricity through the use of different appliances and machinery can convey several benefits for households and firms.

Households' income can improve through the increased productivity of domestic tasks that may liberate time for paid employment; cost reduction of energy consumption; the creation or improved performance of enterprises; or higher agricultural productivity. Non-income aspects of poverty can improve through opportunities for a better education as children and adults are able to study or read in the evenings; better health via food storage or less indoor air pollution; reduction of fire hazards; gender equality through better access to information and less time spent on non-paid work; entertainment, communications and access to information via TV, radio and mobile phones; outdoor safety with street lighting; and improved comfort and convenience indoors. This list is non-exhaustive and many other benefits are claimed by the existing literature. For example, Cecelski and Glatt (1982) list up to 50 discrete benefits.

In addition to the direct benefits for households and firms, electricity can improve the quality of health and education services for the poor. In health facilities, electricity facilitates services such as sterilisation, water supply and purification, sanitation, and refrigeration of essential medicines (GTZ and NL Agency 2010). Electricity in schools provides better lighting and allows the use of ICTs in teaching and learning (GTZ and NL Agency 2010: 12). However, one review (World Bank 2008b) finds no evidence for effects through these routes in rural areas (for instance in immunisation rates), and instead points to the effect that electricity provision increases the willingness of more educated workers (such as teachers, doctors, nurses, and extension agents) to reside in rural areas.

The literature on the benefits of electricity for the poor is vast and there are a number of reviews of evidence (including some commissioned by DFID) on direct links between electricity consumption and development benefits for poor households (e.g. Suarez 1995; Brenneman and Kerf 2002; AEAT 2003; Future Energy Solutions/DPU 2002; Willoughby 2002; World Bank 2008a, 2008b; Bernard 2010; Cook 2011; IOB 2013). Empirical studies vary in their level of sophistication, from those providing a mere list of potential benefits, to quantifying concrete benefits and finally to establishing an actual causal linkage between electrification and its development outcomes.

The quantification of the impacts of electricity and the attribution of causality present many challenges. Firstly, the outputs of electrification are very difficult to define and measure, as many of them are indirect benefits. Many effects only become evident after long periods of time, but as time passes effects become more difficult to attribute to electricity. Also, the benefits of electrification take place through long causal chains with interactions with many other external factors which makes it difficult to differentiate the part of the impacts attributable to electricity. Comparisons of units with and without electricity also raise problems of differences in initial conditions, so that impact measures may in fact capture the impact of these initial differences and not that of electrification. This is particularly relevant for electricity, where 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 leads to the so-called placement bias or selection bias. Robust evidence must avoid these problems by using appropriate counterfactuals and adequate controls.

D. Relationship between electricity consumption and economic growth at the macro level

The provision of electricity infrastructures may stimulate economic growth at the national or regional level (and thus indirectly stimulate poverty reduction) by reducing production and transaction costs; enabling new activities that were not possible without electricity; increasing private investment or improving agricultural and industrial productivity.

The existing evidence on causality between electricity consumption and economic growth is, however, inconclusive. Electricity consumption can cause growth, but growth also causes greater demand for electricity – so-called reverse causality, or 'endogeneity'. This problem is believed to have caused over-estimates of the impact of infrastructure on growth in early studies (Estache & Fay 2007). An important question for the prioritisation of development funds relates to the importance of electricity in relation to other factors of production, such as capital or labour. An increase in electricity supply, access and reliability will lead to economic growth only if electricity is one of the key binding constraints or growth (UNDP 2012).

Through question D, this review analyses the existing evidence on the relationship between electricity consumption and economic growth in developing countries, focusing on two main related questions: the direction of causality and the quantification of the impact of electricity consumption on economic growth. As previously explained, even if electricity is proved to cause growth, this will not ensure poverty reduction. This will only happen to the extent that growth is pro-poor. There is a wide literature linking growth to poverty reduction, but it is outside the scope of this review to examine this subject in detail.

3 Methods

3.1 Approach: a 'realist review'

Unlike 'traditional' systematic reviews, mainly applied to the health sector, the evidence available on the impact of electrification on growth and poverty reduction is not largely in the same form. There is not a critical mass of randomised control trials (RCTs) available to provide comparable quantitative assessments of the evidence available. This is due to the difficulty of randomising the provision of electricity. As a consequence of the large capital investments required for electrification, providing entities generally follow a plan to reach more developed and densely populated communities first before moving the services out to more remote and less developed areas in order to increase chances of cost recovery. This makes it difficult to construct a credible and robust counterfactual to evaluate the poverty impacts of electrification. For this reason, evidence is available in a range of forms, including Multilateral Development Banks and other donor impact evaluations, academic studies relying on qualitative case study analysis, quantitative analysis showing relationships between electrification and several benefits for the poor, and quasi-experimental studies.

Given the heterogeneous nature of the available evidence on the question under review, it was decided to employ a 'realist' approach, which Pawson *et al*. (2005: 1) describe as follows:

> Realist review is a relatively new strategy for synthesizing research which has an explanatory rather than judgemental focus. It seeks to unpack the mechanism of how complex programmes work (or why they fail) in particular contexts and settings.

A realist review begins by elucidating a theory to break down the causal chain between an intervention and its impacts in several stages or links. Evidence is then assembled to support assumptions made for each of these links so as to inform future interventions and improve desired outcomes.

3.2 Conceptualising and interrogating the causal chain

The description of the different links in the causal chain between interventions to increase access to electricity and poverty impacts was provided in Section 2.2. In this section, we make explicit the assumptions that underpin each link in the chain and the key questions that need to be addressed by the review to test those assumptions. We also identify and provide a rationale for the selection of the key links to be covered.

A. What is the relationship between increased renewable energy generation capacity and higher availability and reliability of supply?

Given time and resources constraints, this study cannot deal with a detailed review of reliability assessments in developing countries beyond those available in the academic literature, with an assessment of the availability of data required for a technical assessment, or with the actual power system analysis in developing countries. Instead, we review available academic literature and suggest an approach for power system reliability analysis in developing countries on the basis of experiences in developed countries. We also suggest the next steps for the analysis.

The review of different electrification strategies in developing countries also falls outside the scope of this study, which focuses on the impacts of electricity for the poor once this is made available in their communities. Narrowing down the scope of the review is essential, given the vast literature on different aspects of electrification in developing countries. For the purpose of informing donors' planning of low-carbon electricity capacity, a country-by-country analysis of the political economy of electrification processes would be advisable, instead of a high-level perspective of different strategies followed in the developing world.

B. What is the relationship between higher availability and reliability of electricity and increased connection rates and actual consumption by households and firms?

The review tests two main assumptions. Firstly, that several barriers can prevent households and firms from connecting to the grid or gaining access to off-grid systems once these are made available in their communities. Alternatively, some other factors can facilitate connection by households and grids. The review will question what these factors are and what their impact is on the likelihood that a household or firm connects to the grid or obtains access through off-grid systems. Secondly, that once a household has gained connection to the grid or access to an off-grid system, a number of factors can prevent or facilitate the level of electricity consumption. The review will question which are the factors that influence actual use and will show estimates of the magnitude of their impact, when elasticities of electricity consumption are provided. Given the different understanding of 'access to electricity' in the literature, we will also question each reviewed paper about their definition.

C. Once households and firms get a connection and start consuming electricity, what is the evidence of the impacts of this consumption for the poor?

The main assumption to be tested is that use of electricity has positive impacts for the poor. This impact depends on the amount and specific use of the electricity consumed by firms or households, which in turn depends on the complementary technologies used to turn electricity into energy services. In addition to the appliances used, several factors influence the incidence and magnitude of poverty impacts, including gender relations and enabling factors complementing the electrification intervention. The understanding of the poverty impacts of electricity consumption also requires that the definition of poverty is made explicit. All these issues are considered in this review through the following questions:

- What are the main uses of electricity by households, public services and firms?
- What is the concept of poverty the study aims to test?
- What are the poverty impacts of electricity used by households and can these be quantified?
- What are the impacts of electricity use for productive activities and can these be quantified?
- Which factors enable the incidence and magnitude of electricity consumption impacts?
- Does the study consider gender differentiated impacts?

D. What is the relationship between electricity capacity or consumption and economic growth at a macro level?

The main assumption to be tested by this review is that electrification and in particular, electricity consumption, causes economic growth. The key questions to be addressed in this review to show the evidence that backs or refutes this assumption are:

- What is the direction of causality between economic growth and electricity consumption?
- What is the magnitude of the impact of electricity consumption on economic growth?

This review will not analyse the poverty reduction effect of impacts of electricity for productive activities, as there is an extensive literature on the poverty impact of economic growth which cannot be analysed within the time frame and resources of our study

3.3 Searches

3.3.1 Databases and grey literature

The search encompassed both peer-reviewed studies and grey literature. The following databases were queried in the search for relevant studies:

- Google Scholar
- Elsevier Science Direct
- IDEAS
- British Library of Development Studies (BLDS)
- Eldis
- ProQuest dissertation database
- JOLIS
- JOLISplus
- World Bank
- IEA
- UNDP

In addition to articles extracted from bibliographic databases, our review also includes studies identified through back referencing of existing literature reviews and empirical articles. Due to time and accessibility constraints, books were not included in the review.

3.3.2 Search strings

Each of the databases above was questioned for a string of search terms included in Appendix 1. The first set of search terms captures interventions to increase the access to electricity. The second set captures the direct results of those interventions as regards the actual use of electricity. The third set captures different poverty outcomes of the increased use of electricity. The fourth and fifth aim at limiting the results to studies based in developing countries and dealing with low-carbon technologies. Because electricity is a homogeneous service, regardless of the technologies used, we did not exclude studies that did not focus specifically on low-carbon technologies.

There was a need to balance the imperative of including all relevant literature with the need to keep the costs of the review within budget by minimising the probability of including irrelevant studies which then have to be manually excluded from the review. To achieve these aims the search design was aligned with the sub-questions outlined in Section 3.2 above. Each sub-chain of the logic model was covered with a set of search terms. These sets were combined using logical operators such as AND or OR to construct search strings for use in electronic databases. The search strings initially used for each of the review sub-questions are detailed in Appendix 2.

We conducted pilot searches to ensure that the results did not include irrelevant studies having similar words from other unrelated disciplines or excluded relevant studies because they contained only synonyms of the keywords used here. We found that different databases were more or less efficient in identifying relevant studies. Accordingly, we had to adapt our search strings to each specific database to ensure that relevant studies were included and minimise the number of irrelevant ones. The final search strings used for each database are included in Appendix 2.

3.4 Study inclusion criteria

3.4.1 Electricity systems

This review is interested in on-grid electricity, mini-grids and stand-alone systems. The two latter categories are important because they are expected to play a major role in meeting universal access in sub-Saharan Africa and India by 2030, with 60–65 per cent of new generation occurring either in mini-grids or in stand-alone systems (IEA 2010). Decentralised electricity supply is most attractive in remote or sparsely settled areas where grid infrastructure is an expensive option, although Deichmann *et al*. (2011) emphasise that it is difficult to make generalisations because spatial factors vary so much between countries. While question A refers specifically to grid-connected low-carbon generation capacity, the rest of the questions will take into account the impact of electricity regardless of how it was generated. This is because electricity is a homogeneous service and its effects on poverty are expected to be similar regardless of the generation source. Studies referring to the impact of energy consumption, without differentiation between electricity and other energy sources, will not be included in the review.

3.4.2 Definition of 'poor' and 'non-poor' households

Different studies define what constitutes 'poor' in different ways. We do not propose to use any particular definition of poverty to reject or accept studies, partly because there is no absolute basis for doing so. Rather, we will attempt to make explicit the definition of poverty used by each study and group studies accordingly, to allow appropriate comparisons of results.

3.4.3 Geographical scope

Following the 2010 bilateral aid review, DFID has increased its focus on low-income countries. However, the purpose of this review is to learn from a wide evidence base in developing countries. At the same time, investments under the ICF may be considered in some middle-income countries as well as in LICs. Therefore we propose to consider evidence on the four areas above from all developing countries (i.e. low-income or middle-income countries, as defined by the World Bank). Studies including data from both high and middle/low-income countries where individual outcomes for low/middle income countries were not presented were excluded from the review.

3.4.4 Measurement of development benefits

There are many possible measures of the ultimate impact of electricity consumption on poor people. These include final outcomes, such as increased income, health and education improvements, and intermediate outcomes, such as increased employment, time allocation, access to information, safer food storage or lower long-term cost of lighting. We also make a separation between productive and non-productive uses, indicating when studies refer to households, industry or both. Additionally some studies analyse specific impacts on gender. Since the effects of electricity access may work through many potential routes, we have an open approach to outcomes and do not exclude any studies on the basis of a fixed list of such indicators. As part of question D we also analyse the potential indirect benefits for the poor through increases in economic growth attributable to electricity. However, the relationship between economic growth and poverty reduction is not analysed.

3.4.5 Time horizon

We have not set any restrictions on the time of interventions studied. This is because on one side, if a short period is chosen, there may not be sufficient time for the benefits of electricity access to be felt even though they may be significant in the long term. A short time period also prevents assessment of the sustainability of the intervention and its impact. In addition, the time taken for different benefits of electricity consumption to be evident is likely to vary. However, on the other hand, the longer the period, the greater is the potential for confusion between impacts due to changes in electricity provision and those possibly due to other factors. This would be the case at the level of a household or at the economy-wide level. When reviewed studies explicitly include it, we will detail the time of the intervention analysed. However, many studies only refer to the impacts of 'electrification' without indicating when electricity was made available.

3.4.6 Methodological approach

Following DFID's terminology (DFID 2013), we only include primary and empirical studies [P&E] as opposed to secondary [S], theoretical or conceptual [TC]. DFID distinguishes three types of P&E studies: Experimental [P&E; EXP], Observational analytical [P&E; OBS-AN] and observational descriptive [P&E; OBS-DES]

According to DFID's internal documentation for the quality assessment of literature, experimental research designs (also called 'intervention designs' and 'randomised designs') administer a treatment or intervention to a treatment group, but not to a control group. In such designs, the researcher deliberately manipulates the intervention (or 'independent variable') in order to explore its effects on the subject group. Experimental designs allocate subjects (people, villages, etc.) to treatment or intervention groups at random. This increases the chances that any difference in effect observed is a direct result of the treatment administered. Experimental research designs subject any observed differences in the subsequent behaviour of the two groups to quantitative analysis (specifically 'inferential statistics'). The combination of random assignment and quantitative analysis enables the construction of a robust counterfactual argument (i.e. 'what would have happened in the absence of the intervention or treatment?'). Such designs are useful for demonstrating the presence, and size of causal linkages (e.g. 'a causes b') with a high degree of confidence. Randomised Control Trials (RCTs) are a well-established form of experimental research. Although RCTs are considered the gold standard and would be the highest quality approach, no such studies have been on the poverty impacts of access to electricity. This is due to the difficulty of randomly allocating access to electricity, given the high upfront costs of grid extension and off-grid systems, which requires some planning. Bernard (2012) points at a new upcoming study by Chemin and De Laat on the poverty impact of an off-grid micro-hydro scheme implemented in Kenya. The impact evaluation will use a randomised phasing-in approach across communities, comparing households with mini-grids connected early on to those where power will only come later. The supplier randomly chose which of the 20 mini-grids were to be connected first, in order to avoid potential placement biases. Additionally, a paired matching was conducted based on observable characteristics collected at the baseline to further ensure that the households within the first ten mini-grids to be electrified were sufficiently similar ex-ante to those in the following ten mini-grids. The results of that study are not yet available and therefore could not be taken into account in this review.

Observational (sometimes called non-experimental) research designs may be concerned with the study of groups that have received a treatment with comparison groups that have not. However, unlike experimental research designs, the researcher does not deliberately manipulate the intervention: s/he is merely an observer of a particular action, activity or phenomena (hence the name 'observational').

Observational analytical studies include quasi-experimental approaches with non-random treatment assignment that have a proper argumentation about how selection bias is controlled for. Other analytical studies that do not address causality are regression analysis, cohort and/or longitudinal designs, case control designs, cross-sectional designs (supplemented by quantitative data analysis); and large-n surveys with inferential statistics.

Observational descriptive studies include description of data, interviews, focus groups, case studies, historical analysis, ethnographies and political economy analysis. These studies may be more appropriate for teasing out explanations for causal relationships.

Our review of questions B and C will include both OBS-AN and OBS-DES studies. The methodological quality of the studies will be assessed according to the criteria defined in Section 3.6 about study quality assessment. High-quality studies will be prioritised for in the synthesis of the literature and the discussion.

Our review of question D, about the relationship between electrification and economic growth at the macro level, only includes OBS-AN studies. Two types of studies are included, those that consider the direction of causality and those that estimate the size of the effect. For those studies that estimate the size of the effect, we include those that report some growth elasticity that can be compared across studies. For example, Adeleke (2010) or Abanda *et al.* (2012) study the significance of the Spearman's correlation coefficient, but are not part of our analysis as they cannot be included in either of the analysis since they do not consider causality and do not report elasticity estimates. Another example is Frederiksen (1985) who employs OLS estimates in order to show that regional income increases with the percentage of electrified homes. However, the author did not include a discussion about causality and the outcomes could not be translated into elasticity estimates.

3.4.7 Language

Only studies in English were included.

3.5 Selection of studies

Once the searches were complete, studies were categorised for inclusion. The first inclusion criterion applied was the relevance to the main subject of the review. Our first assessment of relevance was limited to titles, abstracts and keywords (where available) for papers in the above databases. The inclusion criteria were applied successively to titles, abstracts and full reports.

A first assessment of relevance was undertaken as part of the database search, looking only at titles. Most of the studies found by databases delivering a large number of results were found to be irrelevant after screening titles. A first screening allowed for the reduction from around 20,000 studies to 470 for further review of the abstract. The 470 studies were split for the review of the abstract among two researchers. When the abstract was not clear enough, a quick screening of the full report was required for relevance assessment. Most of the books delivered by the searches were not available, and given the large amount of literature for review, we decided to exclude all books and focus on reports and academic papers. In total 49 books or non-accessible studies were excluded. The two researchers carried out a cross-review of abstracts to test the consistency of decisions regarding inclusion/exclusion at title and abstract level, sometimes requiring reading the full text when the abstract was not clear enough. The final number of documents to be reviewed amounted to 143 studies.

3.6 Study quality assessment

We followed DFID's guidelines for the quality evaluation of the literature, complemented with specific methodological guidance applicable to the quantitative evaluation of electrification interventions. DFID's principles of quality for reviewed literature are summarised in Appendix 3.

Additional methodological guidance attributed higher quality to studies with a higher level of sophistication, from the less sophisticated including a mere list of potential benefits, to the quantification of concrete changes in output pre- and post-electrification and finally to attempting to establish an actual causal linkage between electrification and central results.

High-quality quantitative studies take into account confounding factors that may be causing benefits for the poor apart from electricity (control variables); define an appropriate and credible comparison group (the counterfactual); choose a representative sample; in the case of panels there is a pre-intervention baseline survey so that differences between control and treatment groups can be assessed; correct for potential endogeneity of the electrification variable; and justify the selection of particular specification methods. The highest quality studies are expected to consist of quasi-experimental approaches with non-random treatment assignment that have a proper argumentation about how selection bias is controlled for. Some high-quality approaches would be:

- Instrumental variables that account for non-random assignment of access to electricity. Preferably if the instrument involves some kind of randomisation, such as an encouragement approach. If randomisation is not possible, the instrumental variable should be very well argued. A prestigious journal is a way of certifying that the argument is well developed although this will be taken with some prudence.
- Difference-in-Differences (DID) or Fixed Effects, considering that time variant unobservables might be present. Baseline surveys before the intervention would be much better than having a first round where the intervention was already present. Including the level variables at the first round of the survey would provide more robustness.
- Propensity Score matching (PSM). It should include some kind of matching quality test or sensitivity test for the possible effects of unobservables on the outcomes.
- DID-PSM.
- Regression discontinuity design. It should test if the rule that determines treatment is actually exogenous.
- OLS, provided that it contains some argument or additional techniques to assess selection bias, omitted variable bias, etc.

Studies are considered as low quality when they assume causality by just comparing observations along time, with before and after measurement of their characteristics. These studies do not distinguish between correlation and causality. Other low-quality studies are those that just show the differences between a treated and control group, not taking into account placement bias; and studies merely based on perceptions and not measurement.

3.7 Data extraction strategy

All studies passing the title screening were stored in information management software (EndNote). The screening at abstract/full text level was recorded in an Excel spreadsheet, including the reasons for exclusion. For each included paper, descriptive information was recorded in an Excel spreadsheet. The data extraction form showing all fields considered is included as part of the Appendix 4.

In addition to the Excel database, a short description including all relevant evidence to answer our research questions was recorded in Word format.

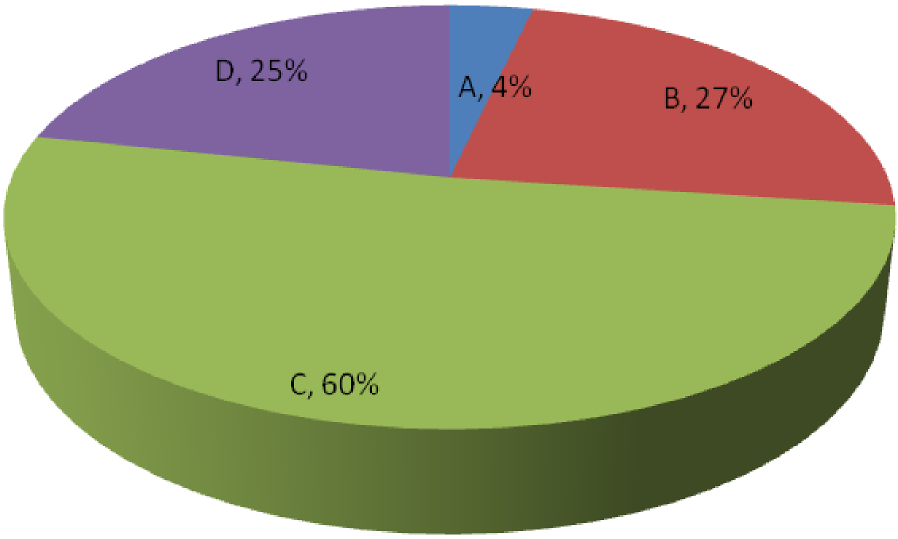
3.8 Data synthesis and presentation

The synthesis of the data was guided by the four key questions that describe the causal link between additional generation capacity and poverty impacts. The synthesis provides for every question a high-level description of the existing literature, the details of the included studies, explores regularities in the evidence, explains the key methodological issues found and finally provides a synthesis of the evidence base to respond to each of the key questions.

4 Survey of the literature reviewed

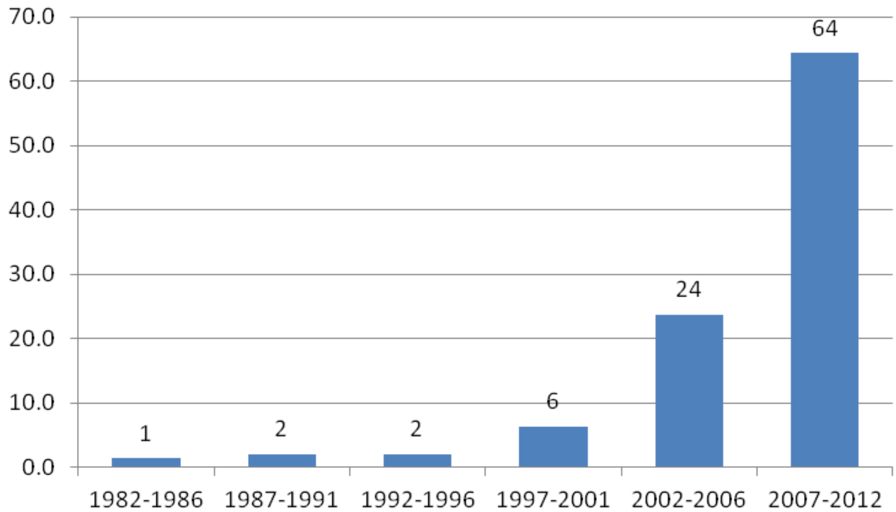
A total of 143 papers were reviewed. The largest share of the literature focuses on the impacts of electricity consumption for households and businesses in developing countries (question C) covered by 60 per cent of the studies, followed by literature about the factors that determine connection or consumption (question B), with 27 per cent. 25 per cent deal with question D. The evidence about power systems reliability in developing countries (question A) is quite thin.

Figure 2 Studies per review questions



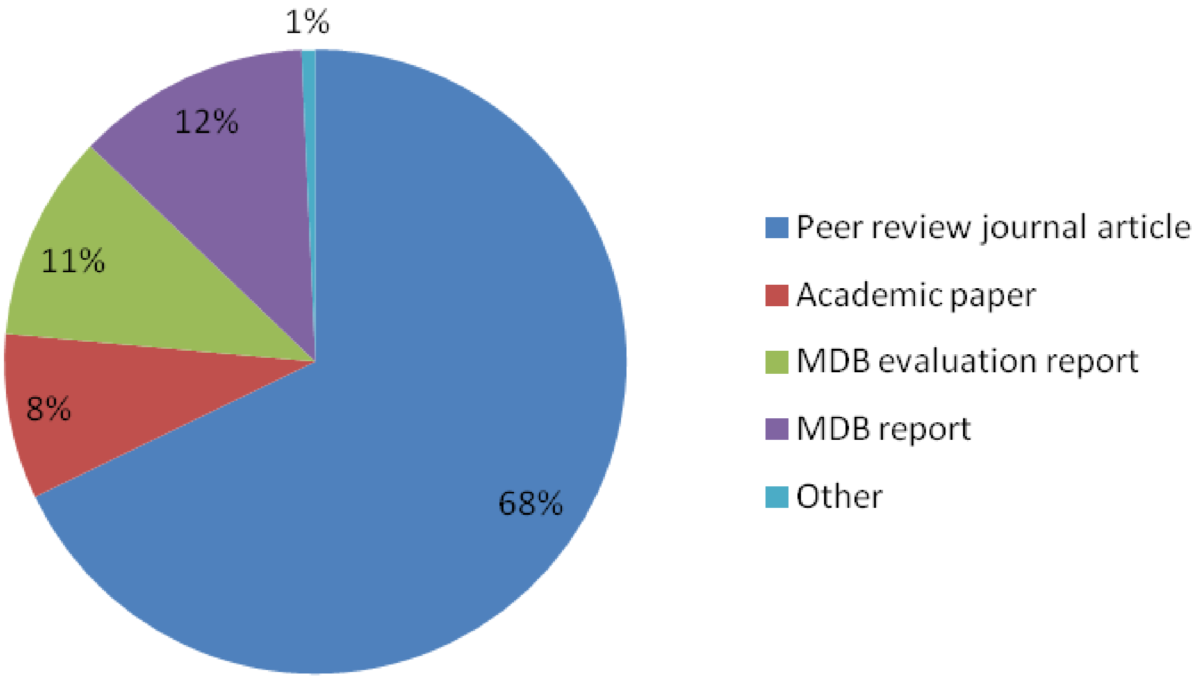
Even though we did not set any temporal limits, most studies concentrate on the last five year period 2007–12, followed by the previous five-year period and with a small participation of publications from the 80s and 90s.

Figure 3 Studies per publication date



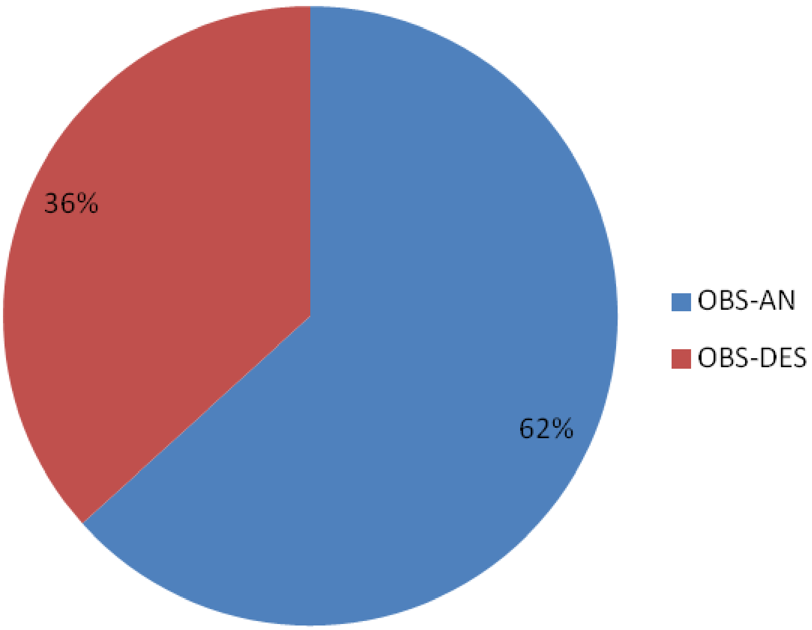
A majority of publications come from peer-reviewed journals (68 per cent). Donor impact evaluations or other types of reports make up 23 per cent of our reviewed literature.

Figure 4 Studies per type of publication



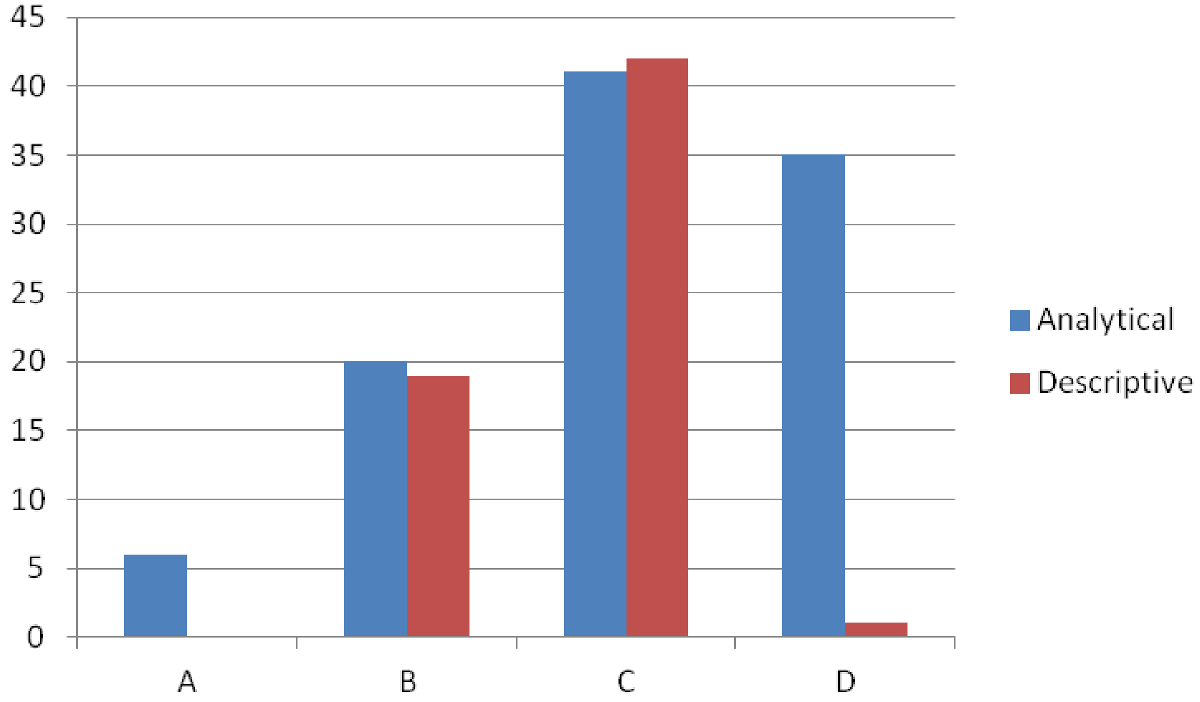
The majority of the literature reviewed is analytical, therefore measuring impacts, studying causality or estimating the monetary value of the benefits of electriciy.

Figure 5 Studies per research design



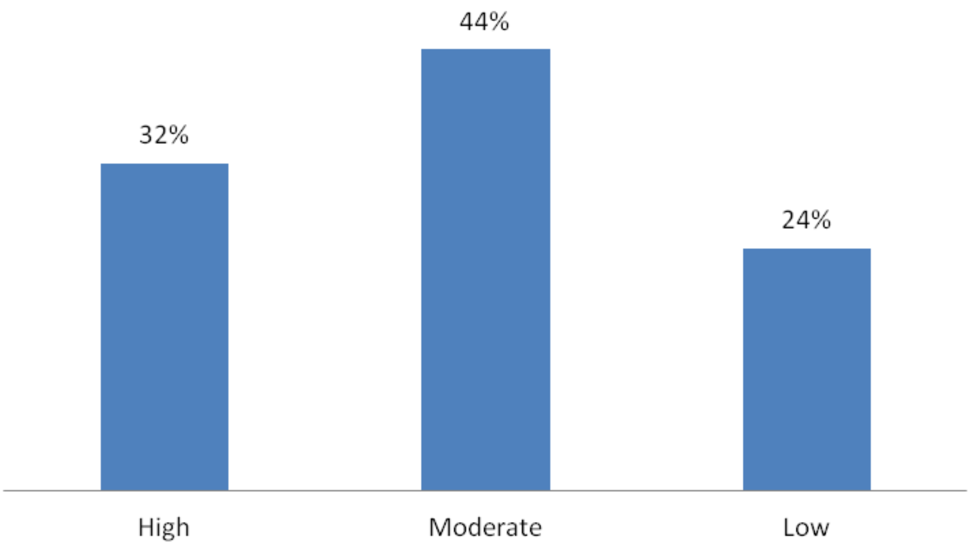
Studies addressing questions B and C have a balanced representation of analytical and descriptive research designs. Many of them use case studies and ethnographic research to provide a more in-depth analysis of the reasons behind low connection and use, the benefits of electricity for the poor and the channels through which these happen. However, questions A and D are almost exclusively addressed by analytical studies, as they involve quantitative modelling of the relationship between electricity and economic growth at the macro level (question D) or power systems reliability analysis (question A).

Figure 6 Research design per question



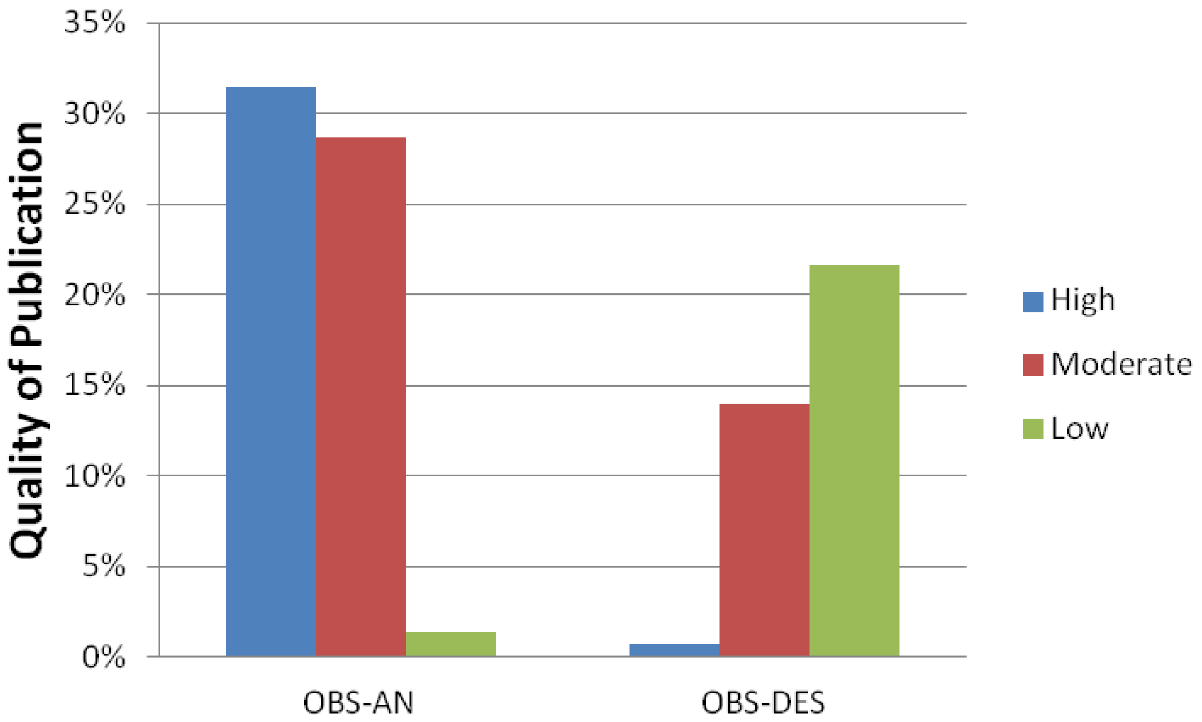
32 per cent of reviewed studies are considered high quality. 44 per cent are of moderate quality and 24 per cent are low-quality studies.

Figure 7 Studies per quality



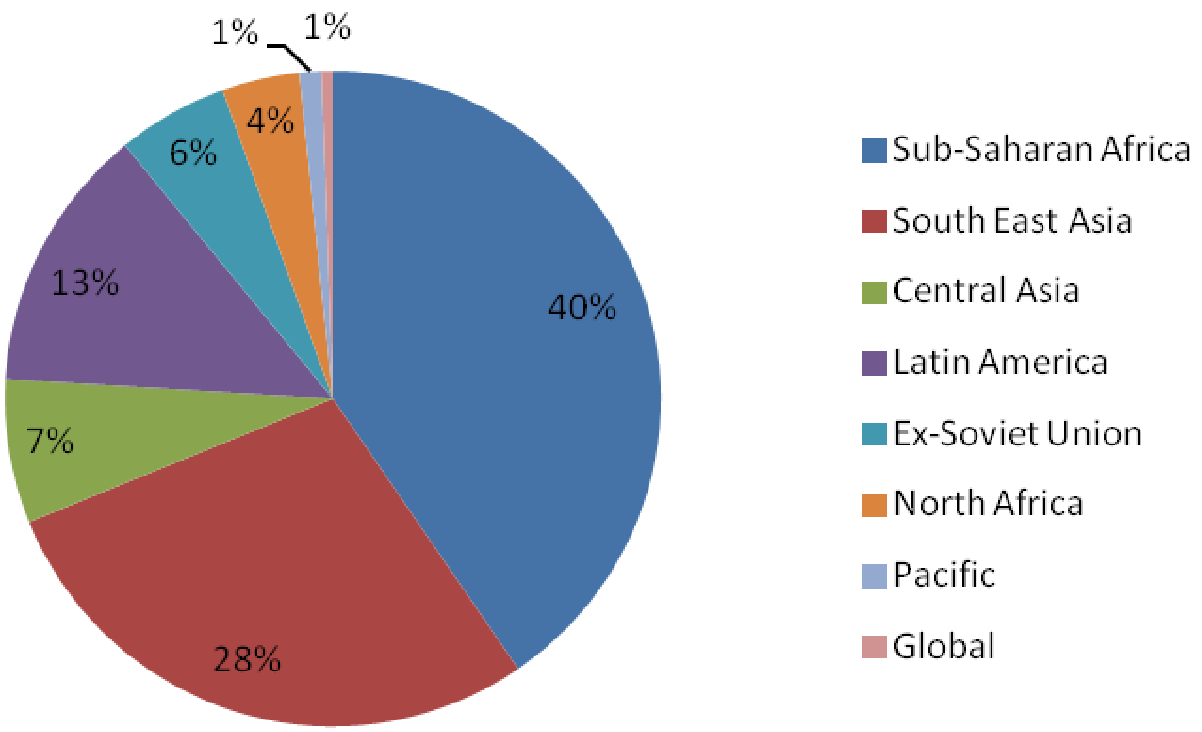
Quality tends to be higher in analytical studies using large samples, presenting credible counterfactuals and taking into account a number of control variables.

Figure 8 Quality per research design



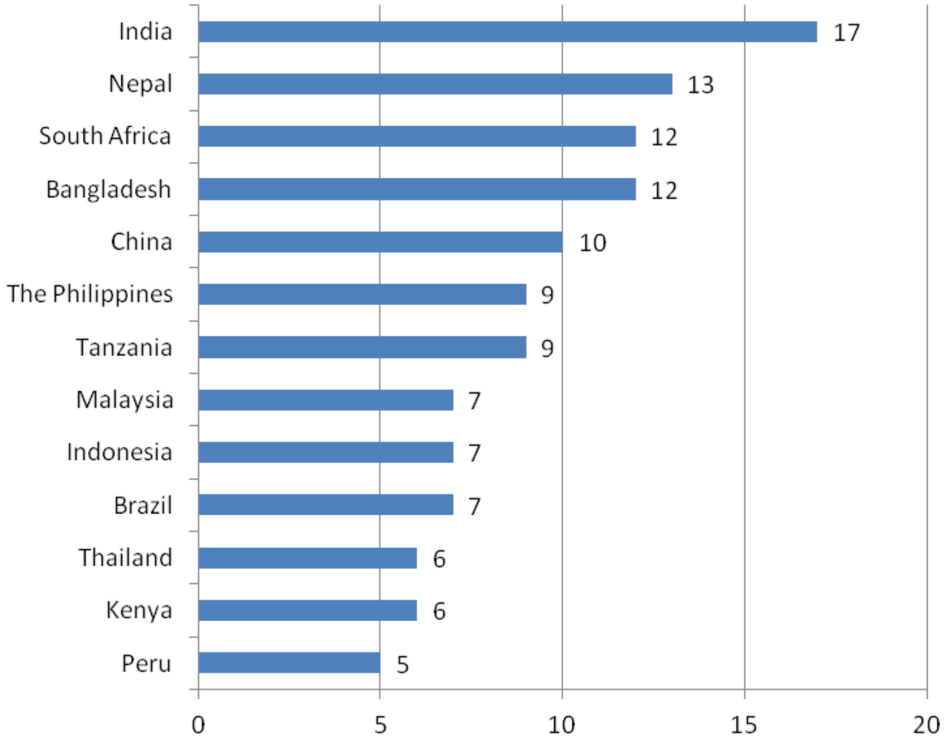
74 developing countries are covered by the literature reviewed. Per regions, most of the studies look at electrification in sub-Saharan Africa, followed by South and East Asia (including India and Pakistan) and Central Asia (including China).

Figure 9 Percentage of studies covering geographic areas



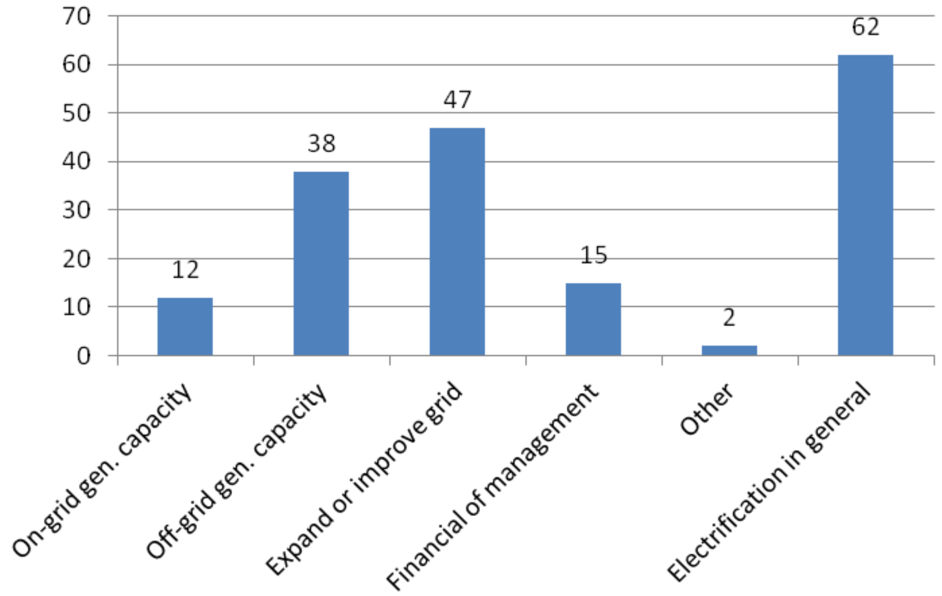
A small number of countries take up most of the studies, with large Asian countries being the most analysed by the literature.

Figure 10 Countries that appear in five or more studies (number of studies)



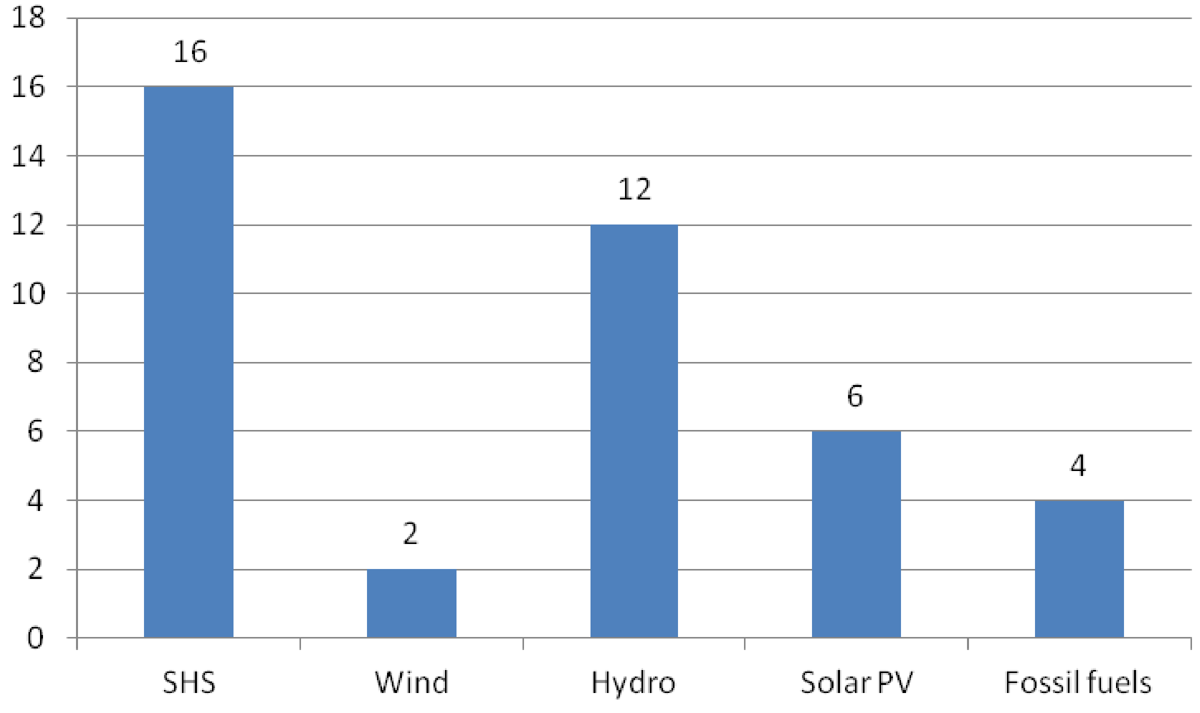
Many studies do not specify the intervention they relate to as they analyse the effects of electrification in general (62 studies). For those that specify interventions, expansion or improvement of the grid (47 studies) is the most common, followed by off-grid generation capacity (38 studies).

Figure 11 Number of studies dealing with the intervention



Some studies dealing with specific generation projects, mostly off-grid systems, can identify the electricity generation technology. Solar Home Systems are the most frequently covered by the literature, followed by hydro.

Figure 12 Number of studies covering specific generation technologies



5 Synthesis

5.1 Question A: Relationship between electricity capacity and availability and reliability of supply

Technical, economic and political factors influence the potential of new electricity generation capacity to improve the quantity and reliability of power supplied and the communities that may get improved access to electricity as a result. This sub-section starts by providing a brief overview of the existing literature on power systems reliability for developing countries. The section continues with a discussion of economic and political aspects that influence which communities get improved access to electricity as a result of improved quantity and reliability of power supplied.

5.1.1 Power systems reliability analysis in developing countries

The potential additional generation capacity in a grid electricity system to increase the number of electricity consumers, the consumption of existing consumers or to improve the reliability of their supply depends on a number of factors, including:

- 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 availability of renewable resource at different times of day/week/year
- Changes in the number of consumers, including not only legal network extension but also illegal connections (which are common in developing countries).

Power system reliability analysis in developing countries can predict the expected impact of additional capacity on reliability of supply and final consumption taking these data into account. However, the literature in international journals and conferences on power system reliability analysis methods specialised to developing countries is very limited.

About ten years ago, Roy Billinton (University of Saskatchewan), one of the founders of power system reliability analysis, supervised a PhD project on reliability of supply in the Nepalese system. This included phases on assessment of interruption costs (Billinton and Pandey 1999b; Pandey and Billinton 1999), reliability of supply analysis (Pandey and Billinton 2000) and generation capacity expansion (Billinton and Pandey 1999a). Data availability was identified as a difficulty in the study, but this work otherwise proceeded in a similar way to analyses in developed country systems.

The other significant activity has been at Cape Town University in South Africa. This includes work on cost of customer interruptions (Herman and Gaunt 2010) and an industrial paper on reliability based network planning (Van Harte *et al*. 2005). Prof. Trevor Gaunt has also written a number of other interesting papers on electrification in South Africa which do not principally address reliability.

Literature on power systems reliability analysis in developing countries is therefore very scarce as compared to economic and other social sciences literature on electrification. Power systems reliability remains an area where methods need to be developed based on a combination of the literature on assessment in western countries and expertise in general statistical and probabilistic modelling, rather than being able to draw much inspiration directly from relevant literature. Appendix 5 includes information on power systems reliability analysis in developed countries and contrasts with developing countries.

A future collaborative study between Durham University, IDS and partners in Ghana and Kenya[11] aims to develop methodologies which can be applied widely across the development community to specify new reliability and value-of-supply metrics for developing countries, based on the available data and applied problems supplied by the African partners. It will further permit exploration of the consequences for calculation results of limited data.

5.1.2 Economic and political aspects of electrification

Even if additional renewable generation capacity improves quantity and reliability of electricity supply, this may still not reach the poor. The imperative of cost recovery and cost-effectiveness as a consequence of the disappointing results of several rural electrification projects involve the prioritisation of the more profitable communities for the provision of electricity. These are usually the more densely populated, closer to the grid, with a high average community income and productive potential and access to roads (World Bank 2008a, 2008b). A minority of rural electrification projects have explicitly targeted the most deprived areas or roll out electrification following geographical balance criteria.

To predict the potential effect of increased on-grid generation capacity for the poor in a specific country therefore requires an understanding of the strategies followed to prioritise the communities that get increased access. Increases in connection rates can either come from intensification (increase the percentage of electrified population inside electrified communities) or extensification (increase the percentage of population living in electrified communities) strategies. The final impact of these strategies on the poor depends on whether they are mostly located in electrified or unelectrified communities. The World Bank recommends considering both financial sustainability and the poverty reduction impact when deciding on rural electrification strategies. For many African countries that still have to embark on rural electrification, connection costs will be high and the emphasis will be on coverage by extensive growth, which will imply relatively low community connection rates. For countries where the grid is available for most of the rural population and utilities are close to financial sustainability it makes sense to shift to intensive growth by reducing monthly connection rates for late connectors and increasing and diversifying patterns of electricity use through consumer education and support to productive uses. Countries with electricity available for a large share of the population but whose utilities are struggling to establish financial sustainability may require tariff increases. Finally there will be areas beyond the reach of the grid that will be suitable for off-grid connections (World Bank 2008b).Extensification strategies can prioritise communities on the basis of cost-effectiveness or social criteria, with the latter expected to have a higher impact on the poor (World Bank 2008b).

Evidence gathered by a recent review of the literature on barriers to increased use of modern energy services among the poor (Watson *et al*. 2012) shows that in addition to economic and social considerations, political and institutional barriers play an important role in determining who gets access to electricity. The review shows evidence of corruption and the behaviour of vested interests, as well as a lack of political will to extending energy services to sparsely populated rural areas.

Given the importance of these economic and political aspects, a political economy analysis of the electricity sector of countries receiving donor support for electrification could provide a better understanding of the expected impacts for the poor.

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[11] The DFID/EPSRC funded project on 'Green Growth Diagnostics for Africa'.

5.2 Question B: Relationship between availability of electricity and actual consumption

5.2.1 High-level description of the literature

This section aims at finding out why once the technical, economic and political hurdles that prevent electricity from reaching the poorest have been solved, and grid or off-grid electricity reaches poor communities, connections and use still remain low. This problem has been identified in several studies. For example Louw *et al*. (2008) remark that household connections in South Africa have not led to a concomitant rise in demand, which makes cost recovery for electrification exceedingly difficult. The World Bank (2008) observe that in the Philippines the connection rate is still 50 per cent three years after electrification; in Lao 20 per cent of households remain unconnected 10 years after the grid reaches a village; in Thailand 25 per cent of households remained unconnected more than 20 years after electrification; or in India, even though 90 per cent of villages have electricity, only 40 per cent of rural households have access. Meier *et al*. (2010) note that the average connection rate in electrified villages of Peru is 80 per cent. Off-grid technologies can also show low pick-up rates as shown by studies in Kenya (Jacobson 2007), Bangladesh (Komatsu *et al*. 2011a) or the Philippines (Hong and Abe 2012).

A very recent systematic review (Watson *et al.* 2012) aimed at answering the question 'what are the major barriers to increased use of modern energy services among the world's poorest people and are interventions to overcome these effective?'. The review includes all types of modern energy services, among which electricity, which was in fact the most commonly discussed modern energy service, covered in 22 of their 41 reviewed articles. The main difference between this study and ours is that the former does not split the causal link of access to electricity for the poor in two steps as we do: firstly the factors that drive or prevent electricity from reaching a community and secondly those factors that drive or prevent poor people from connecting to and using electricity once it is made available.

Still, their results are highly relevant for our study. As regards the second link of our causal chain, they conclude that the literature strongly reports high upfront costs as one of the main barriers to increased demand, regardless of the technology. This demand-side economic barrier normally is linked to a lack of access to finance. The literature reviewed by Watson *et al*. (2012) covers mostly qualitative studies and hence the impact of upfront costs on the likelihood of connecting is not quantified. Electricity tariffs are not reported as a barrier to increased use of electricity by this study. Two more barriers strongly and consistently reported by the literature are technical in nature. A first barrier refers to the quality and performance of hardware, in particular low-quality equipment and installations of SHSs, and poor performance and unreliability of grid electricity. A second technical barrier refers to the low technical capacity to adequately maintain and operate energy systems. This refers in particular to low skills and knowledge amongst end-users and local technicians in the case of off-grid solutions; low capacity of public utilities to operate and maintain power stations and electric networks; dependence on donors' technical support; and poor managerial skills to provide adequate after-sales services.

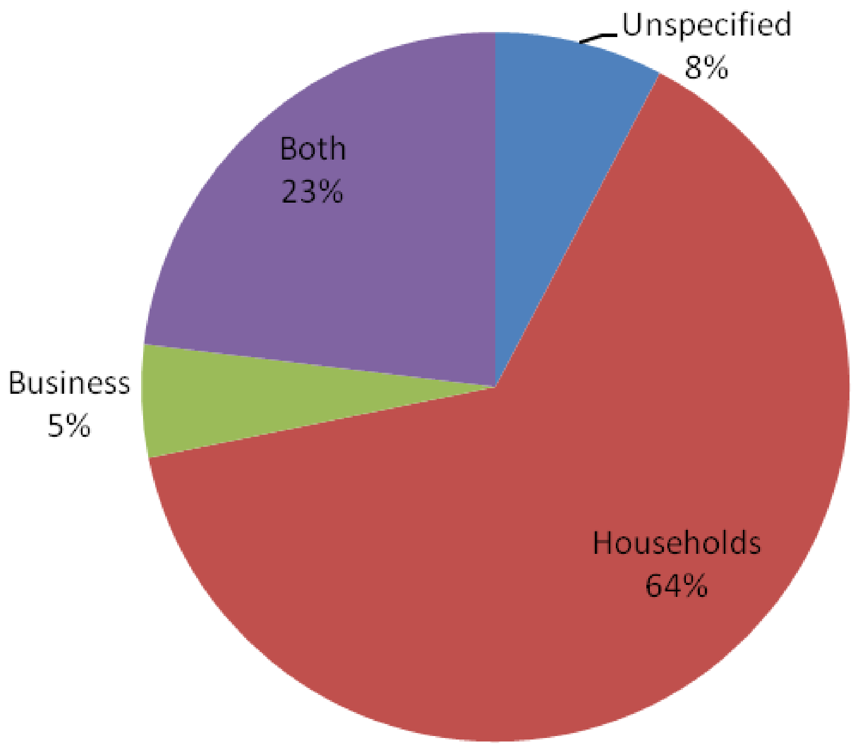
Our literature review covers 39 studies dealing with question B of our causal chain. Ten of these are considered of low quality to answer our question and are not included in the synthesis of results, even though we include them in the general statistics about the reviewed literature. Seven of our included studies are shared with Watson *et al*. (2012).

Our reviewed literature has a balanced coverage of quantitative and qualitative studies. The 12 quantitative studies deal with three main issues. Firstly, price, cross-price and/or income elasticities of electricity demand (Arthur *et al*. 2012; Filippini and Pachauri 2004; Kebede *et* *al*. 2002; Khandker *et al*. 2012; Louw *et al*. 2008). These studies estimate the impact of electricity tariffs, household income and the price of other energy alternatives on households' consumption of electricity. Secondly, estimation of the factors that influence the likelihood of a household or firm connecting to the grid or buying an off-grid system (Banerjee *et al*. 2011; Khandker *et al*. 2012; Khandker *et al*. 2009a; Khandker *et al*. 2009b; Peters *et al*. 2011; Komatsu *et al*. 2011b; Bensch *et al*. 2010). Third, measurements of affordability of electricity for households (Kebede *et al*. 2002 and Hosier and Kipondya 1993).

Seventeen descriptive studies are reviewed. Thirteen of them explore the different factors that influence households and/or businesses decisions to connect to or use electricity (ADB 2011; Cecelski and Glatt 1982; World Bank 2008a; World Bank 2008b; Davis 1998; Hong and Abe 2012; Komatsu *et al.* 2011a; Jacobson 2007; Matly 2003; Meier *et al*. 2010; Neelsen and Peters 2011; Obermaier *et al*. 2012; UNDP and ESMAP 2004). They do so through meetings and group discussions, field surveys or interviews with key actors. Six qualitative studies look at the impact of different tariff or subsidies schemes on connection and consumption (ADB 2005; Ilskog *et al*. 2005; Hosier and Kipondya 1993; Hong and Abe 2012; Ilskog and Kjellström 2008; Matly 2003). The papers by Hosier and Kipodya (1993) and Matly (2003) look at both. In our synthesis we will also include the insights of two papers considered as low quality, but that reinforce the views of the other literature about tariff and subsidies schemes (Dube 2003 and Karekezi and Majoro 2002).

Most of the studies covering question B analyse household connectivity and use of electricity. Only 5 per cent focus only on businesses and 23 per cent refer to both.

Figure 13 Question B studies per consumer focus



Qualitative studies are better at analysing in-depth the reasons behind low electricity connection rates and consumption and at identifying a wide number of factors influencing decisions made by households and businesses. Quantitative studies are more restricted in the number of factors they consider, but provide a better idea of the size and significance of the impact of relevant factors. Therefore a combination of both types of studies is considered as the best approach to inform policy.

5.2.2 Synthesis

Factors that influence households or businesses decisions to connect to the grid, buy off-grid systems or consume electricity

Thirteen papers use descriptive approaches to unravel the factors that are preventing households connecting to the grid, use off-grid systems and consume more electricity once this is made available. The methodologies used include interviews, meetings and group discussions with key actors in rural electrification projects; description of field surveys or extensive national household survey data.

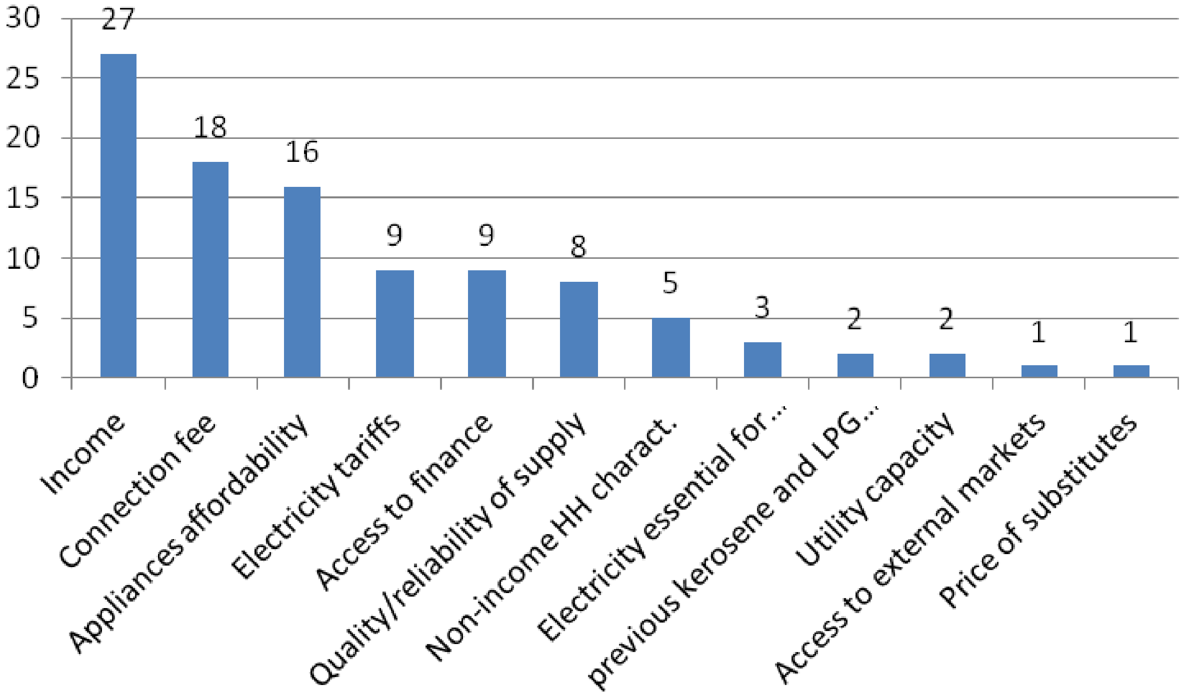
The following factors are reported as preventing higher connection rates in developing countries:

- Income. Strongly and consistently reported by most studies dealing with the issue of connection rates and adoption of off-grid systems. Low financial resources are also behind the low investment in electrical appliances by businesses, which suggests that there is a poverty trap for electricity access.
- Upfront costs, including connection fees, purchase price of SHS, house wiring and electrical appliances are strongly and consistently reported by most reviewed papers. Upfront costs seem to be one of the main hurdles to access by the poor, as they amount to a large share of their monthly income. ADB (2011) finds that even though subsidised connection fees were provided for the poor in Benin, these were still too high for the rural population as it amounted to more than 50 per cent of their monthly income. Connection fees are equivalent to 70–150 per cent of the average monthly income in a rural electrification project based in the Philippines, which makes them unaffordable for many poor families (ADB 2005). Price reductions in SHS are considered as the key determinant of increased adoption once these are made available to households, with around 61 per cent of households without SHS in rural Bangladesh showing a desire to purchase them if the prices decreased by 10 per cent. (Komatsu *et al*. 2011a). The inability to pay for electrical appliances is also a major hurdle, and strongly related to income of households and businesses.
- Electricity tariffs are less frequently reported as a barrier to initial connection. The analysis of an off-grid solar PV project managed by a cooperative showed that when the minimum price per month was decreased, the number of users increased, which indicates that many households in the community wished to connect but could not afford a high monthly minimum (Hong and Abe 2012). A study of rural electrification in Peru shows that 28 per cent of households not connected living in electrified villages claim inability to pay monthly fees as their main reason. Also, a study about microenterprises in electrified villages of Lake Victoria, Uganda, reports that 25 per cent of those without a connection claim they cannot afford consumption fees.
- Access to finance can improve connection rates for households and businesses, according to three of the papers (World Bank 2008b; Cecelski and Glatt 1982; ADB 2011).
- The quality and reliability of supply and the capacity of the utility to cope with subscription applications are also behind the incidence of connection rates, according to three of the reviewed studies (ADB 2011; Cecelski and Glatt 1982; Neelsen and Peters 2011; UNDP and ESMAP 2004). Particularly for productive activities, availability and reliability are more important than price as energy costs are usually only a small percentage of total production costs.
- The need for electricity for the operation of the business (Neelsen and Peters 2011), as well as the knowledge about what for and how to operate electrical equipment (ADB 2011) can also explain business connection rates.

Anecdotal information from GIZ projects adds two factors to the list: a) poor households have difficulties to do the necessary paperwork for a subscription, b) utilities refuse to connect households if the in-house wiring does not fulfil the required safety standards.[12]

A general survey of all the reviewed literature shows that income is the most widely reported barrier to increased connection to the grid or purchase of off-grid systems, with 27 studies referring to it. The next two barriers more widely referred to are connection fees and appliances, which added together as upfront costs would be at the top position.

Figure 14 Number of studies reporting barriers to increased connection rates



Evidence shows that even once households and businesses are connected to the grid or using off-grid systems, consumption can remain disappointingly low, damaging the financial sustainability of electrification projects. Demand of electricity is in fact a derived demand and hence it depends on demand for a number of activities such as irrigation, education (requiring reading at night), or demand for the products of industries using motive power (Cecelski and Glatt 1982). Some factors identified by the literature as hindering higher electricity consumption levels are:

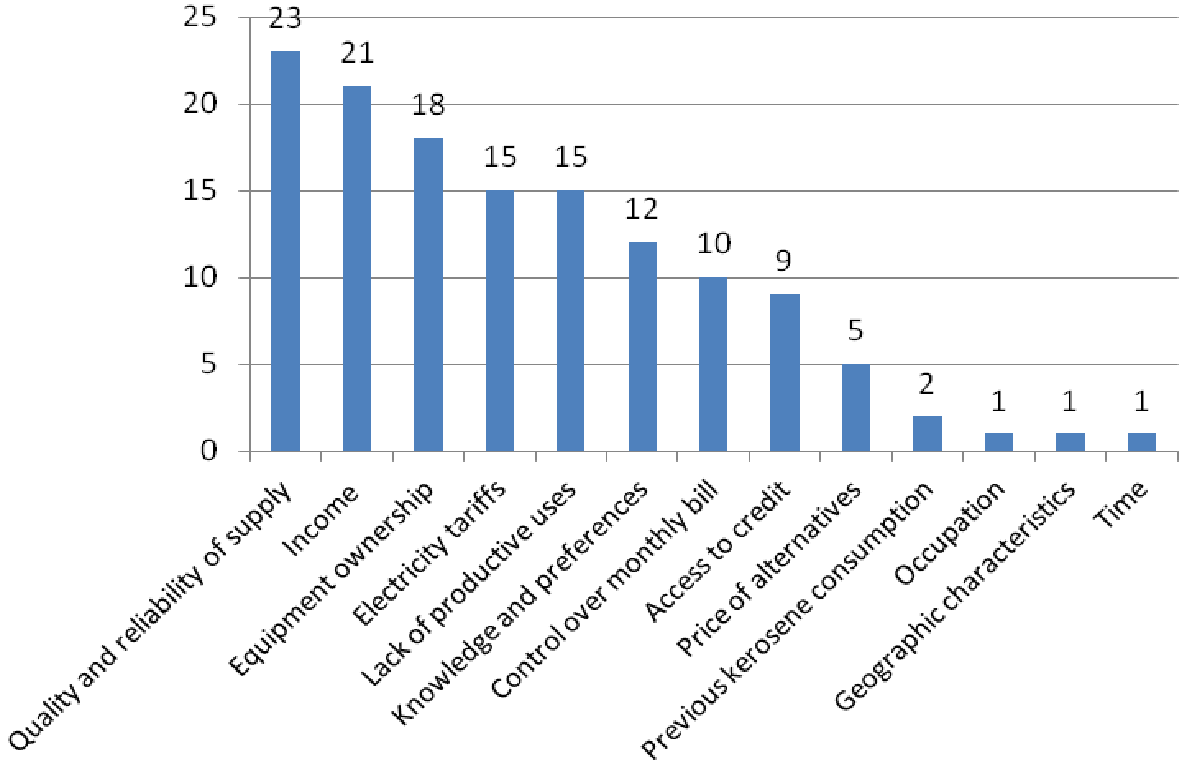
- Household income or financial situation of businesses. Income is found to be a key determinant of household's electricity consumption. Evidence from South Africa shows that there is a tendency for higher income households to rely more heavily on electricity, while low-income electrified households have more diverse fuel sources, with electricity for cooking used only by higher income groups (Davis 1998). The literature shows that the influence of income on consumption is more related to the possibility of affording electrical appliances than to the ability to pay electricity tariffs. The rural middle class that can afford to connect and to buy electric appliances are therefore the ones capturing most of the benefits of electrification.

[12] Comments provided by Dr Carsten Hellpap, Programme Director of Energising Development. Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH, 24 June 2013.

- Electricity tariffs are mentioned as a barrier by two of the thirteen papers included in this sub-section. However, several authors insist on the evidence of willingness to pay for electricity in poor communities on the basis of their payment of tariffs at cost recovery levels and their pre-electrification energy costs (World Bank 2008b; Matly 2003; Cecelski and Glatt 1982). This suggests that the heavily subsidised tariffs that make utilities unviable are often unnecessary. As this issue arises in several articles, it is further assessed in another sub-section about the impact of different tariff and subsidy schemes.
- Appliances/equipment ownership. Ownership of appliances or productive equipment are key determinants of consumption. Among businesses, some of the reasons for low investment in electrical appliances include lack of financial resources, limited access to loans and poor knowledge about how to use electrical equipment and for what purpose. Among households, income is also highly relevant, as well as household dynamics influencing investment decisions (ADB 2011; Matly 2003).
- Quality and reliability of supply/good systems maintenance. Several studies highlight the importance of the quality of the energy service to achieve substantial levels of electricity consumption. This is even considered as more important than the price of electricity for increased use, as households and industry can face high costs as a result of voltage drops or blackouts (Cecelski and Glatt 1982). Bad quality of service is often linked to the financial weakness of utilities or managing cooperatives (Hong and Abe 2012; World Bank 2008b) caused by unsustainable subsidised tariffs or poor management. In the case of SHS it is often due to poor maintenance of the systems, due to lack of training or to maintenance not being a priority in electrification programmes.
- Knowledge about electricity/preferences. Insufficient knowledge about the economic and productive benefits of electricity, as well as deeply engrained habits of using specific energy sources for cooking and lighting prevent people from further using electricity, even when it makes economic sense.
- A lack of control over the monthly bill is also mentioned by several papers. As opposed to kerosene, where households can pay as they consume and quickly react to price changes, electricity billing procedures are sometimes unclear. 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.
- Lack of productive uses. Several papers attribute low electricity consumption in rural or poor settings to the high share of residential uses, concentrated in a few hours of the early evening, instead of productive uses more evenly spread throughout the day. On one side, this jeopardises the financial sustainability of electrification projects and on another side it limits the income generation effect expected. Projects where agricultural or industrial uses have been promoted with specific policies tend to be more successful. Communities with flourishing industrial and agricultural activities previous to the electrification projects also seem to be able to profit more from electricity (UNDP 2012). The productive use is even lower for small off-grid systems (Jacobson 2007). A more in-depth review of the main uses of electricity is provided as part of the synthesis of question C.
- Household characteristics. Education and occupation of household heads also has an impact on consumption levels as better educated users tend to engage in business activities which may translate to higher income and hence higher consumption patterns. (Hong and Abe 2012).
- The effect of time is also highlighted by several authors, with low consumption levels giving way to higher electricity 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 *et al.* 2009a; Thom 2000; Khandker *et al.* 2009b).

The most widely reported barrier to increased use across our reviewed literature is the bad quality and reliability of existing supply (23 studies). Income, equipment ownership, electricity tariffs and lack of productive uses are also widely reported.

Figure 15 Number of studies reporting barriers to increased use of electricity



Quantification of the impact of different factors on the likelihood of households or businesses connecting to the grid

Seven studies use probit models to estimate households or businesses' likelihood of connecting to the grid or adopting off-grid systems once these become available in their communities (Banerjee *et al.* 2011; Khandker *et al.* 2012; Khandker *et al.* 2009a; Khandker *et al.* 2009b; Peters *et al.* 2011; Bensch *et al.* 2010; Komatsu *et al.* 2011b). The dependent variable of these models is the connection status and several factors are tested for their impact on increasing the probability of connection. Results are summarised in Table 1.

All these studies, except for Banerjee *et al*. (2011) and Komatsu *et al*. (2011b) use propensity score matching (PSM) to estimate the impacts of access to electricity avoiding the problem of selection bias. Their main aim is therefore to respond to question C. To provide robust results they use a probit model to create a control group in non-electrified communities that resembles the treatment group in electrified communities. Members of the control group are matched to members of the treatment group on the basis of their predicted probability of participation, calculated through the coefficients of the probit model. The selected covariates to be included in the probit model for their use in the matching process must be non-responsive to the connection status. Besides, they must be able to affect both the decision to connect and the outcome variable. For this reason, probit models used for PSM do not include income as a covariate, even though it is likely to significantly affect the propensity to connect. Upfront costs and tariffs are not included in the models either as they are not useful to split the control sample according to the propensity to connect to the grid. These are also key determinants of connection rates.

Table 1 Impact on the likelihood of connecting to the grid

	Dependent variable	Age of HH head	Sex of HH head	Educ. (years)	HH size	Log of HH landholding	Price other fuels	Geog. charact.	Building charact.	Availability of elec. (h/day)	Price of elect.	Income	Ownership of appliances
Banerjee *et al*. 2011	Connection of HH in electrified villages – India	0.001	–0.022 (M=1, F=0)	NS	0.011	0.03	Kerosene 0.014 (Rs/kg) -LPG 0.002 (Rs/kg)	Altitude – 0.008 (100m) Rainfall 0.005 (100mm/year)					
Bensch *et al*. 2010	Connection of HH in electrified villages – Rwanda		–0.151 (F=1, M=0)	0.058 (HH head)					Cemented floors 1.322 Buildings 0.416 Rooms 0.219				
Khandker *et al*. 2012	Connection of HH in electrified villages – India	NS	NS	0.012 (males) 0.015 (females)		0.049	Firewood 0.028 (Rs/kg) Kerosene: NS			0.027 (hrs/day)	–0.224 (Rs/kWh)		
Khandker *et al*. 2009a	Connection of HH in electrified villages – Bangladesh	0.004	–0.153 (M=1, F=0)	0.03 (HH head) 0.053 (males) 0.039 (females)		0.116	Firewood 0.122 (Tk/kg) Kerosene: NS		Brick-built 0.681				
Khandker *et al*. 2009b	HH connection to electricity (all villages) Vietnam	NS	NS	NS		NS	NS		NS				
Komatsu *et al*. 2011b	Adoption of SHS in Bangladesh						Kerosene 0.132 (consumption)					0.33	Batteries 0.788

Ns: Not significant; grey shade: variable not included in the model.

The model by Khandker *et al*. (2009a) in Bangladesh includes observations from both electrified and non-electrified communities and only those factors related to the electrification status of the community and the probability of a village getting a connection are found significant. It is not considered a high-quality model.

Peters *et al.* (2011) estimate a probit model where the dependent variable is the decision to connect of micro-enterprises in Benin. The covariates are very different to those that explain households' decisions and hence they are not included in the summary table above. Their model finds no clear evidence of differences between types of industries in their likelihood to connect, with all the sector dummy coefficients being statistically insignificant. The gender of the entrepreneur also does not play a significant role. By contrast, the entrepreneur's age and the quantity of the investment for firm creation are both significant and have a positive effect of being connected.

Results in the summary table show that income or those variables related to income, such as the quality of the dwelling, the household landholding or the ownership of appliances, have a clear impact on the decision to connect to electricity or purchase SHS. The level of education of adults in the household also has a significant impact. Age of the HH head seems to have a small effect, and the effect of the sex of the HH head delivers some contradictory results. The effect of the price of kerosene is not conclusive, whereas the positive effect of the price of firewood is more consistent across studies. The negative impact of unreliability of supply for the decision to connect is worth highlighting, even if it is only considered by one study.

Table 2 Literature results on own-price, cross-price and income elasticities of electricity consumption

	Income	Own-price	Cross-price	Other factors	Context
Arthur *et al*. 2012	0.69	–0.6 total –0.49 urban –0.69 rural	Almost non-existent	Ownership of appliances	Rural and urban households, Mozambique
Filippini and Pachauri 2004	0.64 winter 0.63 summer 0.6 monsoon	–0.42 winter –0.51 monsoon –0.29 summer	Either non-significant or almost non-existent (for kerosene)	Household size Age of head of family Geographic dummies	Urban households, India. Equations for three seasons: winter, monsoon and summer
Kebede *et al.* 2002	1* all 1.03* non poor 1.06* poor	–0.74 all urban –0.77 non poor –0.75 poor	Dung cakes: 0.28 Kerosene: –0.84 Firewood: 0.59 Sawdust: 0.35	Location	Urban households, Ethiopia
Khandker *et al.* 2012	0.337**	–0.275***	Fuelwood: 0.331 Kerosene: 0.028	Age of household head Education of male and female adults Availability of electricity in village (hours/day)	Rural households, India
Louw *et al.* 2008	0.243	n/a	n/a	Woodfuel usage Iron ownership Lights ownership Credit obtained	Rural households, South Africa

*Income proxied as budget share of energy source (per cent).
**Income or wealth proxied as household agricultural land (acres) in log.
***Measured as Rs/kWh, with no logs, therefore not an elasticity, but showing that an increase in 1 Rs. leads to a decrease in electricity consumption by 27.5 per cent.

Price, cross-price and income elasticity of electricity demand

Five authors estimate income, price and/or cross-price elasticities of electricity consumption. Some of them also estimate the impact of other factors such as household characteristics, geographic dummies or appliance ownership dummies. All five studies are considered high quality. Their results are summarised in Table 2.

The results of different studies are not always comparable, due to the different approaches for the estimation of the electricity demand equation and for the measurement of income and price. Also some studies include a number of other influential factors, as detailed in Table 2. In any case, some conclusions can be derived from the existing evidence:

- Own-price elasticity. The impact of tariffs on electricity consumption is consistently negative and significant, as expected. The coefficient is lower than 1 in all reviewed studies, which indicates that electricity consumption is price-inelastic. This could be due to the low availability of substitute energy sources that can provide the same service or to a low ability to react to price changes due to billing systems. Changes in prices still have a sizable impact and tariff increases are expected to significantly reduce electricity consumption. Studies providing own-price elasticities for other energy sources show that electricity has a lower price-elasticity than kerosene, but higher than low grade sources of energy such as firewood and charcoal (Arthur *et al*. 2012; Kebede *et al*. 2002).
- Cross-price elasticities are not consistent among studies. Two studies show almost non-existent or insignificant cross-price elasticities (Arthur *et al*. 2012; Filippini and Pachauri 2004). This would indicate that different energy sources are not substitutes, but complementary and are used for different purposes. Kebede *et al*. (2002) and Khandker *et al*. (2012) show significant and positive cross-price elasticities for fuelwood, dung cakes and sawdust. These two publications show contradictory results for the kerosene cross-price elasticity of electricity. Kebede *et al*. (2002) show a significant and negative cross price elasticity whereas Khandker *et al*. (2012) show a positive cross-price elasticity. Insignificant cross-price elasticities indicate the low substitution of kerosene and electricity, with kerosene remaining as a rural source and electricity as an urban source in many countries.
- Income elasticity is consistently significant and positive, as expected. Its coefficient is lower than 1 in all studies, except for Kebede *et al*. (2002) indicating that electricity consumption is income inelastic. This suggests that electricity is a necessity and the relatively high value of the coefficients implies that with further economic development, one can expect to see a rise in the electricity consumption of households. Income elasticity is particularly low in the study by Louw *et al*. (2008). Estimates in Kebede *et al*. (2002) are not comparable as income is proxied as budget share of energy sources. One of the studies comparing the income elasticity of electricity to that of other energy sources shows lower responsiveness to changes in income than candles and kerosene (Arthur *et al*. 2012).

In addition to income, price and cross-price elasticities, some studies estimate the impact of other factors on electricity consumption. Two papers estimate the impact of ownership of appliances (Arthur *et al*. 2012; Louw *et al*. 2008). As expected, assets ownership such as electric cook stoves, irons or lights favour the consumption of electricity. Two papers look at the impact of household characteristics (Filippini and Pachauri 2004; Khandker *et al*. 2012). Their findings show that dwelling size significantly influences the electricity consumption of Indian rural households (Filippini and Pachauri 2004), whereas education of male and female adults and the age of the household head significantly influence electricity consumption of rural households in India (Khandker 2012). Other influential factors found by a single study are the access to credit (Louw *et al*. 2008), service reliability (Khandker *et al*. 2012) and geographic dummies covering differences in the overall level of development of different regions and sociocultural habits of the inhabitants (Kebede *et al*. 2002; Filippini and Pachauri 2004). Service reliability plays a major role in households' consumption to electricity, with increases in the average availability of electricity at the village level by 1 hour expected to deliver increases in electricity consumption by 12.4 per cent. Evidence by Khandker *et al*. (2012) shows that Indian villages without power outages have an electrification rate of 81 per cent, while those with more than 20 hours of power outages per day have an access rate of only about 38 per cent, which affects their electricity consumption.

Affordability

Two quantitative studies measure affordability of electricity for the poor.

Kebede *et al*. (2002) compare the initial cost of fuels to the purchasing power of poor urban households in Ethiopia, measured by their energy budget, to examine affordability. The cost of electricity takes into account five cost components: the electricity bill, light bulbs, internal wiring with and without electric pole, *mtad* (appliance to produce pancakes) and electric cook stoves. The paper does not clearly state whether the electric bill includes connection costs and tariffs or only one of them. It is not clear either on why particular appliances are included or excluded from the cost components. Eight alternative costs are estimated from different combinations of these cost components. The purchasing power of the poor is proxied through the energy-related expenditures of households. Three types of energy expenditures are computed: a first category including items recorded as 'fuel and power' in the national survey used by the study, a second category including also transport fuel, motor oil and greases and a third category including also expenditures on energy-related appliances. They consider electricity as 'affordable' when the ratio of mean energy expenditure to cost is equal or greater than one. Their results show that all the alternative cost combinations of using electricity are significantly higher than the three categories of mean energy expenditures for urban poor households. Therefore, electricity is unaffordable for poor urban households in Ethiopia. The paper points in particular at the large share of electricity costs that need to be paid upfront, which places very high barriers for access by the poor.

Hosier and Kipondya (1993) measure affordability as the percentage of household expenditures taken by an energy source. Their study focuses on Tanzania's urban households. The cost of electricity and other energy sources is calculated as its monthly price per effective MJ, taking into account the typical efficiency of cooking devices, plus the monthly cost of a low-cost cooking appliance. Calculations show that electricity is the most affordable fuel for cooking on the basis of useful energy. The paper then attributes the fact that electricity is rarely used for cooking to a lack of availability of electricity. However, a large body of evidence shows that electricity is rarely used for cooking even when it is available, and hence the paper seems to miss the point behind the reasons for the low electricity demand in poor households.

Affordability is a key issue for access to electricity by the poor. The imprecise results and definition of affordability provided by the two studies included in our review point at the need for a more in-depth review of this issue in the context of developing countries. A paper by Fankhauser and Tepic (2007) analyses affordability of electricity in more detail. They provide two alternative definitions of affordability of electricity. A simple one, where affordability would be defined as the share of monthly household income spent on electricity, and an alternative, often more accurate, where affordability would be expressed as the share of electricity payments in total household expenditures. Several options are provided for the measurement of utility expenditures and to take into account the quality and efficiency of services provided. The concept of affordability also requires the definition of a threshold to determine what constitutes an acceptable level of utility expenditure. The paper goes through the challenges of setting this threshold. On the basis of governments and international financial institutions' *ad hoc* rules of what constitutes an acceptable level of monetary utility outlays, an acceptable threshold of 25 per cent of household expenditures is defined jointly for electricity, heating and water and an individual benchmark of 10 per cent is assumed for electricity. Estimates of affordability of electricity, water and heating are provided for 27 transition economies. The paper was excluded from our review, as it addresses the issue for a sample of countries that include a significant number of high-income countries. However, we suggest that it should be taken into account for the next step of this work, which will consist of developing a methodology to maximise the poverty impact of specific generation capacity projects. Fankhauser and Tepic (2007) point at other sources discussing affordability in the context of designing social support programmes or as part of poverty assessments (Lampieti *et al*. 2001; Lovei *et al*. 2000; Tabor 2002; Velody *et al*. 2003; Pachauri and Spreng 2003; Estache *et al*. 2002; Foster *et al*. 2000; IPA Energy 2003). These should also be reviewed as part of the next steps of our work.

Impact of different tariff and subsidy schemes

Seven descriptive papers look explicitly at the impact of different tariff schemes or service provider management structures on the levels of electricity consumption (ADB 2005; Ilskog *et al*. 2005; Hosier and Kipondya 1993; Hong and Abe 2012; Ilskog and Kjellström 2008; Matly 2003; Dube 2003).

Ilskog *et al*. (2005) analyse the performance of an independent electricity cooperative in a town in Tanzania, showing that despite a tariff more than 15 times higher than in neighbouring towns served by the national grid, the number of household, industrial and institutional consumers has grown steadily, as well as the reliability of supply. They point at a change in tariff schemes as one of the key elements of success. Instead of a flat monthly rate, much lower than the cost of actual consumption, the cooperative installed individual meters that enabled charging consumers for their actual consumption. This led to a significant increase in tariffs and a reduction in average household consumption, but a significant increase in the number of consumers, which showed willingness to pay for the service. Control of individual consumption and tariff increases improved the financial sustainability of the cooperative and hence the quality of the service provided. Ilskog *et al*. (2005) conclude that this experience shows that subsidised tariffs may be unnecessary as there is a willingness to pay for good service. The study also shows that control of individual consumption increases willingness to consume electricity as a result of a better understanding of its costs.

A more recent study with several cases of electrification cooperatives in Kenya, Tanzania and Zambia reinforces these points, showing that considerably low subsidised tariffs do not necessarily result in higher use by low-income households or by commercial activities. Instead, they are considered as a major obstacle to the expansion of rural electricity supply, deterring what could be profitable businesses (Ilskog and Kjellström 2008). This article argues that in any case, it is unrealistic to believe that significant expansions of supply can rely entirely on tariff financing and hence financial support will always be required to cover initial capital costs.

Hosier and Kipondya (1993) also look at the case of Tanzania analysing why heavily subsidised lifeline tariffs are not being effective to guarantee access for the poor and are instead benefiting the better off and damaging the utility’s finances. The lifeline tariff guarantees all domestic electricity consumers a first block of electricity at a subsidised price. This first block is normally set to be equal to some small quantity of electricity which is sufficient to provide a household with lighting for one month. After meeting these basic needs, the marginal cost should again serve as the guide to electricity pricing. However, in Tanzania, the tariff structure provides a large lifeline tariff that ensures low-cost lighting for all households connected to the grid as well as sufficient electricity to cook, run a refrigerator and support some additional end uses. The size of the lifeline is ten times the basic lighting needs for every household. Anyone connected to the grid can qualify for the subsidy, regardless of income. Households in the highest income groups are more likely to be connected and to afford more electrical appliances, therefore consuming more electricity at the expense of public funds theoretically aimed at benefiting the poor. Tanzania's subsidy is therefore jeopardising the financial health of the national electricity system, damaging the quality of the service provided and preventing the utility from connecting a higher number of consumers.

Failing service as a result of subsidised tariffs is also described by Hong and Abe (2012) for a solar PV plant run by a community cooperative in the Philippines. The deteriorating plant was only able to provide electricity at a low voltage during high peak times. This damaged potential productive uses of electricity and consumers able to afford higher consumption levels. However, no willingness to pay was found among poor people in the community. This is because no significant economically lucrative activities requiring electricity were found, which would improve people's ability to pay for it. The obligation of having a minimum monthly cost also discouraged many households from connecting and fewer connections meant a higher cost for connected users. However the cooperative's decision to further decrease the price of power to accommodate low-income users only damaged further the plant's financial viability and reliability of supply, forcing users to return to conventional energy sources.

The fact that low uniform tariffs benefit only the better off and pervert public service solidarity mechanisms is reiterated by other authors (Banerjee *et al*. 2011; Matly 2003; Dube 2003). Policy recommendations in the reviewed literature stress the need for subsidies able to better target the poor and particularly subsidies to upfront costs (for the set-up of decentralised systems, connection fees, off-grid equipment, electrical appliances), advising against concessionary capital for organisations which are not covering their operating and maintenance costs (Kirubi *et al*. 2009).

5.2.3 Policy recommendations

The following policy recommendations can be derived from the evidence reviewed:

- Subsidies or liberal credit should be provided to cover upfront costs (including connection costs, house wiring and electrical equipment), which are considered to be very important barriers to connection and use. These subsidies should be specifically designed to target the poor, for example through subsidised connection rates for late connectors, which usually include the poorest.
- Electrification strategies based on intensification (increasing connection rates in already electrified communities) could be much more cost-effective than extensification strategies, involving extending the grid to reach additional communities. This is because once a village is electrified, the marginal cost of connecting an additional household falls rapidly as more households connect. Besides, fewer connections mean a higher cost for already connected users (World Bank 2008b). Indonesia's rural electrification programme showed that the average cost per new connections in already connected villages was a third of that in newly connected villages (World Bank 2008b).
- Subsidised tariffs are often not necessary, as evidence shows that there is willingness to pay and they have been found to benefit the better off (those who can connect and buy appliances). If required to lower project risks at the start, they could have a phase-out period, aiming at financial sustainability in the long term.
- It is not enough to provide the possibility of connecting to the grid. The service provided must be reliable and high quality. To achieve this, tariffs should guarantee the financial health of operation and maintenance activities of the utility. They should also cover the potential expansion of generation capacity. Capacity development for

efficient management of utilities and local cooperatives is also necessary. Only then, utilities will be able to provide a high-quality service to a large number of consumers in the long term.

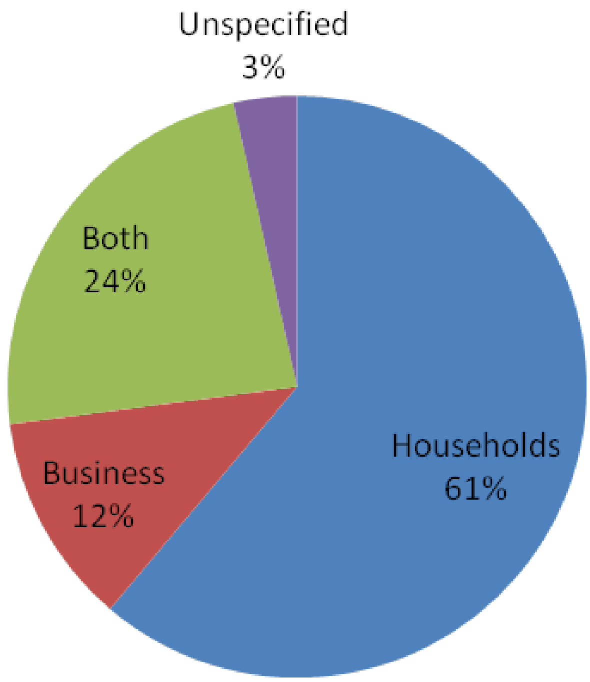
- The effects of privatisation of the power sector for the poor are not conclusive. It may increase tariffs and not expand the grid to rural areas, but it may also improve quality and reliability, expand networks and liberate public finances to support rural electrification (Clark *et al*. 2005; Victor 2005).
- Interventions are required to increase the control of consumers over their monthly bill, as evidence shows that poorly understood payment schemes are a barrier to higher consumption by the poor. This can be done through individual meters and pre-payment schemes.
- Interventions that promote productive uses of electricity are likely to deliver higher levels of consumption.
- Consumer education is also recommended to stimulate demand, ensure that consumers derive maximum benefit at least cost, and to increase the lifetime of individual off-grid systems.

5.3 Question C: Relationship between electricity consumption and poverty impacts

5.3.1 High-level description of the literature

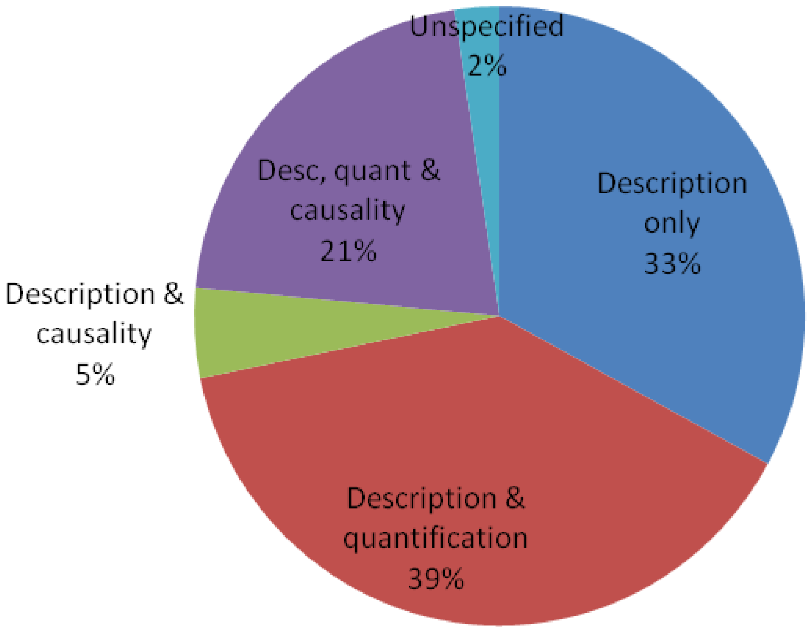
The group of studies linking electricity consumption to a number of development impacts is large and diverse. Eighty-nine studies are deemed relevant to answer Question C of our review. 30 of these were considered as low quality according to our evaluation criteria. All the studies are considered for the graphic survey of the literature, but the descriptive synthesis of the literature will take into account mostly those classified as high or moderate quality. The large number of studies reviewed focus on different impacts of electricity at the household level (61 per cent of studies), business level (12 per cent) or both (24 per cent).

Figure 16 Question C studies per consumer focus



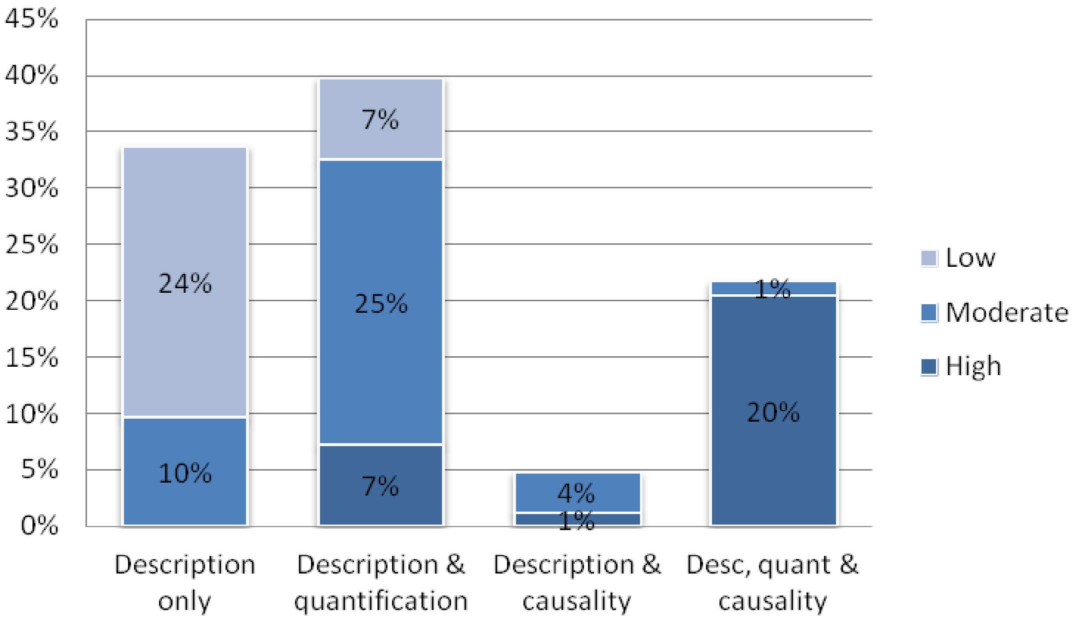
Three types of studies can be differentiated in terms of their level of sophistication: those merely describing benefits, those attempting to quantify concrete changes and finally those attempting to establish an actual causal linkage between electrification and central results, as opposed to mere correlation. Only 21 per cent of the studies reviewed can tackle the issue of causality, with most studies (39 per cent) describing and quantifying impacts without any specific methodology to confirm attribution of the impacts of electricity and not to other external factors. 33 per cent provide descriptive accounts.

Figure 17 Level of sophistication of reviewed literature



Studies tackling causality are considered as higher quality than those only measuring impacts and these are usually deemed as higher quality than studies merely describing impacts.

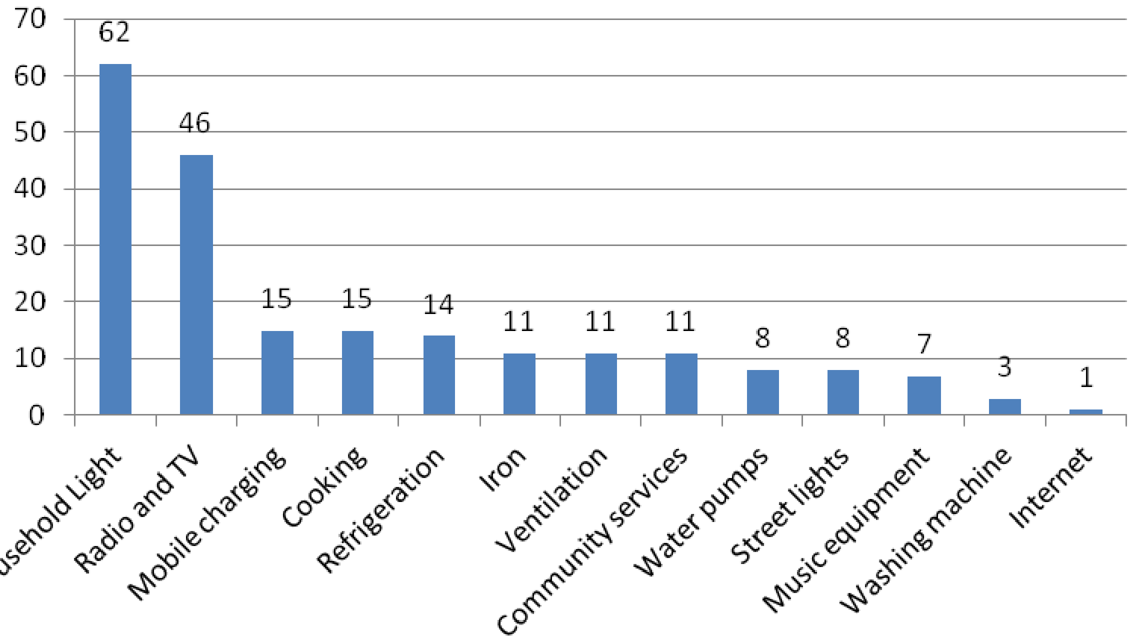
Figure 18 Sophistication and quality of the literature



Studies that measure impacts use different indicators and methodologies to do so. This diversity makes it very difficult to compare the results provided through an orderly synthesis.

The studies reviewed identify multiple benefits attributable to electricity consumption. The more direct and short-term benefits are directly related to the energy services provided by electricity. In the residential sector these include: reading, indoor and outdoor lighting; image and sound through radio and TV; communications through mobile phones; food preservation through refrigerators; space cooling through fans and AC; heat for cooking and boiling water through stoves, ovens or boilers; laundry washing and ironing through washing machines and irons; and keep 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 benefits for the poor.

Figure 19 Number of studies referring to residential uses of electricity

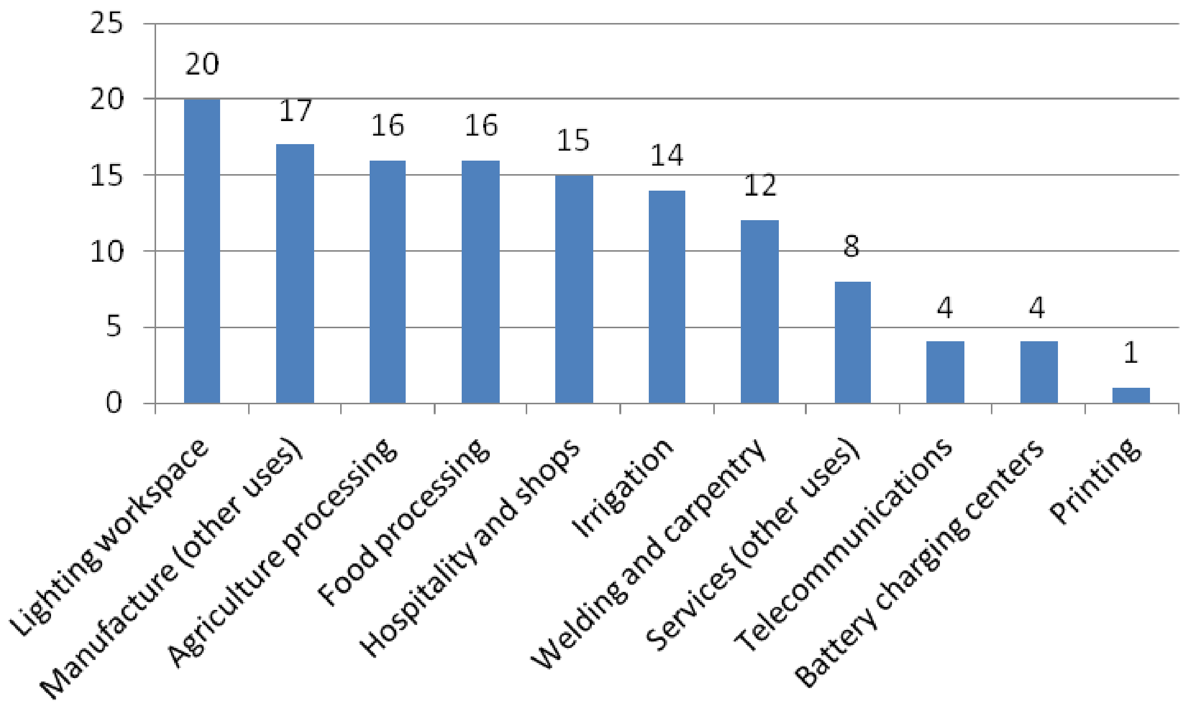


Direct benefits related to these services include:

- Improved education as a result of more hours to read in the evening by children and adults, and to prepare lectures by teachers, also as a result 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 saved for tasks such as buying or collecting fuels and water or charging mobile phones. Also increased flexibility to perform domestic tasks throughout the day instead of concentrating them during daylight hours.
- Improved comfort in the household as a result of better lighting, 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 with electricity supply.
- Improved possibilities for entertainment, thanks to the use of TV.
- Improved communications, through the use of mobile phones.

Productive uses are less widely reported in the literature. They refer to irrigation and productive work through agricultural and non-agricultural electrical equipment, as well as lighting for several productive activities. Figure 20 shows the most widely observed productive uses of electricity. Lighting is at the top of the list, but it is not expected to have a significant productive impact as compared to other electrical equipment.

Figure 20 Number of studies referring to productive uses of electricity



Benefits allowed by these productive uses of electricity include:

- Increased productivity of agricultural, industrial and services activities through the use of electrical equipment
- Possibility to produce new products and services or improve the quality of existing products and services through the use of electrical equipment
- Possibility to extend opening hours of businesses
- Better quality of the 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 directly linked to 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. It 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.
- Income and business revenues. Income increases are heavily dependent on the use of electricity for productive activities, but requires the interaction of other factors.
- Creation of enterprises. Electricity may facilitate the emergence of new businesses, which would have beneficial effects for income and employment generation.
- Gender equality. Better access to information through reading, radio and TV, the reduction of drudgery in the household and time saved 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.

The aim of our synthesis is to assess the existing evidence about the actual incidence of these benefits. To do so, we have organised the available literature in several themes:

1. Analytical literature that quantifies the impacts of electrification on households or businesses

This group of studies is divided into two sub-themes, one addressing impacts for households and another for businesses. The evidence in each of these sub-groups will be classified in two smaller groups, one with those papers whose results are considered more robust, as they tackle the issue of causality, and another with good quality papers that do not meet the highest standards to address causality but provide good insights about the size of impacts of electrification and the channels through which they happen.

The lack of robust evidence of the impacts of electricity has been highlighted by several reviews of the literature (for example, Bernard 2010; Kohlin *et al*. 2011; World Bank 2008a). One author reflects that 'the more objective the study and the more thorough the data collection and analysis techniques, the fewer benefits can be attributed to rural electrification' (Cecelski and Glatt 1982). The challenges of measuring impacts and attributing them to electricity have been discussed in the background section to this document. Two of the main issues to be avoided are:

- missing variables that have played an important role in achieving the outcome, attributing changes to electricity when in fact they have been caused by something else;
- placement and selection bias, that can overestimate benefits when simple comparisons of with and without groups are made without taking into account different starting points.

The higher standard for what counts as evidence puts a strong emphasis on careful causal inference and requires that outcomes of interest (income, health, employment, etc.) are measured for at least two sub-groups (control and treatment) before and after the intervention For gender differentiated studies four sub-groups would be required, as control and treatment samples would be split into male and female groups. Each sub-group must be large enough so that there is some degree of confidence in that estimate. A plausible control group must be carefully created through experimental (random selection of treatment) or quasi-experimental approaches to address the issue of endogeneity of the treatment. Additionally, the sample should have sufficient variation over policy-amenable variables such as access to roads, size of the local market, quality of local institutions, education of the household head, etc. To our knowledge, none of the existing studies on impacts of electrification use experimental approaches, due to the difficulty of randomly allocating electricity to specific households. Therefore the highest standard is provided by studies using quasi-experimental approaches such as instrumental variable estimation to correct the placement bias by using instruments for electricity access (such as the land gradient in Dinkelman 2011) or the definition of plausible control groups through propensity score matching techniques (for example: ADB 2010; Banerjee *et al.* 2011; Bensch *et al.* 2010; Khandker *et al.* 2009a, 2009b; Kumar and Rauniyar 2011; Peters and Vance 2011).

Analytical studies that do not meet those previous requirements but provide valid evidence use several techniques to describe and measure the impacts of electricity such as willingness to pay; tests of the statistical significance of differences in impact indicators or through regression models that do not correct for placement and selection bias.

2. Analytical studies providing a monetary quantification of consumer benefits from electricity

Six reviewed studies quantify demand-side benefits from access to modern energy services (ESMAP 2002; Meier *et al*. 2010; World Bank 2008b; Legros *et al*. 2011; Mulder and Tembe 2008; Munasinghe 1998). The methodology usually involves comparing expenses in energy services of households or businesses without electricity to those of households with electricity. The economic benefits of electricity are then estimated as households' willingness to pay for increments in energy services provided from electrification. For example, benefits of lighting are measured as WTP for lumens and benefits of TV are measured as WTP for hours of TV.

Some methodological challenges arising from the economic quantification of benefits of electricity are:

- The benefits of electricity are derived from a variety of energy services, some of which overlap. Therefore it is not meaningful to add up estimates over all benefit categories, as this would lead to double counting. Instead, all lighting related benefits should be considered jointly and non-lighting related benefits can be considered as independent from each other.
- Some benefits are very difficult to quantify, as they may take decades to be realised (i.e. improved educational outcomes from better study habits or improved income generation opportunities).
- Long-term outcomes blurred by migration from rural to urban areas.
- Some benefits are inherently difficult to quantify, such as avoided burn injuries to children.
- Benefits of electricity are far greater than those that may be inferred from replacement costs alone, due to their higher quality of service. The avoided cost method is therefore not appropriate. However, it would not be correct to assume that households with no electricity would be willing to pay for the better service provided by electricity at the same unit cost that they are paying at the moment. The demand curve for energy services has a negative slope, with a decreasing price for every additional unit consumed. The benefits for the consumer are estimated as the consumer surplus, or the difference between what the consumers are willing to pay (on the basis of current consumption of kerosene or other alternative) and what they actually have to pay for electricity. The calculation of WTP depends on the shape of the demand curve and the assumption of a linear demand curve can lead to an overestimation of WTP.

Of particular relevance is the World Bank (2008b) report for methodological and policy reasons. Methodologically, the report solves some of the previous challenges. It is policy relevant because its quantification of benefits is used to support the economic case for investment in rural electrification, arguing that benefits to rural households are above the average long-run supply costs. This report therefore represents a turning point from the World Bank's 1995 report, which is said to have triggered a significant reduction of financial support to rural electrification on the basis that evidence to date did not show poverty reduction impacts of electricity.

3. Descriptive literature showing the benefits of electricity and the causal chains leading to these

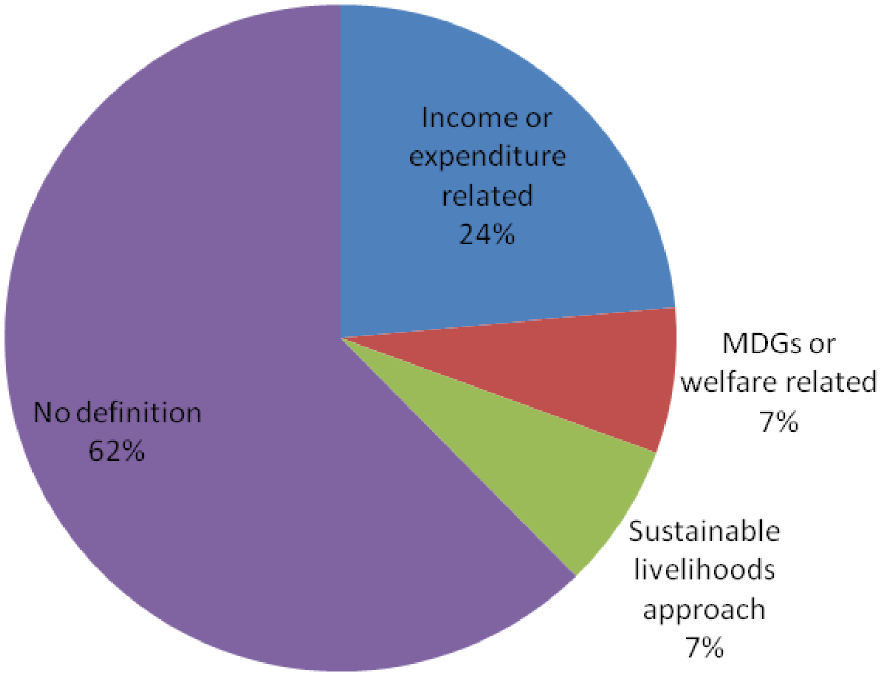
Descriptive literature can provide more in-depth insights on the links between electricity, income generation, poverty and in some studies, gender. It can disentangle complex aspects of the causal chain that remain obscure in quantitative studies. It can also look in more detail at the reasons behind high productive uses of electricity in some communities as opposed to others where electricity does not seem able to catalyse growth. Description of success and failure of specific electrification projects as regards their achievement of development impacts can also provide useful insights applicable to other programmes.

Sixteen studies, classified as high or moderate quality provide a descriptive account of the benefits of electricity for poor households and for businesses and the channels through which these happen.

Gender and poverty are treated as cross-sectional issues in all the themes above.

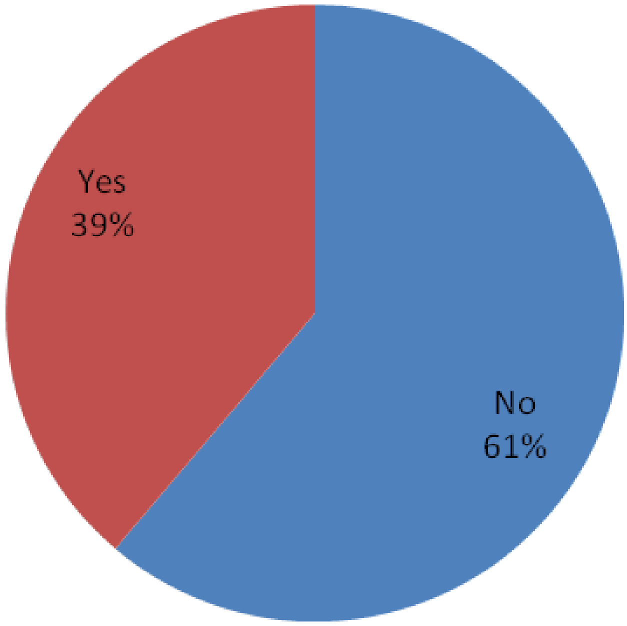
An explicit reference to poverty is provided by 38 per cent of studies covering question C. Most of these studies understand poverty in its traditional sense of low income and consumption. Some other studies present wider perspectives of poverty as related to welfare and the different Millennium Development Goals or the sustainable livelihoods framework, which understands poverty as vulnerability to stress and shocks, and takes into account the ability to maintain or enhance capabilities and assets and provide sustainable livelihood opportunities for the next generation, as well as the possibility to contribute net benefits to other livelihoods at the local and global levels in the long and short term (Chambers and Conway, 1992). Figure 21 shows the share of publications considering different definitions of poverty.

Figure 21 Definition of poverty



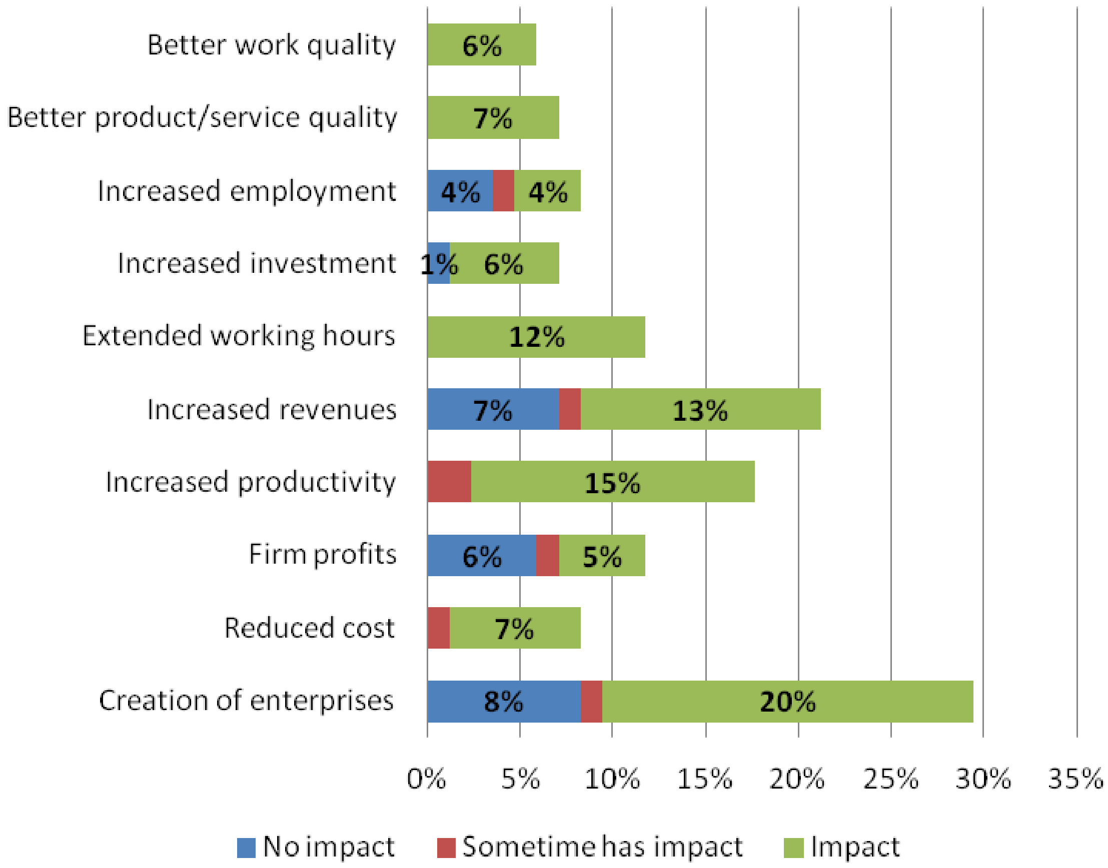
Close to 40 per cent of papers present impacts of electricity considering gender differentiation.

Figure 22 Gender differentiation



We will highlight which papers directly address them and which conceptual and methodological framings they use to do so.

Figure 23 Impacts of electricity consumption for businesses reported in the literature



5.3.2 Synthesis

Measurement of impacts of electricity for businesses

A survey of all the reviewed literature (high, medium and low quality) shows that the creation of enterprises is the most widely covered impact of electricity on productive activities. However, a significant share of the studies dealing with this issue find that electricity has no effect. An increase in revenues is the second most reported impact, but there is no consensus either on whether or not it takes place. Increased productivity is the third most reported impact, with no studies claiming that impacts do not take place.

Only one publication meets the highest quality standard and deals with the issue of causality. The study looks at the impacts of connecting to the grid on profits of micro-enterprises in Benin (Peters *et al*. 2011). Using firm-level data, the analysis employs Propensity Score Matching techniques to measure differences in profits according to a grid connection. The report finds that firms created after the grid reaches the community to perform activities that critically depend on electricity, perform much better than firms created before grid access. These firms use more electrical appliances and have better market access because they offer new products to final consumers and intermediate products to other enterprises. For pre-existing firms they find no positive impacts of electrification as compared to matched counterparts from non-electrified regions. The reasons behind the poor performance of pre-existing firms after electrification is their limited access to external markets and the limited local market, which does not provide an exit for additional production. Some other reasons are the weak productive take-up of electricity, which is often used for lighting of the workspace and the lack of robust business plans that back the investment in electrical equipment.

A paper analysing electricity usage by micro-enterprises in Lake Victoria, Uganda finds evidence of substantial investments driven by access to electricity but weak evidence of impacts of electricity on firm performance (measured by profits or employee's income) and job creation (Neelsen and Peters 2011). The paper has some pitfalls in research design, lacking comparable groups with and without electricity, but it recognises its pitfalls and its results back those found by the previous, more robust study by Peters *et al.* (2011).

Obeng and Evers (2010) test the statistical significance of differences in impact indicators in Ghanaian rural micro-enterprises with and without access to solar PV systems. The paper proves a significant association between lighting services and extension of working hours beyond daylight but does not prove statistically significant additional working hours of solar PV electrified enterprises as compared to non-electrified ones. It only proves additional income after sunset for solar PV electrified grocery businesses as compared to non-electrified ones. Links could not be proved for other types of businesses. Another significant result is that when PV systems are used for income generation there are more chances of good maintenance of the systems and hence they can last longer and be cheaper in the long term.

Arnold *et al.* (2006) investigate the relationship between productivity (measured as TFP) of African manufacturing firms and their access to services inputs, among which electricity. They use data for over 1,000 firms in ten sub-Saharan countries from the World Bank Enterprise Survey. Their model shows a significant negative relationship between days of power outages and TFP, meaning that firms in regions with more frequent outages are less productive than their counterparts in regions with higher reliability. The model also finds a strong and positive relationship between TFP and the share of firms in a region that own a generator for self-supply of electricity. Firms in the Philippines corroborate this view, with a recent survey indicating that about 33 per cent view unreliable electricity supply as a major or severe constraint to investment, behind macroeconomic stability (40 per cent) and corruption

(34 per cent). Losses from power failures in the Philippines amounted on average to 8 per cent of production and were larger for small and medium firms that often cannot afford their own generator (ADB 2005).

Grimm *et al*. (2011) don't find any systematic evidence of the contribution of access to electricity to the value added of SMEs of the informal sector in seven capital cities in West Africa: Benin, Burkina Faso, Côte d'Ivoire, Mali, Niger, Senegal and Togo. They attribute this to the heterogeneity of activities, motives and resources with which informal sector firms operate. This diversity cannot be taken into account in a cross-sectional study like theirs which does not capture other factors influencing value added. A second analysis focusing on a single profession and location (tailors in Burkina Faso) finds a positive and significant impact on enterprise turnover. Quantile regressions show that the impact is only significant at the highest quantiles of revenues, meaning that only the largest and more solid businesses benefit from electricity. Channels through which impacts take place are longer working hours and the use of more productive machinery.

Oakley *et al*. (2007) use a combination of qualitative and quantitative methods to analyse impacts of electricity on the creation of micro-enterprises, their turnover and profits. Their method does not consider the creation of a plausible counterfactual and faces several challenges, such as the opening and closing of many microenterprises throughout their period of research, which could not be attributed to electricity and which prevented tracking post-electrification performance. Regardless of these challenges, the study finds a limited overall livelihood impact of electricity due to minimal employment creation and limited increases in number of microenterprises and their turnover. Very few of the microenterprises created involved manufacture or export-oriented activities, considered as having the highest potential for significant growth. Thus, they conclude that electricity is only one enabler of microenterprises and cannot alone realise their full growth potential. Other enablers that need to be promoted are: capital outlay and technical skills; access to export markets; availability of credit and vulnerability to cash shortages.

The World Bank (2008b) analyses the impact on microenterprises of its rural electrification projects in the Philippines, Lao, Peru and Ghana. The underlying hypothesis is that access to electricity increases the amount of hours households put into businesses, increases productivity through the use of equipment and tools and improves community infrastructure required to reap economic benefits. The expected impact would be an increase in profits. They use regression analysis to test this hypothesis, building several equations with the following dependent variables: propensity to operate microenterprises; hours worked; equipment purchased (only in Ghana) or value of worth (in Peru as a proxy for equipment purchased); and revenue. Explanatory variables included household characteristics, among which electrification; entrepreneur characteristics, and community characteristics, among which community electrification status. Their findings are not conclusive across countries. The probability of a household running a business was found to be positively related to household electrification status in the Philippines and to community electrification status in Ghana, whereas it was unaffected by electricity in Peru, and Lao PDR. Ownership of equipment was significantly and positively related to electrification only in Ghana. Amount of hours worked was positively related to electrification only in the Philippines. Finally, revenues increased by a small but significant amount with electrification in Lao PDR, Ghana and the Philippines, but not in Peru.

Mulder and Tembe (2008) undertake a cost-benefit analysis of a typical rural electrification project in Mozambique assessing the impacts on households, the public sector, agri-business and commerce. They find significant benefits for the existing industrial sector, with much larger savings in energy costs than the residential sector and large improvements in efficiency. However, the study does not have an appropriate counterfactual that allows attribution of the outcomes to electricity.

Munasinghe (1988) develops a comprehensive analytical model for identifying benefits in the industrial and residential sectors. He applies it to Malaysia, finding that the main measurable benefits for industry come from increased output and are much higher than benefits for the residential sector.

Finally, Yang (2003) develops an econometric model to identify and assess the economic development (income per capita) and poverty reduction (population below the poverty line) impact of rural electricity supply (investments in the rural power sector and electricity consumption by different types of industries) in six Chinese provinces. The model shows very different impacts per province. In highly economically developed areas, electricity is more likely to be used in productive activities, which leads to an increase in output and subsequently increases income per capita and reduces poverty. In very poor provinces the impacts are more limited.

The existing quantitative literature on impacts of access to electricity for business does not show conclusive evidence of improved performance, measured as number of enterprises created, productivity, revenues or value added. The different impacts according to countries, communities and/or professions suggest that electricity is a necessary, but not sufficient condition for growth. Other significant enablers of improved business performance need to be promoted jointly with electricity. The pre-existing conditions in the areas to be electrified play a big role in the number and magnitude of positive impacts that can be expected, with areas more economically developed, with access to new markets or a large local purchasing market, and with a solid pre-existing industry more likely to benefit. Additionally, businesses not only need access to electricity to improve their performance, but a reliable service. This implies that a one-size-fits-all methodology that would try to predict the productive impact of electricity would be likely to deliver misleading results.

Measurement of impacts of electrification for households

A survey of all the literature reviewed including high, moderate and low quality shows that non-income related impacts are the most widely reported for households, with education at the top, followed by quality of life. Although a significant share of studies deal with income related impacts, only 24 per cent report a positive impact, whereas 16 per cent of studies cannot find any impact of electricity.

Only the impact measurements of the 19 studies tackling the issue of causality are considered in the synthesis as they provide the most robust evidence. Different non-experimental approaches are used to reduce the problem of endogeneity, mainly propensity score matching, difference-in-differences and instrumental variable.

The most widely analysed impacts among this group of papers are income and education, covered by nine papers each. Six papers analyse impacts on time allocation and five impacts on employment (paid work). Health and women empowerment are covered by four papers each. Impacts on fertility are addressed by three papers and finally, impacts on deforestation are covered by two papers. Table 3 shows the different impacts reported by the literature. Comparison between results of different papers is not straightforward, as often outcomes are not measured with the same indicator, the treatment whose effect is tested is not always similar and control variables vary across studies. Treatments analysed by the literature include household connection; community electrification; access to cable TV signal; use of SHS; privatisation of the electricity sector; and access to reliable electricity, considering the number of blackouts in a community.

Table 3 Impacts of electrification in papers tackling causality

Impact	Publication	Country	Treatment	Indicator	Quantification of impact
Employment	Chowdhury 2010	Bangladesh	Community electrification	Probability of participation in non-farm work	+0.1 (women) +0.649 (women – joint treatment of electrification and road access)
	Dinkelman 2011	South Africa	Community electrification	Employment growth (per cent)	+9.5% (women) Not significant for men
				Wages growth (per cent)	–20% (women) Not significant changes for men
	Grogan and Sadanand 2011	Guatemala	Community electrification	Probability of women's employment outside HH	+9%
				Wages	Increases in male's earnings No significant changes for women
	Khandker *et al*. 2012	India	Household connection	Total hours worked growth (per cent)	+17% Women +1.5% Men
	Costa *et al*. 2009	Ghana	Community electrification	Total hours worked (hours)	+0.21 Men No impact for women
Income	ADB 2010	Bhutan	Household connection	Non-farm income growth (per cent)	+72%, only 29% of total income
				Farm-income growth	No significant changes
	Banerjee *et al.* 2011	Nepal	Household connection	Non-farm income (Rs/pc/month)	+0.112
				Expenditure (Rs/pc/month)	+0.09
	Bensch *et al*. 2010	Rwanda	Community electrification	Total income (1000 FRw)	+174.8*
				Energy expenditures (FRw)	720
	Gibson and Olivia 2010	Indonesia	Access to reliable electricity	Share of rural income from non-farm enterprises	+27%
	Herrin 1983	The Philippines	Community electrification	Income	No impact
	Khandker *et al.* 2012	India	Household connection	Income per capita growth (per cent)	38.6%
				Food expenditure growth (per cent)	+14%

Impact	Publication	Country	Treatment	Indicator	Quantification of impact
				Non-food expenditure growth (per cent)	+ 30%
				Total expenditure growth (per cent)	+18%
				Poverty rate growth (per cent)	–13.3%
	Khandker *et al.* 2009b	Vietnam	Household connection	Farm income growth (per cent)	+30%
				Non-farm income growth (per cent)	No impact
				Total income (per cent)	+25%
	Khandker *et al.* 2009a	Bangladesh	Household connection	Farm income growth (per cent)	PSM results: +24.1% IV results: +52%
				Non-farm income growth (per cent)	PSM results: +73.7% IV results: +23%
				Total income growth (per cent)	PSM results: +16.7% IV results: +12%
				Expenditure per capita growth (per cent)	PSM results +9.2% IV results +8.2%
	Kumar and Rauniyar 2011	Bhutan	Household connection	Non-farm income growth (per cent)	+62%
				Total and farm income (per cent)	No significant impact
Creation of microenterprises	Herrin 1983	The Philippines	Community electrification	Number of enterprises	No significant impact
	ADB 2010	Bhutan	Household connection	Number of enterprises	No conclusive impact
	Kumar and Rauniyar, 2011	Bhutan	Household connection	Number of enterprises	No impact
Health	ADB, 2010	Bhutan	Household connection	Cough incidence Respiratory ailments Eye irritation Headache	–2.8% –5.6% –13.5% –4.2%
	Banerjee *et al.* 2011	Nepal	Household connection	Respiratory problems	Women: –3.4% Girls: –1.6% Boys: –6.1%

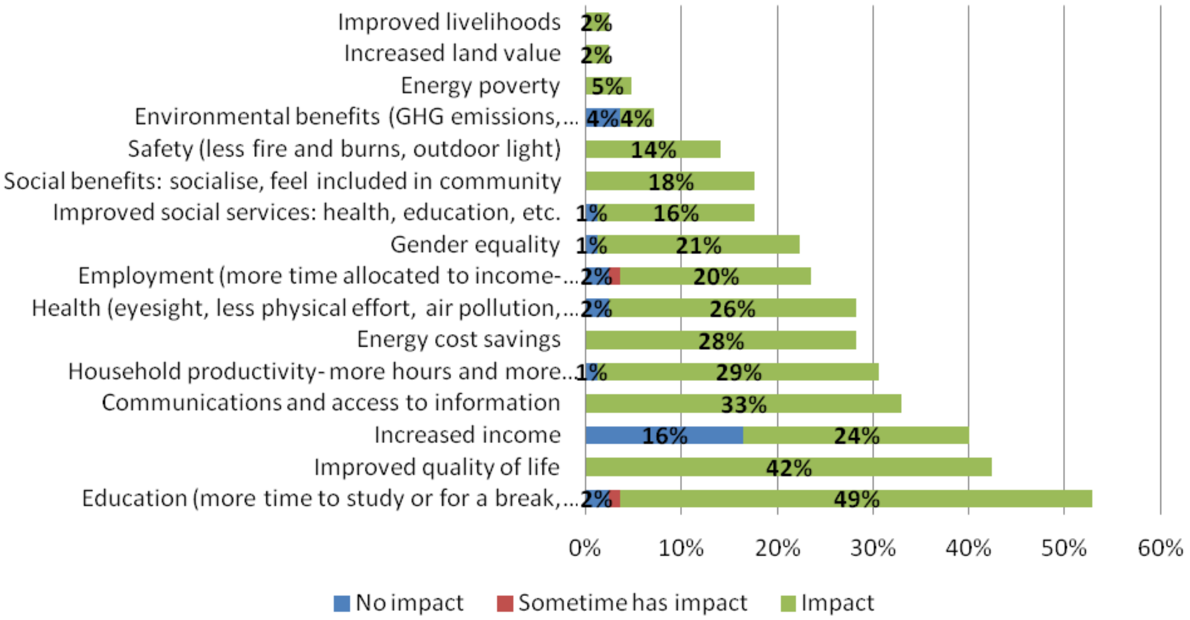
Impact	Publication	Country	Treatment	Indicator	Quantification of impact
				Gastrointestinal problems	Girls: –1.43%
	Gonzalez-Eiras and Rossi 2007	Argentina	Privatisation of the power sector	Low birth weight and child mortality	Weak evidence of impacts
	Herrin 1983	The Philippines	Community electrification	Health impacts	Limited impacts due to low use
Education	ADB 2010	Bhutan	Household connection	Years of schooling completed	All: 0.52 Girls:0.64 Boys: 0.42
				Study time (min/day)	9.4
	Banerjee *et al.* 2011	Nepal	Household connection	Years of schooling completed	Girls:0.24
				Study time (min/day)	Girls: 12 Boys: 7.7
	Bensch *et al.* 2010	Rwanda	Community electrification	Children study time (hours/day)	0.23
	Gunther *et al.* 2012	Senegal	Use of SHS	Children study time (min/day)	21
	Herrin 1983	The Philippines	Community electrification	Children study time and performance	Limited impact, as more light but no more textbooks and cannot afford TV
	Jensen and Oster 2009	India	Access to cable TV	School enrolment	Increases
	Khandker *et al.* 2012	India	Household connection	School enrolment	Boys:6% Girls: 7.4%
				Study time (hours/week)	1
				Completed schooling years	Boys: 0.3 Girls: 0.5
	Khandker *et al.* 2009b	Vietnam	Household connection	School enrolment	Boys: 11% Girls: 10%
				Completed schooling years	Boys: 0.524

Impact	Publication	Country	Treatment	Indicator	Quantification of impact
	Khandker *et al.* 2009a	Bangladesh	Household connection	Schooling years	PSM results Boys: 0.17 Girls: 0.12 IV results Boys: 0.092 Girls: 0.133
				Study time	PSM results Boys: 10.4 Girls: 12.0 IV results Boys: 6 Girls: 8.9
	Kumar and Rauniyar 2011	Bhutan	Household connection	Literacy	5.7
				Years of schooling	0.745
				Study time (min/day)	9.366
Time allocation	ADB 2010	Bhutan	Household connection	Time spent on fuel collection (hours)	All: –0.4 Men: –0.21 Women: –0.28
	Banerjee *et al.* 2011	Nepal	Household connection	Women’s time in income generation	0.19
				Women’s time studying	0.2
				Women’s leisure time	0.21
	Chowdhury 2010	Bangladesh	Community electrification	Hours spent in unpaid work	–0.016 (women)
	Grogan and Sadanand 2011	Guatemala	Community electrification	Women’s time cooking	–34%
	Khandker *et al.* 2012	India	Household connection	Fuel collection time (hours/month)	–3.3
	Costa *et al.* 2009	Ghana	Community electrification	Women’s hours fetching water	+0.182
				Women’s hours in unpaid work	No significant impact

Impact	Publication	Country	Treatment	Indicator	Quantification of impact
Women's empowerment	ADB 2010	Bhutan	Household connection	Participation in decisions on education and health index	+0.049
	Banerjee *et al.* 2011	Nepal	Household connection	Independent decision making on fertility	+0.042
				Independent decision making about children	+0.027
	Chong and Ferrara 2009	Brazil	Access to cable TV	Share of women separated or divorced	Significant increase
	Jensen and Oster 2009	India	Access to cable TV	Acceptability of spousal abuse, son preference, autonomy and fertility.	Significant improvements
Fertility	ADB 2010	Bhutan	Household connection	Number of children born in the last five years	–0.05
	Banerjee *et al.* 2011	Nepal	Household connection	Contraceptive prevalence rate	0.038
	Grogan and Sadanand 2011	Guatemala	Community electrification	Number of children	–28%
Deforestation	ADB 2011	Bhutan	Household connection	Yearly consumption of trees	–0.41
	Herrin 1982	The Philippines	Community electrification	Deforestation	No impact, as wood still preferred fuel for cooking

*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.

Figure 24 Impacts of electricity consumption for households reported in the literature



Our synthesis of the results provided in the table is complemented by insights from analytical studies that also measure the impacts of electrification on households, but don't use specific methodologies to deal with the issue of endogeneity and confounding variables (Peters and Vance 2010; Obeng *et al*. 2008; Anderson *et al*. 2005; UNDP and ESMAP 2004; ESMAP 2002; ADB 2005; Legros *et al*. 2011). These studies use appropriate methodologies and present a good argumentation for their modelling approaches and results, which reinforce findings by the previous studies.

Results are consistent for **employmen**t, particularly for women. Several authors report increases in women's employment, total hours worked, and probability of participating in non-farm or non-household work. Men's employment does not consistently increase. One author finds a significant decrease in female wages and constant male wages (Dinkelman 2011). Another author finds significant increases in male wages and constant female wages (Grogan and Sadanand 2011). The results by Dinkelman (2011) are considered particularly robust. She 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. Her paper also investigates the causal chain through which impacts in employment take place. Households switch from wood to electric cooking and lighting in newly electrified communities. Electricity increases household productivity, releasing female time from home to market work. Household electrification does not stimulate large-scale rural industrialisation. Instead, it is more plausible that new employment comes from self-employment and microenterprises, as electricity lowers the cost of new home-based products and services.

Impacts on income seem conclusive as regards non-farm income growth with exception from findings from Khandker *et al*. (2009b). Impacts on total and farm income are not consistent across studies, with some studies reporting no impact (ADB 2010; Herrin 1983; Kumar and Rauniyar 2011) and others showing significant positive impacts (Khandker *et al*. 2009a; Khandker *et al*. 2009b). In the evaluation of its assistance to rural electrification in the Philippines, the ADB (2005) finds that availability of electricity has not been a determining factor for rural poverty reduction, with poverty understood in terms of income. Another study looking at the impacts of energy infrastructure on poverty reduction shows that mere access does not show a significant impact on poverty reduction, but an increase in service quality has a strong positive relationship with poverty reduction in China (Cook *et al.* 2005). The joint effect of several development programmes (electrification, industry, infrastructure, education, health, nutrition, environmental sanitation and family planning) on income needs to be taken into account (Herrin 1983). Also, the lack of impacts reported by some studies could be due to a small time period between the availability of electricity and the evaluation of impacts (Herrin 1983).

One author uses a quantile regression to estimate electrification benefits per household groups based on their welfare outcomes such as income or expenditure, finding that richer households benefit more than poorer ones. Households in the lower two expenditure quantiles accumulate no electrification benefits and for households in the highest quantile the electrification impact on their per capita expenditure is nearly twice that of those in the middle quantile. This is explained because electrification benefits happen through multiple channels and poorer households can only benefit from lighting, while richer households can use a number of energy services (Khandker *et al.* 2012).

The three authors analysing the impact of electricity on the **creation of enterprises** find no significant impacts, which would challenge reported increases in income and employment.

Two authors show evidence of **health improvements**, particularly less incidence of eye irritation and respiratory ailments, with results based on people's perceptions. Another author notes that solar PV lighting is likely to reduce the proportion of household members being affected by indoor smoke from kerosene lanterns by 50 per cent and that of household members who get blackened nostrils from soot by nearly a third (Obeng *et al.* 2008). This last publication is not included in the summary table as it uses the with/without method, not tackling causality.

Improvements in **education** are widely and consistently reported, with homogeneous measurements, mainly: years of schooling completed, study time and school enrolment. Impacts are generally higher for girls than boys, probably as they need to perform less household tasks with the introduction of electricity. One paper looking at distributional impacts finds that benefits are higher for rich households in terms of schooling years and study hours (Khandker *et al.* 2012). Positive impacts on health and education, particularly for women, are also reported in Anderson *et al.* (2005) and Legros *et al.* (2011) although using a methodology that does not deal with causality.

Publications dealing with impacts on **time allocation** focus on different uses of time, which make it difficult to gather a substantial evidence of the impacts. Time spent collecting fuel or cooking decreases according to three papers, but time spent fetching water increases. Impacts on the amount of time spent doing unpaid work are not conclusive. A report comparing the mean time spent in a number of activities by a large sample or rural Indian women with and without electricity presents more clear results (UNDP and ESMAP 2004). It finds that women from households with electricity lead a more balanced life between work and leisure activities. They spend less time collecting fuels, fetching water and cooking and instead spend more time on earning an income, reading and watching television. These impacts happen regardless of income level.

Two of the publications dealing with **women's empowerment** look at the positive impact of improved access to information through cable TV. Two other publications look at access to electricity in general, finding that it leads to improvements in women's participation in household decisions.

Positive impacts on **fertility** are backed by three studies. Another publication notes that electrification has in fact opposing effects on fertility in urban and rural areas. The effect of electricity is positive in the former and negative in the latter. The authors argue that this could be due to electricity facilitating childcare in urban areas, where childcare is more expensive, while in rural settings the major impact of electricity comes from its modernising impacts through the provision of information as well as shorter nights and other entertainment opportunities (Peters and Vance 2010). This last publication is not included in the summary table as it does not consider causality but its results are considered robust to inform our review.

The impact of electricity on **deforestation** is not conclusive, given the prevalence of fuelwood for cooking.

Electrification can also lead to negative outcomes as a result of the **migration** it brings about from non-electrified areas, which creates congestion externalities (Dinkelman and Schulhofer-Wohl 2012).

Monetary quantification of consumer benefits from electricity

Six analytical papers measure the economic benefits of electricity (ESMAP 2002; Meier *et al.* 2010; World Bank 2008b; Legros *et al.* 2011; Mulder and Tembe 2008; Munasinghe 1998).

The publication by the World Bank (2008b) is considered as the higher quality one. It follows a similar approach to ESMAP (2002) but is improved as the latter considered a linear demand curve that lead to an overestimation of benefits. The World Bank considers a large number of benefits for a diversity of locations (Philippines, Peru, Lao PDR and Bolivia). Results for all the publications above, with an average provided for the several values included in the World Bank report, are summarised in Table 4. The figures provided by Mulder and Tembe (2008) and Munasinghe (1988) refer to the benefits of electrification projects as a whole and are therefore not comparable with the other studies.

Table 4 Electrification benefits (US$/household/month)

	World Bank 2008b	**ESMAP 2002**	**Meier *et al*. 2010**	**Legros *et al*. 2011***
Lighting	10.5	36.75	5.3–34	
TV	7.5	19.6	2.9–4.6	
Education	12.5	37.07		
Time saved for household chores/increased leisure	5.5	24.5		
Productivity home business: existing business	3.2	34		10
Productivity home business: new business	2.5	75		76
Improved health	0.0			
Reduced fertility	0.1			
Increased agricultural productivity	0.0			
Reduced pollution (global benefits)	0.2			0.33
Reduced energy expenditures				0.32

*Figures provided per year in original publication, estimated per month for comparability with the other studies.

Estimates of benefits of electricity are quite uncertain, as shown by the wide range of the figures provided. The studies use different methodologies and are based in different locations with differing preconditions in terms of cost of electricity and of energy alternatives. However, all studies agree that benefits are higher than costs.

The World Bank (2008b) finds that the average household WTP is well above the average supply cost. They argue that connection costs vary between US$150 and US$2,000 per household, depending on the location and size of the community, and are even lower for already electrified communities. Household annual benefits are estimated as US$600, meaning the breakeven point is between one and three years. Thus, rural grid connections can be good investments. However, some caveats to this estimation are required. Firstly, the World Bank notes that low-income households may be willing to pay but cannot afford to, given high upfront costs and the absence of credit markets. They recommend filling the gap in the credit market and subsidising the connection fee for poorer households. Secondly, their breakeven point estimation is problematic as most of the benefits are not 'cashable', in that they are monetised values of non-monetary benefits, rather than actual increases in real income resulting from electricity use. Therefore, the monetised benefits of electricity will not contribute to the user's ability to repay connection costs.

Description of benefits of electricity for poor people and the channels leading to these

Descriptive literature provides a valuable analysis of the causal chain leading to poverty impacts due to electrification. Poverty impacts when poverty is understood in its traditional sense of low income and consumption are related to the potential of electricity to improve income levels through its use for productive activities. Wider definitions of poverty are related to welfare and sustainable livelihoods and take into account other benefits of electricity.

The first link in the causal chain of poverty outcomes of electricity consumption relates to the specific uses of electricity. A wide understanding of poverty as welfare looks at uses that allow improvements in health, education, gender equality, comfort, safety, social interaction, leisure, communications, access to information or environmental benefits. These uses can include for example: lights, TV, radio, mobile phones, refrigerators, cooling appliances, washing machines, cooking equipment, irons, mobile chargers, computers, music equipment or street lights.

Productive uses are seen as those having the highest potential to get the poor out of the poverty trap, as defined in IDS (2003): 'lack of energy makes their productivity low, which does not enable them to get enough income to pay for energy access. The provision of quality energy services and related appliances and potential uses is essential to break this trap'. Evidence shows that rural electrification projects rarely deliver income generation activities (Green 2004; Hong and Abe 2012; Jacobson 2007; Komatsu *et al.* 2011a; Kooijman-van Dijk and Clancy 2010; Tobich 2008). Lighting and TV are the most widespread uses of electricity but have a limited income generation potential. Only one of the papers reviewed under this sub-section demonstrates a clear positive impact of electricity for productive activities (Kirubi *et al.* 2009). The paper studies a community-based electric micro-grid in rural Kenya and describes how access to electricity enables the use of electric equipment and tools by small and microenterprises, resulting in significant improvement in productivity per worker. Access to electricity simultaneously enables and improves the delivery of social and business services from a wide range of village-level infrastructure including schools, markets and water pumps. These benefits can be explained through a set of favourable pre-conditions of the township where the electrification project took place.

What then determines what electricity is used for and hence its benefits for the poor?

At the household level, the first and obvious element is the number of appliances that the poor can afford. Facilitating factors include credit for the poor, free distribution of appliances or an increase of income due to electricity. Some authors also point at the importance of household dynamics regards decisions about which appliances to buy or which are used when there is limited power supply. Gender relationships are particularly important, as well as the priority placed on children's education (Jacobson 2007; IDS 2003; Clancy *et al.* 2001).

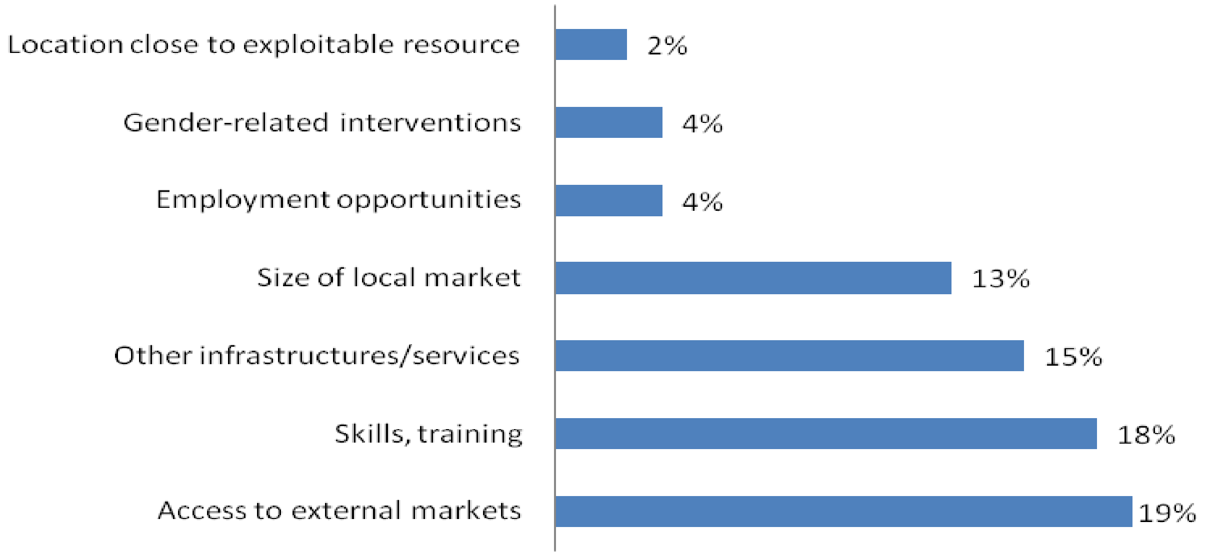
At the level of productive activities, most authors agree that ‘electricity is a necessary but insufficient condition for income generation and poverty reduction’. It cannot create development on its own if other complementary inputs are missing and needs to be placed in the context of integrated rural development programmes. Several ‘enablers’, ‘complementary inputs’ or ‘facilitators’ of income generation are identified by the evidence-based literature:

- **Integrated development programmes.** These include roads that allow access to external markets, access to credit to purchase end-use technologies, training programmes and professional support for enterprise creation, business promotion and development, demonstration projects of the use of electricity appliances for irrigation and for industries, technical assistance in converting enterprises to electricity (IDS 2003; Bastakoti 2003; Hong and Abe 2012).
- **Location.** Businesses are more likely to flourish if they are located in towns that are articulation nodes to other communities (i.e. trading centres), have reliable road and telecommunications networks, have an easy and reliable access to exploitable resources (for example, agriculture or tourism).The location of the households inside their village is also very important in providing them with business opportunities (Calderon Cockburn 2005; Green 2004; Kirubi *et al.* 2009; Bastakoti 2003; Kooijman-van Dijk and Clancy 2010).
- **Market development.** Electrification can increase productivity but income benefits will only be realised if a market is found for this additional production (Green 2004; Matly 2003; Kooijman-van Dijk 2012; Kooijman-van Dijk and Clancy 2010; UNDP 2012). A growing local economy with demand for non-basic goods can provide this market. External markets can provide further possibilities, but skills are required to access them. Saturation of the market is a key problem for new enterprises.
- **Skills to produce better quality products, innovate and reach new markets.** Skills are required to identify the new business opportunities created by electricity, to use electrical equipment efficiently and to identify and access new markets for the new products and services provided (Kooijman-van Dirk 2012; UNDP 2012).
- **Pre-existing productive activities.** Electricity is more likely to benefit existing businesses than to promote the creation of new businesses. This can happen through improved productivity, the possibility of improving the quality or diversity of products and services, improved workspace quality or energy cost savings (Tobich 2008; Kooijman-van Dijk and Clancy 2010). The local industry and agriculture businesses can create a large initial demand for electricity and contribute to an important share of its initial costs (Kirubi *et al.* 2009; UNDP 2012). The tea sector in east Africa and the mobile phone sector in southern and east Africa are two good examples of this. Growing demand was local in the case of mobile phones and international in the tea sector. Both industries had the political and financial power to promote electrification and remove constraints to growth (UNDP 2012).
- **Quality of energy supply.** Low voltage SHS or solar battery charging systems cannot enable productive uses of electricity, being able to supply electricity only for lighting and small appliances (Green 2004). In-grid systems, blackouts or fluctuating voltage causes damage to appliances and products and has high costs, which leads to reduced uptake and use of electric appliances by industry (Kooijman-van Dijk 2012).
- **Favourable business environment** (UNDP 2012).

These enabling factors complement the results found by the analytical literature, which emphasised the importance of access to markets. However, it contradicts Peters *et al.* (2011), who found no positive impact for pre-existing firms and instead a very good performance of newly created enterprises dependent on the use of electricity for their activities.

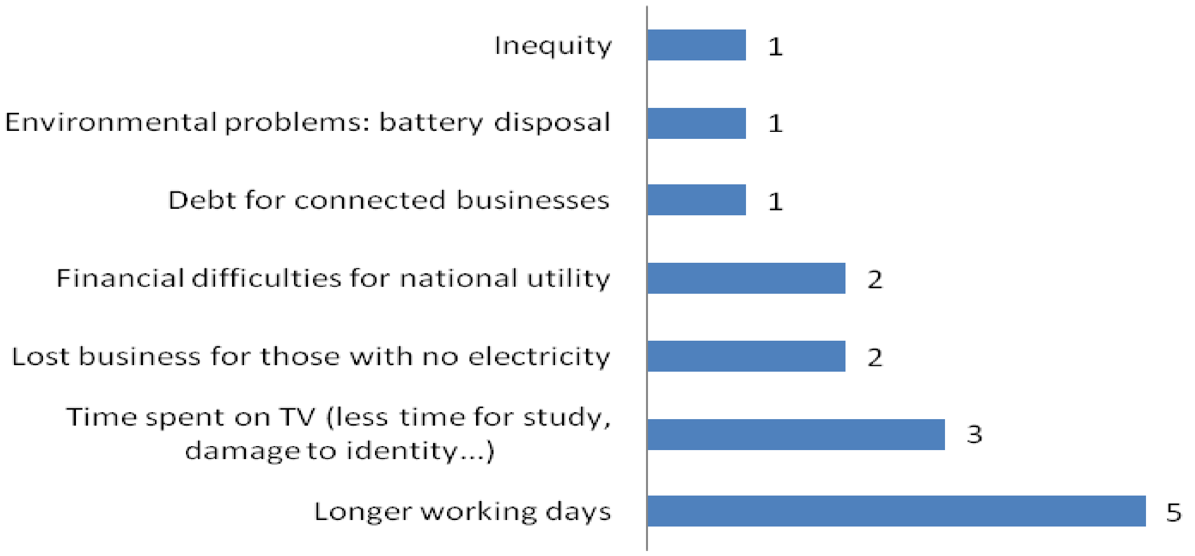
A survey of all the reviewed literature (analytical and descriptive, high, medium and low quality) shows that the most widely reported enabling factors for the realisation of electricity impacts are the access to external markets, the skills and training of existing and potential entrepreneurs, the availability of other infrastructures and services for productive uses and the size of the local market.

Figure 25 Enabling factors of electricity impacts



It is also worth highlighting that not only positive impacts result from electricity. Several negative impacts are identified in the literature. Access to electricity can involve longer working days, particularly for women, with domestic tasks extending well into the evening as they are able to participate more actively in productive activities. Five papers mention this effect. Three papers refer to the negative impacts that TV can have for households and communities, including damage to identity, less time to study for children or stereotypes on gender relationships, for example. Other negative impacts less frequently reported are summarised in Figure 26.

Figure 26 Number of publications referring to negative impacts of electricity



5.3.3 Policy recommendations

The benefits of electricity for the poor depend on how much and for what it is used. There is also evidence showing that wealthier households and businesses financially better off benefit more than poorer ones.

Policy can influence consumption patterns through several activities. As regards general welfare benefits for households, policy can facilitate increased access to electrical appliances for the poor through microcredits, free distribution or favourable payment conditions. Policies can also be designed to train users on the potential uses and benefits of electricity. Gender targeted policies are also 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.

Productive uses of electricity are particularly important to get the poor out of the poverty trap. Two main policies can be followed to encourage these. A set of criteria could be developed to prioritise rural areas with the highest potential to use electricity for income-generating activities. These would include communities with a large internal market and easy access to external markets; a pre-existing diverse and growing productive sector including agriculture, manufacture and services; a set of infrastructures conductive for business development, such as road and telecommunications networks; and easy and reliable access to exploitable resources such as agriculture and tourism. Alternatively, more deprived areas with lower economic potential can be targeted but electrification should be integrated with other development programmes that contribute to create the appropriate environment for productive activities. This could include support to purchase productive equipment and to develop the skills to efficiently use it, infrastructures (particularly roads and telecommunications) and social skills to access external markets; or support for the creation of businesses.

5.4 Question D: Relationship between electricity consumption and economic growth at the macro level

5.4.1 High-level description of the literature

The empirical literature about the relationship between electricity consumption and economic growth has focused on two main related questions. A large number of studies analyse the direction of causality between economic growth and electricity consumption. A smaller number of studies quantify the impact of electricity consumption on economic growth without focusing on the direction of causality. In this section, we synthesise the evidence regarding both elements.

Most of the literature in the area of electrification and economic growth has focused on understanding the direction of causality between both variables, and it is less concerned with measuring the size of the potential impact of electrification on economic growth. However, a smaller subset of studies has attempted to estimate electricity consumption on growth elasticity, based on the assumption that causality runs from electricity consumption to economic growth.

The focus of our review is strictly on the relationship between electricity consumption and economic growth and, therefore, those studies dealing with energy in general are excluded. However, the methodological approaches, as well as the theoretical frameworks used on those studies analysing other types of energy consumption are similar. Furthermore, some studies use electricity consumption as a proxy for total energy consumption and, therefore, they extrapolate the results to the link between energy consumption in general and economic growth.

The first study dealing with causality between economic growth and energy consumption was based on a United States dataset from 1947 to 1974 (Kraft and Kraft 1978). The authors concluded that there was unidirectional causality, but from the Gross National Product to energy consumption. The main importance of this seminal paper is that it started this line of research. Numerous papers have followed this paper, including studies using longitudinal panel techniques.

The finding by Kraft and Kraft (1978) of causality from income to electricity consumption is not unanimous even for the case of the US. Other studies in the US with different time spans, data frequency or methodologies have reached different conclusions. For example, Akarca and Long (1980), Yu and Hwang (1984) or Stern (1993 and 2000) cited in Chen, Chen *et al.* (2012) suggest that the direction of causality runs from energy consumption to economic growth.

Other studies have also found contradictory findings even within the same country. Using different datasets or techniques, these studies reach opposing conclusions about the relationship between economic growth and electricity consumption. This could be attributed to inaccurate measurement or to techniques that either might fail to capture particular patterns in the data, such as shocks, or that are simply inadequately applied.

Ozturk (2010) and Payne (2010) review the literature on causality between energy/electricity consumption and GDP and suggest four possible causality outcomes or 'hypotheses' found in literature:

1. No causality or '*neutrality hypothesis*': The analysis cannot find causality in any direction between economic growth and electricity consumption;
2. Causality from economic growth to electricity consumption or '*conservation hypothesis*';
3. Causality from electricity consumption and economic growth or '*growth hypothesis*';
4. Bidirectional causality or '*feedback hypothesis*', economic growth leads to electricity consumption and vice versa.

These four different causality outcomes have very different policy implications. In the neutrality hypothesis case, policies affecting electricity consumption do not impact growth and vice versa. In the second case, growth causing electricity consumption, policies aiming at reducing consumption and waste of electricity could be adopted with no consequences on growth. The third hypothesis, the 'growth hypothesis', implies that there is a critical contribution of electricity consumption to growth. Electricity in this case contributes to economic growth as an input, as in the case of capital and labour. Thus, restrictive policies on electricity consumption or shocks on electricity supply would negatively affect economic growth (Ozturk 2010). In addition, this hypothesis suggests that measures aiming at increasing the access to electricity and improving efficiency in its use would boost economic growth. Finally, under the fourth hypothesis, electricity and growth impact each other and, therefore, electricity consumption stimulates economic growth and this, in turn, increases energy consumption.

The survey by Ozturk (2010) covers all types of energy sources in relation to the energy consumption–GDP relationship, while Payne (2010) constrains his scope to those papers which strictly refer to electricity and its relationship with GDP. This last paper is in line with our focus on electricity consumption. Nevertheless, the study mainly focuses on high-income countries, which are excluded in our review.

In addition to these literature reviews, one interesting recent study, Chen, Chen *et al.* (2012) uses meta-analysis to analyse the determinants of the different hypotheses defined above: neutrality, conservation growth or feedback. Concretely, the authors use a multinomial logit model with 174 causality estimates. In order to explain the likelihood of each of these causality hypotheses, they use as independent variables GDP per capita, electricity consumption (proxying energy consumption) and several dummies showing whether the country belongs to OPEC, whether it implements a carbon tax, whether it belongs to the Annex I countries from the UNFCCC, whether it is a developing country and also time dummies.

They find that most of these variables are significant in explaining the probability of these causality outcomes. Specifically, the authors find that a higher GDP per capita increases the likelihood of the conservation and feedback hypotheses, while reducing the likelihood of the neutrality and growth hypothesis. In the case of electricity consumption, increases in consumption increase the likelihood of the growth and feedback hypothesis. Finally, the coefficient on the developing country dummy shows that the conservation hypothesis is more prevalent in these countries.

The studies reviewed above suggest that when summarising the literature in this area, it is critical to understand the direction of causality as well as the size of any impacts. As a result, our synthesis employs two stages. In the first stage, we focus on understanding the direction of causality. In the second stage, we focus on synthesising the size effect for those studies that assume the ‘growth’ hypothesis where electricity consumption increases growth. To this end, we perform a meta-analysis of the elasticities reported in included studies that are comparable.

5.4.2 Characteristics of the studies included

Following the criteria established in the protocol, only studies that treated the link between electricity and economic growth in developing countries are included in the synthesis. This implies that we excluded two related types of studies:

- Those that focused on the relationship between energy and growth, in which the type of energy source is not disaggregated and, therefore, the causality relationship with respect to electricity could not be inferred.
- Those that focused only on high-income countries or on both high and middle/low-income countries. In the latter case, studies were included only when individual outcomes for low/middle-income countries were presented.

In addition to these exclusion criteria, we also excluded some studies due to methodological considerations. Specifically, since the literature shows the importance of estimating the direction of causality, we exclude studies that ignore this important issue. Furthermore, for the synthesis of the size of the effect, we include those studies that report some growth elasticity that can be compared across studies. For example, Adeleke (2010) or Abanda *et al*. (2012) study the significance of the Spearman’s correlation coefficient, but cannot be included in either of the analyses since they do not consider causality and do not report elasticity estimates. Another example is Frederiksen (1985) who employs OLS estimates in order to show that regional income increases with the percentage of electrified homes. However, the author has no discussion about causality and the outcomes could not be translated into elasticity estimates.

In total we include 36 studies, which are summarised in Appendix 5. Out of these studies 30 deal with the issue of causality between electricity and economic growth, two studies report growth elasticity coefficients (Ramcharran 1990; and Sharma 2010). Finally, three more papers deal with both causality issues and elasticities (Jumbe 2004; Kumar Narayan and Singh 2007; Bildirici and Kayikçi 2012).

Regarding studies that look at the direction of causality, 32 papers are based on time series or panel data analysis, and test for Granger causality in one way or another. The remaining two papers studied causality using different quantitative approaches. Rud (2012) tries an Instrumental Variable approach to prove that causality runs from electrification to manufacturing and Talha Yalta and Cakar (2012) use a more complex maximum entropy bootstrap-based analysis to show that no causality between electricity and economic growth is found in China. With or without Granger causality methodologies, these 33 papers use an empirical framework where causality is tested, and constitute the core body of included studies in order to establish whether electricity consumption leads to economic growth in developing countries.

The majority of these 36 studies are based on a single country analysis. Therefore, they use time series analysis for the variables of interest. There are also a few multi-country studies using panel data techniques. Chen *et al.* (2007) and Bildirici and Kayikçi (2012) are some examples of these panel data approaches. The former combines a panel data approach and time series causality tests on individual countries. The panel includes Taiwan, Singapore and Hong Kong, but these observations are excluded as they are high-income countries. In Bildirici and Kayikçi (2012) all outcomes belonging to countries in the low/middle-income groups are included. In addition to these two studies, there are four more multi-country studies where outcomes are estimated separately for each country using time series techniques (Wolde-Rufael 2006; Yoo 2006; Squalli 2007; Yoo and Kwak 2010) and 30 single-country studies. In the case of Ozturk and Acaravci (2011), the study is also multi-country but only outcomes for Egypt are included given that other countries are high-income.

The 36 studies included represent a total of 79 observations. From these, 28 observations come from single-country studies and the remaining from multi-country studies. Specifically, we extract from multi-country studies included all observations related to non-high-income countries. These are observations for 11 countries in Bildirici and Kayikçi (2012); 6 countries in Chen *et al.* (2007); 7 countries in Squalli (2007); 17 countries in Wolde-Rufael (2004); 3 countries in Yoo (2006); and 7 countries in Yoo and Kwak (2010).

The distribution of the dataset across countries is not even and some countries are the focus of several studies. The most studied country in our sample is China, which appears in six papers, five of which are country studies and one that focuses only on Shanghai. Other countries that are the subject of study more than one paper are:

- Malaysia in five studies
- Indonesia in four studies
- Bangladesh, India, Nigeria and Pakistan in three studies
- Algeria, Egypt, South Africa, Thailand, Tunisia and Venezuela in two studies.

In addition to these 13 countries, there are 40 other countries represented in the sample, adding to a total of 53 different countries within the 79 observations of the sample.

Interestingly, we find that some studies focusing on the same country (although using datasets with different time spans and different methodologies) reach different conclusions about the direction of causality between electricity consumption and economic growth.

Most of the studies included use annual data. Only two studies use a different periodicity, Abosedra *et al*. (2009) uses monthly data and Tang (2008) uses quarterly data. This allows these studies to maximise the number of observations in the analysis, 132 and 136 respectively.

Regarding the sample period, the earliest year in the sample is 1950 and the latest 2009. For those with annual data, the largest number of years used is 51 years (Altinay and Karagol 2005) and the lowest 20 years (Rud 2012).

In relation to the variables of interest for the synthesis, electrification is defined in most studies as electricity consumption, measured in most cases in kilowatt-hours. In some studies this variable is in per capita terms and in other studies it is shown as total consumption. There are only a few exceptions to this definition. Rud (2012) uses as consumption variable rural electrification measured as the number of agricultural units connected to the electricity network per 1,000 people. In the case of Morimoto and Hope (2004) the variable used is annual electricity production instead of consumption. Their justification to use production as a proxy for consumption is that Sri Lanka is self-sufficient in terms of electricity production and they consume what they produce. Similarly, Yoo and Kim (2006) and Lean and Smyth (2010) also use electricity generation as a proxy for consumption.

For economic growth, the most common variable used is Gross Domestic Product (GDP) expressed in constant prices. In some studies, GDP is expressed in per capita terms or growth rates. Only three studies use a different proxy. Rud (2012) uses manufacturing output and Sebri and Abid (2012) use agricultural value added. Finally, Abosedra *et al.* (2009) use total imports as the proxy for economic growth.

Different studies use different specifications to measure Granger causality. Most studies use a bivariate model in which the only two variables used are electricity consumption and economic growth. This is problematic since the estimates might be suffering from omitted variable bias if variables that are relevant for explaining the dependent variable are not included and are correlated with electricity consumption. If this is the case, the coefficient on electricity consumption is likely to capture also the effects of other correlated variables. Multivariate studies are considered of higher quality in our assessment.

From the included studies, fourteen studies use a multivariate approach that includes additional variables to control for other factors explaining economic growth. Several of these studies use an augmented version of a Cobb-Douglas production function, where economic growth is explained by capital, labour, a technology parameter and an added factor which is electricity consumption (Lorde 2010; Shahbaz and Lean 2012 and Yuan *et al*. 2008). In other cases a lower number of variables are included, such as labour (Kumar Narayan and Singh 2007; Odhiambo 2009) have been used.

As suggested earlier, with the exception of Rud (2012) and Talha Yalta and Cakar (2012), all studies looking at causality issues use a Granger causality framework. This methodology uses several steps which involve the test for unit roots, cointegration and causality (see Box 1).[13]

In what follows, we present the synthesis of results based on the coefficients of the sample of included studies. First we focus on the results for the direction of causality, and then we use meta-analysis to summarise the effects of electricity consumption on growth for those studies that report elasticity estimates.

[13] There are three alternatives for the causality analysis: Standard Granger causality (including Hsiao's version (1981) of this test), Vector Error Correction Model (VECM hereafter), and Modified Wald Test (MWT) which includes Toda-Yamamoto's and Luda-Lutkepol's approaches. The use of one or other test can be conditioned by the tests run in the previous two steps. In the present dataset, the most common causal test is the VECM, followed by the MWT.

Box 1 Granger causality

Granger causality takes advantage of the fact that time always goes forward. Thus if there is an issue X that is taking place before issue Y, it would be possible for X to be the cause of Y. However, it cannot be the other way round as long as Y is ulterior to X.
Thus, in the Granger causality test we intend to know whether past values of one variable (X) have explanatory power over the current values of the dependent variable (Y). If so, then x might be causing y. And we can test the other way round to see whether past values of variable Y are explaining the current values of variable X. In purity, when this happens, it is said that X is Granger causing Y or the other way round.
When approaching the Granger causality test, normally three steps are attempted (in the simplest case of a model with only two variables involved):

1. Testing for the stationarity of the series of X and Y
2. Testing for cointegration between the series of X and Y
3. Granger causality test, whose approach might be conditioned by the outcomes in the former tests.

5.4.3 Synthesis

Direction of causality between electricity of consumption and economic growth

The results of the estimates of the sample of included studies suggest that there is no unanimous causal relationship between electricity consumption and economic growth in low/middle-income countries. The distribution of the different causality regimes for the 79 available observations is as follows:

1. No causality or '*neutrality hypothesis*': 13.92 per cent
2. Causality from economic growth to electricity consumption or '*conservation hypothesis*': 22.78 per cent
3. Causality from electricity consumption to economic growth or '*growth hypothesis*': 32.91 per cent
4. Bidirectional causality or '*feedback hypothesis*': 30.38 per cent

Most studies suggest that there is some causality; only around 14 per cent of estimates support no causality or 'neutrality hypothesis'. However, the direction of causality is less clear. Around one third of estimates support the 'growth hypothesis' where electricity consumption increases growth. On the other hand, around 53 per cent of observations suggest other types of causality; bidirectional causality (30.38 per cent) or causality running from economic growth to electricity consumption (22.78 per cent). Therefore, the evidence regarding the direction of causality remains largely divided and inconclusive.

This heterogeneity of outcomes is not only explained by the country of study but also by the study design and methodology used. The best example to illustrate this is to analyse the heterogeneity of outcomes within the same country of study. Malaysia is a good example. From the five studies analysing causality in this country, Chandran *et al.* (2010) conclude that electricity consumption causes economic growth, while Chen *et al.* (2007) and Lean and Smyth (2010) suggest that causality runs the other way round; and Tang (2008) and (Yoo 2006) estimate bidirectional causality between electricity and economic growth.

Several elements can explain this heterogeneity of outcomes. First, the choice of variables used. The electricity consumption variable for Chandran *et al*. (2010) and Chen *et al.* (2007) is overall electricity consumption; while for Lean and Smyth (2010) is electricity generation per capita or electricity consumption per capita for Tang (2008) and Yoo (2006). The first two studies use real GDP for economic growth and the latter three use real GDP per capita in constant prices from different years. Second, there are differences in the sample periods.

Tang (2008) uses quarterly data from 1972 Q1 till 2003 Q4, 136 observations. The other four studies use annual data. From those, Lean and Smyth (2010) use the largest sample period, 1970–2008, and Chen *et al.* (2007) the shortest, 1971–2003.

In addition, there are differences in the specification used by different studies. Chandran *et al.* (2010) and Lean and Smyth (2010) use a multivariate model. Thus, they include additional variables in the model set up, such as prices and exports. The other three studies are bivariate models using only two variables, energy consumption and economic growth.

Finally, there are also some methodological differences in the way causality is estimated. These differences are clear in the different tests done previously to the causality analysis and also in the causality tests done in the five studies. Chandran *et al.* (2010) and Chen *et al*. (2007) use a Vector Error Correction Model Approach; Lean and Smyth (2010) and Tang (2008) employ a Modified Wald Test approach; and Yoo (2006) uses Hsiao's version (1981) of the Granger test (1969).

This large within-country heterogeneity of outcomes indicates that study design, including variable definitions, sample period or methodology used, are critical elements when explaining causality outcomes.

In order to further analyse this issue of heterogeneity of outcomes, we decompose the results by country, income-level and country region, and compare whether the prevalence of any specific causality outcomes is significantly larger for a specific group of countries.

In Table 5 the different causality outcomes are tabulated in relation to the country income level. The second row for each group shows the percentage of each causality outcome for each income group. Although the 'growth hypothesis' is more prevalent in the case of upper middle income countries and there is little evidence of 'neutrality' or no causality, the results show no clear pattern. Both the 'conservation' and 'feedback' hypotheses are supported by more than 40 per cent of studies, and for the 'feedback hypothesis', bidirectional causality is significantly more prevalent for low-income countries.

Table 6 shows the decomposition of results by region. The neutrality hypothesis is more frequent in East Asia and Pacific and sub-Saharan Africa. In the case of Europe and Central Asia there is no evidence of neutrality and conservation, and most of the evidence supports the feedback hypothesis. In Latin America and the Caribbean region the evidence supports the growth hypothesis, while in the case of South Asia, the distribution is more even.

Overall, the results of the decomposition indicate that this heterogeneity of causality outcomes does not appear to be explained by country or income group, and only for Europe, Central Asia and Latin America and the Caribbean some causality outcomes are very prevalent. In the case of Europe and Central Asia the evidence suggests the feedback hypothesis, while for the Latin America and the Caribbean the evidence mainly supports the growth hypothesis.

In order to further analyse heterogeneity of causality outcomes more formally and determine the contribution of different factors, we estimate a model for the determinants of each of the causality outcomes.

Table 5 Causality by income level

Country by Income		Causality Hypothesis				
		Neutrality	Conservation	Growth	Feedback	TOTAL
Low income		2	2	2	4	10
	% row	20	20	20	40	100
	% column	18.18	11.11	7.69	16.67	12.66
Lower-middle income		3	10	9	9	31
	% row	9.68	32.26	29.03	29.03	100
	% column	27.27	55.56	34.62	37.5	39.24
Upper middle income		6	6	15	11	38
	% row	15.79	15.79	39.47	28.95	100
	% column	54.55	33.33	57.69	45.83	48.1
Total		11	18	26	24	79
		13.92	22.78	32.91	30.38	100
		100	100	100	100	100

Table 6 Hypothesis by region

Region of the country		Causality Hypothesis				
		Neutrality	Conservation	Growth	Feedback	TOTAL
East Asia and Pacific		3	6	7	3	19
	% row	15.79	31.58	36.84	15.79	100
	% column	27.27	33.33	26.92	12.5	24.05
Europe and Central Asia		0	0	1	11	12
	% row	0	0	8.33	91.67	100
	% column	0	0	3.85	45.83	15.19
Latin America and Caribbean		1	0	6	1	8
	% row	12.5	0	75	12.5	100
	% column	9.09	0	23.08	4.17	10.13
Middle East and North Africa		1	3	4	3	11
	% row	9.09	27.27	36.36	27.27	100
	% column	9.09	16.67	15.38	12.5	13.92
South Asia		1	3	3	3	10
	% row	10	30	30	30	100
	% column	9.09	16.67	11.54	12.5	12.66
Sub-Saharan Africa		5	6	5	3	19
	% row	26.32	31.58	26.32	15.79	100
	% column	45.45	33.33	19.23	12.5	24.05
Total		11	18	26	24	79
		13.92	22.78	32.91	30.38	100
		100	100	100	100	100

Following the approach by Chen, Chen *et al.* (2012) described in Section 2 we estimate a multinomial logit model. Concretely, we estimate the following model:[14]

$$prob_i(y_i = j) = \pi_{ij} = \frac{\exp\,(x'_i\beta_j)}{\sum_1^k exp\,\exp\,(x'_i\beta_j)}$$

where i stands for the country and j for the causality hypothesis or regimes.

The different causality regimes are:

1. Neutrality hypothesis
2. Conservation hypothesis
3. Growth hypothesis
4. Feedback hypothesis

In order to explain each causality regime, and based on the previous analysis we use the following explanatory variables:

- ***ln_ec_kwh***: logarithm of electricity consumption of the country in Kwh (year 2010)
- ***ln_gdp***: logarithm of GDP of the country (year 2010)
- ***years***: number of years that the dataset covers
- ***bivariate***: binary indicating that it is a bivariate model (just GDP and electricity consumptions vs. other models including more variables)
- ***reg_3***: binary indicating that it is an African country
- ***df_adf***: binary indicating that the unit root test used was Dickey Fuller or its augmented version
- ***vcem***: binary indicating whether the Granger causality is found through a Vector Error Correction Model.

Therefore, the model estimates the contribution of size of consumption of electricity, country size, sample size, specification, African country and type of methodological tests on the probability of explaining the likelihood of each of the causality hypothesis.

Table 7 shows the marginal effect estimates, how a change in the explanatory variable affects the probability of the causality regime occurring. Most coefficients are not statistically significant, which is not surprising given the small sample, 73 observations.[15]

Table 7 Multinomial logit model: marginal effects

	Kwh	**GDP**	**Years**	**Bivariate**	**Africa**	**Dickey Fuller**	**VECM**
Neurality	–0.041 (0.032)	0.053 (0.022)	0.001 (0.006)	0.058 (0.077)	0.17 (0.122)	–0.101 (0.107)	0.066 (0.112)
Conservation	–0.037 (0.054)	–0.012 (0.039)	0.007 (0.008)	–0.001 (0.17)	–0.021 (0.137)	–0.049 (0.143)	–0.151 (0.134)
Growth	–0.082 (0.064)	0.053 (0.042)	–0.006 (0.01)	–0.202 (0.185)	–0.068 (0.159)	0.083 (0.171)	–0.168 (0.155)
Bidirectional	0.159 (0.066)	–0.094 (0.041)	–0.002 (0.01)	0.145 (0.124)	–0.058 (0.145)	0.066 (0.17)	0.253 (0.164)

[14] See a description of the multinomial logit procedure in Appendix 2.
[15] In addition, the small sample does not allow convergence of maximum likelihood estimates if the number of explanatory variables increases.

Focusing mainly on coefficients that are statistically significant, a 10 per cent increase in GDP increases the probability of the neutrality hypothesis by 0.53 of a percentage point. On the other hand, a 10 per cent increase in GDP decreases the probability of this Bi-directional hypothesis by 0.94 of a percentage point. This suggests that neutrality is likely to be more prevalent in larger or richer countries, while bi-directionality is more prevalent in smaller or poorer countries. Finally, an increase of electricity consumption of 10 per cent raises the probability of the bidirectional hypothesis by approximately 1.6 percentage points on average. Bi-directionality is, therefore, more prevalent in countries where consumption of electricity is larger.

Given the small size of the sample we use further tests in order to determine the reliability of the estimates. When we test for the joint effect of each variable on the causality relationship, we cannot reject the null that all coefficients are equal to zero. This implies that the effects of electricity consumption or GDP, years, etc. discussed above do not have explanatory power. Furthermore, we cannot reject the hypothesis that all the possible causality regimes established are indistinguishable. These tests, therefore, suggest that none of the estimates above are robust predictors of the different causality regimes.

Therefore these results suggest very mixed evidence regarding the direction of causality between electricity consumption and economic growth. This large heterogeneity is also present when comparing studies focusing in the same country, likely the outcome of different study designs. When looking at what factors may explain this heterogeneity we cannot find any robust results. The ‘feedback hypothesis’ of bidirectional causality appears more prevalent for Europe-Central Asia, while the growth hypothesis appears more prevalent in evidence about Latin America and the Caribbean. This does not match with the results of Chen *et al.* (2012), whose meta-analysis we tried to replicate. In that case the authors found that a higher GDP per capita increased the likelihood of the conservation and feedback hypothesis, while reducing the likelihood of the neutrality and growth hypothesis. In the case of electricity consumption, increases in consumption increased the likelihood of the growth and feedback hypothesis. Finally, the coefficient on the developing country dummy showed that the conservation hypothesis is more prevalent in these countries. Our inability to replicate those results may be due to our low number of observations, as we only include those from low and middle-income countries, while Chen *et al.* (2012) also include observations from high-income countries.

It is difficult to interpret what these results imply for policy. Perhaps the most important implication based on the evidence reviewed is that it cannot be assumed when designing electrification projects that increases in consumption of electricity necessarily cause increases in economic growth.

Meta-analysis of size effects

Keeping in mind the significant caveat posed by the previous section about the causal relationship between electricity consumption and economic growth, this section synthesises the size of the impact of electricity consumption on growth. It is important to ask how large these effects are for those studies that find or assume a causal relationship running from electricity consumption to growth.

Several studies report elasticity coefficients that measure how much economic growth changes in percentage terms when the electricity consumption grows by 1 per cent. Some studies report elasticities only for groups of countries. Also, different elasticities are reported within the same study depending on what method is used in the regression.[16] Out of the six

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[16] Taking Bildirici and Kayikçi (2012) as an example: it reports elasticities by groups of countries but not for individual ones:

- Group 1: Russian Federation, Azerbaijan, Kazakhstan and Republic of Belarus studies reporting elasticities, four of them also find a causal relationship running from electricity consumption to growth (Jumbe 2004; Kumar Narayan and Singh 2007; Bildirici and Kayikçi 2012). These are considered of higher quality than the rest.

In total, six studies provide 16 elasticity estimates. Following Borenstein (2009) a random effects estimator of the elasticities is implemented given the fact that the estimates are drawn from a heterogeneous sample of studies, using different techniques and on different datasets from different countries.

Table 8 shows for each observation the study, number of observations, country, econometric method, elasticity coefficients, confidence interval and sample weight. The final row summarises the random effects estimate for the overall effect. The reported Overall Effect is 0.173 with a 95 per cent confidence interval between 0,021 and 0.325. The effect thus, is positive and this would mean that a rise of one per cent on electricity consumption leads to an increase of 0.17 per cent of the GDP. The 95 per cent confidence interval does not cross the zero value suggesting that the estimated coefficient is significantly different from zero.

Table 8 Meta-analysis: random effects approach

Study	Obs	Country/ies	Regression/ spec	Effect	95 per cent conf interval		Per cent weight
Bildirici and Kayikçi (2012)	84	Group 1	FMOLS	0.52	0.196	0.844	6.53
Bildirici and Kayikçi (2012)	84	Group 2	FMOLS	–0.61	–1.002	–0.218	5.74
Bildirici and Kayikçi (2012)	63	Group 3	FMOLS	0.4	0.138	0.662	7.27
Bildirici and Kayikçi (2012)	84	Group 2	ARDL	–1.94	–3.22	–0.66	1.22
Bildirici and Kayikçi (2012)	63	Group 3	ARDL	–0.45	–0.753	–0.147	6.78
Chandran *et al.* (2010)	33	Malaysia	Spec 1 of model	0.683	0.646	0.72	9.23
Chandran *et al.* (2010)	33	Malaysia	Spec 2 of model	0.787	0.651	0.923	8.64
Jumbe (2004)	25	Malawi	OLS	0.216	–0.085	0.517	6.8
Kumar Narayan and Singh (2007)	32	Fiji	OLS	0.1	0.075	0.125	9.26
Kumar Narayan and Singh (2007)	32	Fiji	FMOLS	0.086	0.065	0.107	9.26
Kumar Narayan and Singh (2007)	32	Fiji	ARDL	0.071	0.034	0.109	9.23
Ramcharran (1990)	17	Jamaica	OLS	0.23	0.072	0.388	8.44
Sharma (2010)	320	Latin & Caribbean	Electricity consumption	0.121	–0.085	0.328	7.93
Sharma (2010)	400	Africa & M. East	Electricity consumption	–0.002	–1.897	1.893	0.6
Sharma (2010)	320	Latin & Caribbean	Electricity production	0.035	–0.839	0.909	2.28
Sharma (2010)	400	Africa & M. East	Electricity production	–0.007	–1.656	1.641	0.78
			Overall effect (dl)	0.173	0.021	0.325	100

- Group 2: Kyrgyzstan, Moldova, Tajikistan and Uzbekistan
- Group 3: Armenia, Ukraine and Georgia

The author also reports different elasticities depending on the regression methodology, whether that be Fully Modified Ordinary Least Squares (FMOLS) or Autoregressive Distributed Lag (ARDL).

We also perform a Cochrane Q test that tests whether all studies share a common size effect. This is clearly rejected, confirming that the studies do not share a common size, effect, size and, therefore, the random effects estimate is the appropriate estimation framework.

Table 9 Heterogeneity indicators: random effects

Measures	value	df	p-value
Cochrane Q	984.64	15	0.000
I^2 (%)	98.48		
H^2	64.64		
tau^2 est (dl)	0.065		

Figure 27 shows the Forest plot of the estimates. In general, it shows that most reported elasticity coefficients are positive and appear statistically significant. Only observations 4, 14, 15 and 16, have very large standard errors.

For robustness, we also compute the fixed effects estimator (Table A2 in Appendix 8). In this case the elasticity reported is 0.175, with a narrower confidence interval, confirming the above outcomes from the random effects approach.

Overall, for those studies that find or assume causality running from electricity consumption to economic growth, and that report elasticity estimates, we find a positive and substantial effect on growth. This result, however, is subject to the caveat about the direction of causality.

5.4.4 Conclusion

This part has analysed the evidence regarding the impact of electricity consumption on economic growth in low and middle-income countries. Given the nature of the question we have focused on reviewing studies that have tried to quantify this effect. In total, we have included 36 studies with 79 observations.

The evidence reviewed emphasises the need to estimate the direction of causality between electricity consumption and economic growth. The finding of the report, however, is that the evidence regarding the causal direction is extremely mixed. More importantly, we cannot find any specific factors that may explain this heterogeneity of causality outcomes.

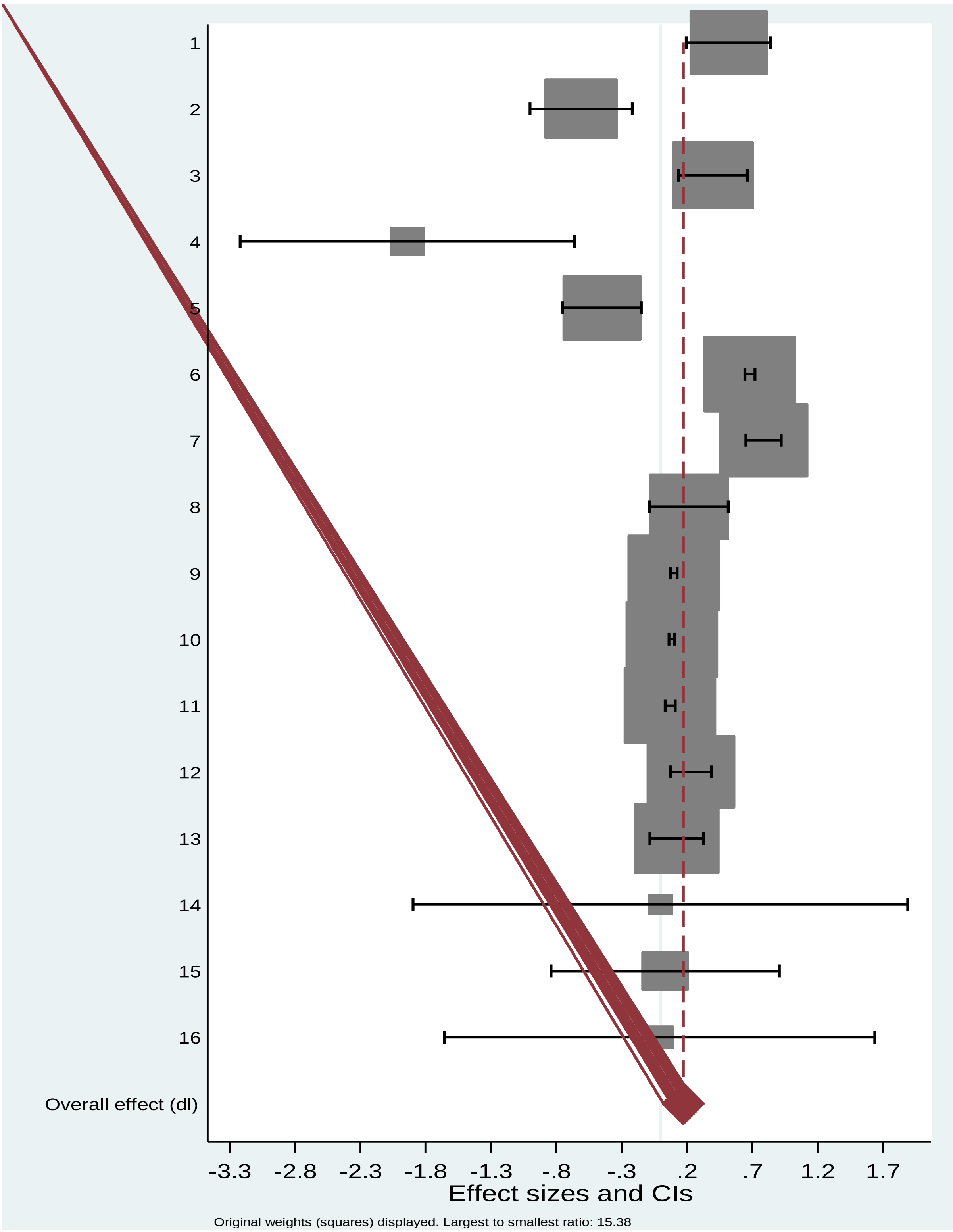
We look also at the size of the impact of electricity consumption on growth for those studies that estimate or assume a direct causality, and that report elasticities that can be compared across studies. The random effects estimate of the overall effect is positive and statistically significant, suggesting that a one per cent increase on electricity consumption leads to an increase of 0.17 per cent of the GDP. This is a substantial effect, however, subject to the caveat about the direction of causality.

In terms of the existing studies, these findings suggest the need for more research that analyses how different study designs impact causality results. The example of Malaysia discussed above is a clear illustration of the problems of using different study designs and how different studies on the same country find three different causality outcomes in similar periods.

The implications of these results for policy are, however, not obvious and do not facilitate the adoption of specific electrification policies. Perhaps the most important element that transpires from these results is the need for electrification projects to not assume the ‘growth’ hypothesis that electricity consumption cause growth, and consider that some reverse causality is also possible.

Overall and looking at the reviewed evidence, the answer to the link between electricity consumption and economic growth remains largely inconclusive.

Figure 27 Forest plot random effects approach



6 Discussion: evidence-based causal chain linking investments in renewable electricity capacity to poverty impacts

The principal aim of this literature review is to provide donors with evidence-based policy advice on how to better target renewable electricity capacity investments to maximise their impact on poverty reduction. Our review can also inform how to evaluate ex-post the poverty impacts of power generation investments. To do so, we have made explicit the different links of the causal chain that connect renewable electricity capacity to poverty impacts and presented the evidence on the existence of these links and the size of the impacts. This section on discussion aims at operationalising the previous findings by introducing the key elements of a methodology for an ex-ante and ex-post evaluation of poverty impacts of generation capacity.

6.1 Methodology for ex-ante evaluation of poverty impacts of generation capacity

The proposed methodology is illustrated in Figure 28. The figure shows each link of the causal chain between new electricity generation capacity and poverty impacts, as well as the proposed methodology to assess impacts of each link and potential policy interventions to maximise impacts for the poor. The budgetary needs to carry out this additional research will need to be weighed up against the potential impact of improved policy design for increased benefits for the poor.

Each of the steps of the methodology to be developed is further described below.

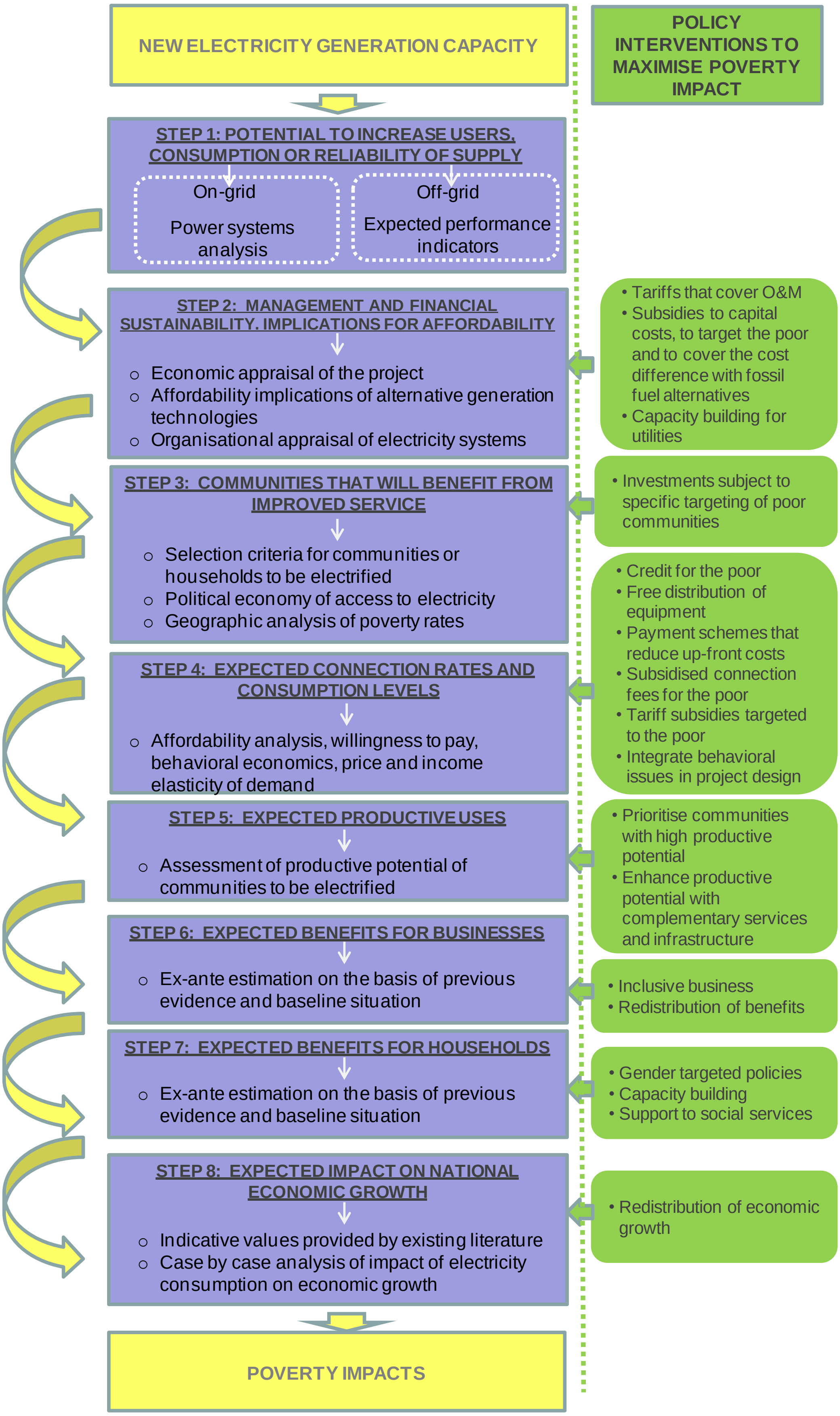
STEP 1: Potential of the future project to increase the number of electricity users, their consumption or the reliability of supply: power systems reliability analysis

Expected technical performance indicators are required for both on-grid and off-grid generation projects. They enable an assessment of the expected improvement in supply of electricity attributable to the project.

Power systems analysis is required for an assessment of the expected impact of the on-grid generation capacity project on the performance of the power system it feeds. The modelling approach is described in Section 5.1 about the synthesis for question A. 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:

- Expected additional number of users/households the new project can feed
- Expected additional final electricity consumption (kWh)
- Loss of Load Expectation (mean number of periods in a year in which the system cannot meet all demand)
- Expected number of forced outages and outage duration
- Availability of electricity (number of hours per day)
- Quality of the electricity supplied (voltage and frequency fluctuation)
- Peak power availability (kW)

Figure 28 Methodology for ex-ante evaluation of poverty impacts of generation capacity



Main data requirements to perform power systems analysis include: location of the new generation plant in relationship to centres of demand; number of consumers; distribution of demand through the day/week/year; layout, capacity and reliability properties of the transmission and distribution systems; statistics of available renewable resource at different times of day/week/year. Power systems analysis will allow the prediction of the expected impact of increased renewable capacity on the quantity and reliability of supply provided to the poor. It will also help identify the weak links in the system.

Expected performance indicators should also be provided for off-grid projects, including: number of households supplied; nominal system voltage; nominal power (kWp); availability of electricity (number of hours per day), expected life of the system.

STEP 2: Management and financial sustainability analysis: implications for affordability

Evidence shows that financial sustainability contributes to ensuring long-term quality and reliability of supply. Even though subsidies are likely to be required to cover upfront investments in generation capacity, expected revenues should be high enough to cover operation and maintenance costs in the long term. The business case for new renewable energy generation capacity in developing countries should therefore include an economic appraisal of the project during its lifetime, to make sure that expected revenues will cover at least the cost of operation and maintenance of the plant.

A fine balance between financial sustainability and affordability for the poor should be achieved to maximise the poverty impact of investments in renewable energy generation capacity, whose costs are often higher than for fossil-fuel alternatives. There are also major differences in cost between different renewable technologies, and between on-grid and off-grid solutions. The proposed ex-ante assessment tool should try to capture these cost differences and their impact on affordability for the poor, so that the cost of achieving benefits for the poor through different forms of electricity could be assessed. Therefore, alternative energy options (where they exist) should also be valued. This need not be particularly onerous if sensible suggestions of proxy values are to be used.

The quality of the management of the power system will also determine the long-term sustainability of the service provided. Policy can contribute with capacity building to improve management skills of the national organisations dealing with generation, transmission and distribution.

STEP 3: Which communities will benefit from the improved supply? Analysis of selection criteria of communities for electrification and political economy analysis of access to electricity

Off-grid projects should explicitly detail their selection criteria for the communities to be electrified.

The identification of communities likely to benefit from improved supply to the grid should be done in coordination with the national utilities providing transmission and distribution services. Improved supply can either provide an improved service to existing customers, enable further connections in already electrified communities (intensification of access) or enable the electrification of communities currently not served by the grid. Only the third option would require grid extension. Grid extension plans can also follow different criteria, mainly cost-effectiveness, which involves extending the grid to communities where it is less costly to do so (close to the current grid, densely populated, high average income), or for social allocation (explicitly targeting deprived or remote communities).

A political economy analysis of access to electricity will also be required to gain an in-depth understanding of who and why gets access beyond publicly available selection criteria, and to understand the transaction costs of connection resulting from bureaucratic and political issues.

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. Hence, the impact of electrification strategies for the poor will depend on whether most of them already have a grid connection, in which case improving reliability for connected users is the best option; they don't have a grid connection but are mostly located in electrified communities, in which case intensification strategies would be the most effective; or they are located in unelectrified communities, and then extensification strategies are the most appropriate.

Policy can contribute to targeting the poor through new electrification projects by making investments in new generation capacity subject to the provision of improved services for the poor through improved reliability, grid intensification or extensification strategies, depending on where the poor are located in the host country.

STEP 4: Expected connection rates and consumption levels: affordability analysis, willingness-to-pay, price-elasticity of demand, behavioural economics

Once electricity reaches a community, the poor may be left behind if they are not able to afford connection rates, appliances or consumption tariffs.

Evidence shows that income and upfront costs are the most significant barriers to increased connection rates among the poor. An analysis of the affordability of electricity for the communities likely to benefit from the improved service can inform policymakers as regards the expected connection rates. Poor households' income should be compared to the cost of electricity including connection rates, internal wiring, basic appliances and the electricity consumption bill. An acceptable threshold level should be decided for the share of income that is spent on electricity. Some publications also use expenditures on alternative energy sources previously to the introduction of electricity as an indication of affordability.

Once households and businesses connect to the grid or purchase off-grid systems, their consumption levels may still remain disappointingly low for a number of reasons. Evidence shows that the most important barriers to increased consumption levels are the quality and reliability of supply, the income level of consumers, the cost of appliances, the electricity tariffs, the lack of productive uses, the lack of control over the monthly bill, the lack of knowledge about the economic and productive benefits of electricity, as well as deeply engrained habits of using specific energy sources for cooking and lighting.

The affordability analysis will indicate if low consumption could be expected as a result of poor people's inability to pay for the service. Evidence shows that there is willingness to pay for high-quality and affordable electricity services at prices that can cover operation and maintenance costs. A fine balance must be found between affordability and financial sustainability of electricity provision. Studies of the price elasticity of electricity demand show that demand is expected to decrease as a result of price increases, but in a lower percentage than price increases. That is to say that electricity consumption is price-inelastic and could withstand some price increases to achieve financial sustainability.

Lack of productive uses is another fundamental reason why electricity consumption levels remain very low among the poor. Due to the importance of this issue, it will be treated in another step of the methodology.

Lack of skills in the form of how to use electric equipment or handle electricity in general has also been identified as a cause of low consumption.

Conclusions regarding behavioural decisions, including intra-household dynamics, are largely missing in the literature. Some behavioural causes for low consumption described in the literature include deeply engrained habits of using specific energy sources for cooking or manual work for productive tasks; or the lack of control over the monthly bill, which can be perceived as a risk and sometimes prevents the optimisation of electricity consumption levels for the poor. Additional aspects should be taken into account in a behavioural analysis. 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 participation. Understanding how to measure preferences can be adopted from the literature on household preferences to adopt a new technology; although this is not perfectly analogous to the decision to connect to or consume electricity, lab-in-the-field behavioural games such as the dictator game, ultimatum game, accept/reject lotteries, choose lotteries, etc. may help identify individual and household preferences that are unique in each community.

Policy can contribute to increased connection rates and consumption levels through the facilitation of credit for the poor, free distribution of productive equipment or household appliances, introduction of business models that reduce upfront costs for the poor (i.e. lease to buy or fee-for service), subsidised connection fees (particularly for late connectors) or payment of connection fees in several instalments. Low consumption levels by the poor in particular can also be improved by targeting subsidies to the poor as opposed to flat tariffs for all that tend to benefit the better off. The poor are thought to have a higher discount rate, which should be taken into account in order to design optimal subsidies. Capacity building, along with entrepreneurial support can improve knowledge on how to use the connection productively in order to achieve maximum development impact, long-term sustainability and create opportunities for growth.

STEP 5: Expected productive uses of electricity: Assessment of productive potential of communities to be electrified

Evidence has consistently shown that the lack of productive uses is one of the reasons why consumption levels remain low and why electrification has a low income generation impact. An assessment of the productive potential of the communities to be electrified could therefore inform investors about the income generation and hence poverty reduction potential of new generation projects. Evidence shows that communities most likely to use electricity for productive activities are those with:

- Large local purchasing power
- Access to external markets (both physical access through roads and telecommunications and knowledge-related access)
- Skilled local entrepreneurs capable of preparing robust business plans for the investment in electric equipment, to take up new technologies and innovate to produce better quality products
- Solid pre-existing industry, agriculture and services activities at all levels (micro, SMEs and large enterprises)
- Access to exploitable resources such as agriculture or tourism
- Community to be electrified is an articulation node to other communities (i.e. trading centres)

An assessment of the productive potential should include these and potentially other factors.

Two main policies can be followed to encourage productive uses of electricity. One would consist of prioritising communities meeting the criteria above for the provision of electricity. Another would involve enhancing the potential of areas with lower economic potential. Some supportive policies could include: 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 electricity 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.

STEP 6: Expected benefits from businesses' consumption

On the basis of the productive potential of the communities to be electrified, the expected benefits of electricity for businesses include: the creation of enterprises; increased revenues, increased productivity; increased firm profits; or increased employment. A methodology to evaluate the impacts of electricity provision for the poor should estimate the expected impacts on these indicators from a baseline situation.

Previous evidence has shown more robust benefits for non-farm income growth than for farm-income and income as a whole. Positive impacts of electricity on women's employment have also been identified by several robust studies. Estimations of impacts of electricity for productive activities will need to be provided case by case, given the diversity of results in the existing literature.

STEP 7: Expected benefits from households' consumption

Electrification can provide both income and non-income benefits for households. Income benefits are related to the use of electricity for productive activities. The potential for productive usage is assessed in the two previous steps of the causal chain. If consumption levels are high enough to provide enough energy services for households, and on the basis of the findings of the literature reviewed that addresses causality, it is expected that electrification will achieve significant benefits for the poor as regards:

- Education: measured as years of schooling completed, study time per day, school enrolment, with higher benefit for girls than boys.
- Time allocation and household productivity: with women in particular dedicating more time to entertainment, education and paid work instead of domestic tasks.
- Women's empowerment, in regards to their participation in household decision-making.

Quantitative ranges are provided by the literature review and can be indicative of the values to be expected by future electrification projects. These values are synthesised in Section 5.3.2.2.

Some of the studies reviewed provide a monetary value of the consumer benefits from electricity, with household annual benefits estimated as US$600 by the World Bank (2008b), which could be used as indicative for future electrification projects.

Descriptive literature also widely reports improvements in quality of life and comfort for the poor; communications and access to information, energy cost savings, health, improved social services, safety and social interaction.

Policy can improve the benefits of electricity for the poor once sufficient consumption levels are in place through gender-targeted policies that promote the uses that improve the quality of life of women and girls; capacity building on the uses and benefits of electricity; and support to the improvement of social services.

STEP 8: Expected impact of electricity consumption on national economic growth

The review of the evidence of impacts of electricity consumption for economic growth at the national level is not conclusive on the direction of causality. It is not clear if electricity consumption causes economic growth or the other way round. Some studies also find bidirectional causality or no causality at all. The majority of studies show either causality for electricity consumption to economic growth (33 per cent of studies reviewed) or bidirectional causality (30 per cent of studies). Regarding the size of the impact, evidence suggests that a 1 per cent increase in electricity consumption leads to a 0.17 per cent of GDP. These figures could be used as indicative of the potential of new electricity generation projects to promote economic growth in their host countries. However, given the diversity of results in the existing literature, a case-by-case analysis is recommended to provide more robust estimates of the expected economic growth impacts facilitated by new electricity generation projects. Distributional issues should also be taken into account before drawing conclusions on the impact of economic growth for the poor.

6.2 Methodology for ex-post evaluation of poverty impacts of generation capacity

Development programmes should be designed to optimally affect the desired outcomes; in the case of poverty reduction impacts through increased renewable generation capacity, the programme is aimed at improving the overall welfare of a poor population, through factors such as improved lighting and communication facilities, reduced health risks due to lower indoor pollution and income generation through the productive use of electricity. Assessing whether this has been achieved, and to what extent the outcomes are attributable to the project's intervention alone, is important policy information. In contrast to monitoring and evaluation, which is meant to track the progress of direct inputs and direct outputs of the programme – for example, how many people have been given access to electricity – impact evaluations measure how inputs are linked to outcomes and results. Although the process of an impact evaluation starts before the project, they are referred to as 'ex-post evaluations' as the effectiveness and impact of the programme can only be assessed fully once it has been completed. Ex-post evaluations typically measure the average impact of the programme on the welfare of the beneficiaries that is attributable causally to the programme. Assessing the effectiveness of a programme quantitatively through a robust ex-post evaluation is important not only to enhance accountability, but to guide policy decisions so that budgets are allocated more efficiently to achieve programme scalability by ensuring not only cost-effectiveness but also sustainability.

Not all projects are suitable for an ex-post impact evaluation, as they are costly, difficult to execute successfully and therefore risky, and it is often difficult to establish causality. Hence, before embarking on an impact evaluation, it must first be assessed whether the project is suitable for evaluation by estimating if the stakes of the programme will be large enough to assess and if the project affects a sufficiently large number of people to make a causal inference. According to the World Bank's Impact Evaluation guide (Khandker *et al*. 2010), a programme should only be evaluated if it is testing a new approach and is replicable, strategically relevant, untested in the community, and influential.

As mentioned throughout the literature review, the current quantity and quality of robust impact evaluations of increased renewable generation is extremely limited. Donors and researchers should take advantage of the need for evidence-based policy advice by improving the quality of the ex-post impact evaluations which will lead to more robust results aimed at improving the outcomes of current and future projects. This detailed literature review can support evaluators mainly in the following three stages of the process: a) posing the right research question; b) creating a rigorous impact evaluation strategy that includes valid treatment and control groups, thus far rare in the literature; and c) providing advice on the needed indicators for the baseline and subsequent questionnaires for the impact evaluation which cover the different links of the causal chain joining generation capacity to poverty impacts. We refer readers to the World Bank's Impact Evaluation guide for step-by-step implementation guidelines for any robust impact evaluation in the developing country context (Khandker *et al*. 2010). Recommendations for the three steps of an impact evaluation that can most benefit from the results of this literature review are provided below.

Pose the right research question

To construct an evaluation, a clear research question must be formulated prior to the start of the project. This should be a participatory process and involve key stakeholders including government entities, NGOs, civil society, and community members to form a common vision of the project and to understand exactly which benefits the electricity access is expected to provide to the beneficiaries and how it should be achieved. Specifically, *what is the impact of the programme on an outcome of interest?* The programme administrators should work with the stakeholders to clearly define the outcomes of interest, i.e. the causal links to be studied, as these will inform the methodological design of the study.

It is crucial to consider from the beginning of the project which of the links in the casual chain we identified in this review the programme implementers wish to influence. It is also important to understand that certain questions within the causal chain cannot be answered by an ex-post impact evaluation. Ex-post impact evaluations can answer questions pertaining only to the specific programme tested; they estimate whether the intervention worked in the households it targeted and to what extent. It can neither answer why it did not work, nor whether it would have been more effective if instead it had been implemented in a slightly different way. For answers to many of these questions, qualitative evaluations must be conducted. It is also important to realise that answers to many questions within the casual chain should have been provided by the ex-ante evaluation, as well as technical reviews and financial sustainability analyses completed before the project begins. In any ex-post impact evaluation, it is always best practice to conduct not only ex-ante evaluations but also qualitative studies alongside the quantitative study as many reasons why a project failed cannot be explained by statistics alone, but rather by processes that failed at each step in the causal chain.

A suggestion of questions that can address the different steps of the causal chain in an impact evaluation follows suit.

The first causal link refers to the relationship between increased renewable energy generation capacity and higher availability and reliability of supply. The state of the transmission and distribution system and other aspects such as the location of demand should have been analysed as part of the ex-ante evaluation at the planning stage of on-grid projects. An ex-post evaluation could complement findings at the planning stage by responding to the following questions:

- Are mini/micro-grids better or worse than grid extensions to meet rural demand? i.e. whether off-grid systems at least match or better exceed the reliability and quality of grid connections. So long as both treatments are compared to a valid control community, programme implementers can test the two system options in a pilot study before implementing a much larger project that covers a greater geographic area.
- What is the cost of electricity supply reliability? This would involve measuring the different demand responses to, for example, an upgrade to the transmission system only, an upgrade to the generation capacity only, or concurrent upgrades to the system as a whole. Using this data, together with information of ex-ante versus ex-post reliability and power quality, as well as observed welfare effects, an estimate of

the true economic cost of electricity grid reliability in developing countries could be achieved, something that, as mentioned in the ex-ante review, is currently not well studied in the literature.
- What is the effectiveness of different policy instruments to improve the financial sustainability and the management performance of utilities?

The second step in the causal link looks at the relationship between higher availability and reliability of electricity and increased connection rates and actual consumption by households and firms. As with Causal Link A, many of the questions will be answered by technical studies conducted prior to the programme start, aiming to understand budget constraints of households in the communities that might be connected, as well as behavioural questionnaires to understand how customers view the reliability of the electricity supply, as well as to identify risk and time preferences, all of which are well documented in Step 4 of the Ex-Ante Evaluation. Household questionnaires used for the impact evaluation can also help to identify answers to sub-questions within this link such as the type and quantity of electrical appliances used and equipment in the household.

However, many of the policy interventions suggested under Step 4 of the ex-ante methodology can be tested with an ex-post evaluation. Some relevant research questions include:

- Which encouragement design has the greatest impact to either attract new customers or encourage greater consumption of existing customers? The impact evaluation could implement a multi-arm treatment approach to encourage communities to increase electricity consumption based on different approaches in each community such as providing different types of subsidies and payment options for tariffs and connection fees, advertising in the community or public awareness campaign. So long as at least one control group does not receive treatment, the various approaches can be tested and compared across all treatments and controls.
- Does providing electrical equipment in addition to the grid connection increase connection rates in the community and consumption in the household or enterprise? This could also be tested with a multi-arm treatment. The question could be answered by providing at least one treatment community with free electrical equipment and comparing it against the communities who received the connection but not the equipment, and then all compared against the control communities.
- Are training programmes on how to use electrical household or productive appliances effective in increasing connection rates and consumption levels? Training should be implemented again through a multi-treatment arm, where some treatment communities receive no training, whereas other communities receive the training and all are compared against the control community.

The third causal link is concerned with the impacts of electricity consumption for the poor once households and firms get a connection and start consuming electricity. Understanding the causal link between electricity consumption and development benefits for poor households is exactly the question that an ex-post impact evaluation can adequately measure. The relationship between electricity consumption and poverty is of great interest and the expected benefits for business and for households will be studied through the ex-ante evaluation via Step 6 and Step 7, respectively. However, very few robust quantitative ex-post studies currently exist, mostly because valid treatment and control communities were not established. However, when implemented correctly, ex-post impact evaluations have the ability to provide evidence of a causal relationship between electricity consumption and realised benefits to businesses and households.

Some questions of interest in an ex-post evaluation are:

- Which interventions are effective in promoting productive uses of electricity? These could include business support services, comprehensive development programmes that address the provision of other infrastructures in addition to electricity, training or provision of productive equipment.
- What is the causal effect of electricity consumption on: creation of microenterprises; employment levels in businesses; business revenues?
- What is the causal effect of electricity consumption on: availability and quality of health care providers; quality and availability of school teachers; test scores of children; education attainment levels of children; employability of graduating students; and crime rates in the community?
- What is the causal effect of electricity consumption on: education; productivity in the household; time allocation; labour choice outcomes; household income; household health; fertility; and gender equality?
- What are the benefits of electricity for women in particular? Impact evaluations studying benefits for women in particular are very rare. Large-scale household surveys, use of experimental and quasi-experimental designs and careful consideration of covariates are required to detect gender differences. Part 2 of this section will highlight the methods that have been employed so far in the papers addressing causality and offer guidance for how to design a more robust evaluation.

The last link in the causal chain about the relationship between electricity capacity or consumption and economic growth at a macro level should not be evaluated through an ex-post impact evaluation. An ex-post impact evaluation is a tool to understand casual links at the micro level, that is, within households and communities where the project is directly targeted. Very rarely do ex-post impact evaluations offer external validity, and even when they do, the economic benefits attributed to the community from the project cannot then be aggregated at the macro level. Meta-analysis of multiple ex-post evaluations conducted within one country but in different regions may provide insights on transmission mechanisms of electrification projects on macro level indicators, but causal inferences are limited.

Develop a robust evaluation strategy through selection of valid treatment and control groups

In order to attribute changes in outcomes after the project's completion, a valid control and treatment group must be identified to ensure internal validity which will establish causality through a counterfactual. The control group must be a community that is identical in all observable and unobservable characteristics to the treated community, except that they do not receive the project intervention, i.e. access to electricity. Comparability between the treatment and control communities is measured through statistical analysis of observable characteristics collected by the baseline survey.

The control group must not be affected by the project intervention or through any spillover mechanism from the treatment. Likewise, the control group should also be isolated from similar policy interventions, such as another electrification project by a different donor that may be occurring simultaneously of the said project. Often, it is unethical or operationally impossible to provide treatment to one group of households and deny it to the other group of households.

Sample sizes of the treatments and controls are also crucial to determine; power calculations must be completed to determine the number of treatment and control groups that is large enough, while still cost-effective, to ensure that any differences in outcomes observed of the groups can be detected with high statistical significance and thus be empirically robust. This calculation should consider that many households may be unwilling to connect once given access and thus include more treatment and control groups than would otherwise be needed to allow for this attrition. It is helpful to note that a straight comparison of those in the community where access to electricity was provided versus a control community where it was not provided will yield the '*intention-to-treat' estimate (ITT),* which is relevant as most policy makers can only offer a programme or project but not force connection upon the target population. However, it is also important to analyse the impact of those who connected to the grid once it was established. The '*treatment-on-the-treated' (TOT)* estimates the impact of the programme on those to whom the treatment was offered and who actually used electricity.

As mentioned in the literature review, Randomised Control Trials (RCTs) are a well-established form of experimental research and are considered the gold standard. However, the poverty impacts of access to electricity have not been studied with this approach due to the difficulty of randomly allocating access to electricity. As of now, the most robust studies available and discussed in this report use quasi-experimental approaches such as using propensity score matching techniques to create plausible control groups or instrumental variables estimation to correct for selection bias. Appendix 9 provides more detailed guidelines on how to design an ex-post impact evaluation in the most robust way through selection of valid treatment and control groups, as well as less robust options, in order of descending robustness, for cases in which randomisation is difficult or impossible to establish.

Include the necessary questions in the baseline and endline survey to measure the impact of interest

Before the project begins, a baseline survey must be carried out which collects information on a sample of the population, which will be followed up by the same questionnaire administered to the same sample but conducted at the end of the project. The differences in outcomes will measure the impact of interest. The survey must also collect enough information to assess confounding factors, for example factors that may be causing benefits for the poor apart from access to electricity. It is important to survey different units such as households, communities, business and community facilities, at various stages of the evaluation cycle including at least the baseline and the endline, but also potentially a mid-term evaluation, to assess if any changes need to be made, so long as budget allows. The survey should be piloted in households to test the sensitivity of question and answer options to ensure it follows the local context.

A3 included in Appendix 10 provides a comprehensive list of criteria and indicators that could be included in a baseline and endline survey for an electrification project looking to achieve poverty impacts. It is based on the evidence provided by this literature review as regards the pre-existing conditions that give place to different impacts of electrification in different communities.

It is of utmost importance to consider which information is relevant for the evaluation of interest. In general, any survey for an ex-post impact evaluation on access and consumption of electricity should include questions on household characteristics, including modules on education, health, employment, migration, anthropometry, fertility, housing, agriculture, household enterprises, income, consumption, expenditures, ownership of durable goods, environmental sensitivity, and savings and credit, all disaggregated by gender.

Information also must be gathered on supply of fuels and electricity used in the household for cooking and heating including pricing, quality, and reliability, as well as the demand including quantities consumed. Questions on availability of alternatives to grid electricity such as diesel generators, photovoltaic solar home systems, and car batteries should be captured including expenditures for acquiring and operating them. In areas where biomass is used for cooking or heating, time use questions are necessary to determine the time burden of collecting biomass. The questionnaire should also identify in detail the end-uses for various primary energy sources in order to quantify the benefits obtained by switching fuel to electricity for different uses. The baseline survey should also collect information on the household's level of choice in energy services, such as the determining factors of fuel choice and consumption levels. This information can then be used to estimate and quantify willingness to pay for electricity. The endline survey should include questions on the quality and reliability of supply. Behavioural questions are also crucial to include, such as knowledge and preferences of electrical equipment, perceptions on price, feeling of control over monthly bill, questions on social benefits such as inclusion in community, etc.

A community characteristics questionnaire is also important and should include modules on schools, health facilities, agricultural practices and infrastructure such as roads, fuel sources, electricity and water. It typically also asks community leaders and groups about available services, natural resource allocation, economic activities, access to markets, and social capital. Often, a questionnaire is also administered to local service providers, such as schools and health clinics, and which includes questions similar to the household modules on energy and electricity sources. In regard to the household survey and community survey, the World Bank Living Standards Measurement Survey (LSMS) provides a benchmark model to construct a baseline survey. Just recently, new modules were introduced to incorporate questions on energy supply and demand.

In general, it must be remembered that the baseline survey not only sets the temporal baseline for the data but also determines which impacts can be evaluated after the endline survey. Once the project is underway it is no longer possible to add further questions, i.e. variables, to the baseline. As a result it is of utmost importance to design the baseline survey carefully, especially considering that simply asking every conceivably relevant question is also not realistic as this will make the survey impractical, in relation to time and cost, to conduct. Finding this balance between practicability and completeness is therefore arguably the most critical step in the design of the survey.

7 Conclusions and recommendations

This review has commented on the available literature on the links between electricity generation capacity and benefits for the poor with the intention of supporting DFID's planning of investments through the ICF in low-carbon generation capacity in developing countries.

The review has analysed a large and diverse range of literature dealing with the poverty impacts of increased generation capacity. A total of 143 studies were reviewed in detail. For the sake of clarity and according to a realist review approach, the work started with the elucidation of a theory to break down the causal chain between the intervention (electricity generation capacity) and its expected impact (benefits for the poor) in several stages. Four different links of stages were defined: A. Relationship between increased generation capacity and higher availability and reliability of supply; B. Relationship between higher availability and reliability of supply and increased connection and consumption by households and businesses; C. Relationship between electricity consumption and poverty impacts; and D. Relationship between electricity consumption and economic growth at the macro level. Only literature analysing developing countries was taken into account.

Technical evidence for link A. of the causal chain is very thin. Power systems reliability analysis in developing countries remains an area where methods need to be developed based on a combination of the literature on assessments in developed countries and expertise in general statistical and probabilistic modelling. There are two key differences between power systems reliability assessments in developing and developed countries which will need to be considered when designing methodologies. The first relates to data availability, particularly about the state of transmission and distribution networks, number of consumers or available renewable energy resources at different times of day/week/year. The second difference relates to the design of reliability indices, as in developed countries these are based on the premise that all customers receive all of their demand almost all of the time, whereas in developing countries there may be no times at which all demand can be supplied. Therefore, in developing countries measurements could refer to the value of having supply at a particular time instead of the cost of interruptions. A future collaborative study between Durham University, IDS, ISSER (Ghana) and KIPPRA (Kenya)[17] aims to develop power systems reliability analysis methodologies widely applicable across developing countries. This future project will allow new reliability and value-of-supply metrics for developing countries to be specified, based on the available data and applied problems supplied by our African partners.

In addition to technical factors, economic and political factors play a significant role in determining who gets access to electricity when generation capacity is increased. The imperative of cost recovery may involve the prioritisation of communities with high average income, densely populated and close to the grid. Politics and interests also intervene in who and why gets access to electricity. The application of a political economy framework which looks at how actors, interest and institutions implement electrification initiatives is therefore of critical importance beyond the assessment of publicly available criteria for the selection of communities to receive improved electricity supply. Governments, NGOs and businesses increasingly recognise the importance of understanding and negotiating the political landscape of actors and interests into which funding is provided. This is crucial for identifying and working with change agents interested in energy access as well as locating areas of resistance and areas of weak governance which may inhibit or undermine effective realisation of the objectives of climate financing mechanisms. Therefore we propose that DFID applies a political economy framework in the countries where it invests in renewable

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[17] DFID/EPSRC funded project on 'Green Growth Diagnostics for Africa'.

energy capacity, which seeks to map and understand the interests and power of key actors and the ways they make sense of climate finance in relation to their own priorities and ways of working.

Literature for link B of the causal chain is mostly focused on connection of households and consumption, with a very small share of the literature looking at factors influencing the connection and consumption of businesses. Evidence strongly suggests that low income of the poor and high upfront costs are preventing higher connection rates in developing countries, even after communities become electrified. Once households and businesses gain access, consumption levels may remain low as a result of low availability and reliability of supply, low income, unaffordability of electric appliances or monthly bills, lack of control over monthly bills or lack of productive uses. Several studies reviewed estimate own-price, cross-price and income elasticities of electricity demand, concluding that electricity is price and income inelastic and that cross price elasticities with alternative energy sources are almost non-existent or non-significant. The evidence reviewed points at the need of electricity suppliers to pay further attention to affordability of electricity for the poor. This needs to be balanced with cost recovery to ensure that quality and reliability of supply are sustainable in the long term. Several policy interventions can address this, including connection subsidies for the poor, business models that enable payments for electricity services instead of requiring upfront payments, access to credit for the purchase of appliances or the payment of connection rates, prepaid meters to overcome of the lack of control over monthly bills, free distribution of appliances, or information campaigns. Conclusions regarding behavioural decisions are largely missing in the literature and as part of our discussion we recommend that these are taken into account in a future methodology to maximise the poverty impact of investments in electricity generation capacity.

Literature on link C of the causal chain is the largest and most diverse, with 60 per cent of the reviewed studies. As with literature on link B, households are more widely covered than businesses. Only 21 per cent of the studies reviewed address the issue of causality and hence use appropriate methodologies that allow the attribution of observed benefits to electricity instead of to other factors. Robust evidence of impacts of electricity for the poor is quite thin, understood as that which tackles the issue of causality by correcting for selection and placement bias and taking into account the interaction of other factors. This is particularly so for evidence related to impacts of electricity for productive activities. Two main types of impacts for the poor are reported by the literature: income and non-income benefits. Income benefits are strongly related to the use of electricity for productive activities, and results are non-conclusive in this respect. Evidence shows that electricity is only one of many factors enabling the take-up of productive activities and leading to increased income for the poor. Evidence on non-income benefits for the poor is more consistent, with several studies pointing at improvements in the quality of life for the poor, and quantifying some of the benefits, mainly on education, health, time allocation, employment and gender equality. Some literature also estimates the economic value of benefits from electrification, which serves to justify rural electrification investments even if income generation is not materialised. However, evidence shows that benefits of electricity are usually mostly captured by the higher income strata of society, who can afford connection in the first place and higher consumption levels. Policy interventions can improve the take-up of productive activities enabled by electricity by providing comprehensive development plans covering other enabling factors, such as access to markets, credit for the purchase of equipment or capacity building. Electrification interventions can also maximise the income generation potential by specifically targeting communities with high productive potential. However, this must be balanced with the need to achieve benefits for the poor, who are most likely located in the most deprived communities. Policy can improve benefits at the household level through gender targeted policies and support to community services (mainly health and education).

Finally, literature on link D of the causal chain analyses the relationship between electricity consumption and economic growth at the macro level in developing countries. The literature is not conclusive about the direction of causality, with 33 per cent of studies finding causality from electricity consumption to economic growth; 30 per cent of studies finding bidirectional causality; 23 per cent of studies showing causality from economic growth to electricity consumption and 14 per cent showing no causality relationship at all. This diversity of outcomes happens even between studies analysing the same country and is due to methodological choices such as variables used, sample periods, and model specification. Six studies under this stage of the analysis look at the size of the impact of electricity consumption on growth, assuming or testing that this is the direction of causality. 16 elasticity estimates are provided, with a reported Overall Effect of 0.173, meaning that a rise of 1 per cent of electricity consumption leads to an increase of 0.17 per cent in GDP. This result must be interpreted with caution, given the lack of consensus as regards the direction of causality. Specific country studies could support DFID’s case for the support of electricity generation capacity in developing countries, if results show that electricity consumption leads to economic growth. Further research is needed to analyse how different study designs impact causality results.

Taking into account the insights of the literature reviewed, an outline has been provided for a methodology that can support DFID and other donors in their planning of electricity capacity projects that achieve high impacts for the poor. This methodology will be further developed by IDS as part of its work on pro-poor access to electricity funded by DFID’s Accountable Grant.

References

Full bibliographic reference of the included papers, question they address and overall quality rating

Full reference	A	B	C	D	Quality
Abosedra, S.; Dah, A. *et al.* (2009) ‘Electricity Consumption and Economic Growth, the Case of Lebanon’, *Applied Energy* 86.4: 429–32				X	High
African Development Bank (2011) *Benin: Project for the Electrification of 17 Rural Centres, Project Performance Evaluation Report (PPER)*, Operations Evaluation Department		X			Low
African Development Bank (2004) *Ethiopia – Northern Ethiopia Power Transmission Project, Project Performance Evaluation Report (PPER)*, August 2004, Operations Evaluation Department		X	X		Low
African Development Fund (2006) *Mozambique: Electricity II Project, Project Performance Evaluation Report, final draft report, ref: ADF/OPEV/2006/27*, October 2006		X	X		Low
Akinlo, A.E. (2009) ‘Electricity Consumption and Economic Growth in Nigeria: Evidence from Cointegration and Co-Feature Analysis’, *Journal of Policy Modelling* 31.5: 681–93			X		Low
Alazraki, R. and Haselip, J. (2007) ‘Assessing the Uptake of Small-scale Photovoltaic Electricity Production in Argentina: the PERMER Project’, *Journal of Cleaner Production* 15.2: 131–42				X	Moderate
Altinay, G. and Karagol, E. (2005) ‘Electricity Consumption and Economic Growth: Evidence from Turkey’, *Energy Economics* 27.6: 849–56			X		Moderate
Anderson, B.; Berg, M. *et al.* (2005) *Achieving The Millennium Development Goals: The Role of Energy Services. Case Studies from Brazil, Mali and Philippines,* New York: UNDP				X	Moderate
Aqeel, A. and Butt, M.S. (2001) ‘The Relationship between Energy Consumption and Economic Growth in Pakistan’, *Asia-Pacific Development Journal* 8: 101–110			X		Moderate
Arnold, J.M.; Mattoo, A. *et al.* (2006) *Services Inputs and Firm Productivity in Sub-Saharan Africa: Evidence from Firm-Level Data*, World Bank Policy Research Working Paper 4048, Washington, DC: World Bank				X	Moderate
Arthur, M.F.S.R.; Bond, C.A. *et al.* (2012) ‘Estimation of Elasticities for Domestic Energy Demand in Mozambique’, *Energy Economics* 34.2: 398–409			X		High
Asian Development Bank (ADB) (2010) *Asian Development Bank’s Assistance for Rural Electrification in Bhutan – Does Electrification*		X			High

Full reference	A	B	C	D	Quality
Improve the Quality of Rural Life?, ADB Impact Evaluation Study, August 2010, ref IES:BHU 2010-27					
Asian Development Bank (ADB) (2005) *Sector Assistance Programme Evaluation of Asian Development Bank Assistance to Philippines Power Sector*, Sector Assistance Programme Evaluation, September 2005		X	X		Moderate
Banerjee, S.G.; Singh, A. *et al.* (2011) *Power and People: The Benefits of Renewable Energy in Nepal*, Washington, DC: World Bank			X		High
Barham, T.; Lipscomb, M. *et al.* (2011) *Development Effects of Electrification: Evidence from the Geologic Placement of Hydropower Plants in Brazil,* CEPR Discussion Paper 8427, Rochester, NY: CEPR		X	X		High
Barkat, A.; Khan, S.H. *et al.* (2002) *Economic and Social Impact Evaluation Study of the Rural Electrification Programme in Bangladesh*, Dhaka: NRECA International Limited			X		Moderate
Bastakoti, B.P. (2006) 'The Electricity-Livelihood Nexus: Some Highlights from the Andhikhola Hydroelectric and Rural Electrification Centre (AHREC)', *Energy for Sustainable Development* 10.3: 26–35			X		Low
Bastakoti, B.P. (2003) 'Rural Electrification and Efforts to Create Enterprises for the Effective Use of Power', *Applied Energy* 76.1–3: 145–55			X		Moderate
Bensch, G.; Kluve, J. *et al.* (2010) *Rural Electrification in Rwanda – An Impact Assessment Using Matching Techniques*, Ruhr Economic Papers 231, Bochum, Germany: Ruhr-Universität Bochum (RUB)			X		Low
Bildirici, M.E. and Kayikçi, F. (2012) 'Economic Growth and Electricity Consumption in Former Soviet Republics', *Energy Economics* 34.3: 747–53		X	X		High
Billinton, R. and Pandey, M. (1999a) 'Generating Capacity Planning Criteria Determination for Developing Countries: Case Study of Nepal', *Generation, Transmission and Distribution, IEE Proceedings* 146.5: 491–95				X	High
Billinton, R. and Pandey, M. (1999b) 'Reliability Worth Assessment in a Developing Country – Residential Survey Results', *Power Systems, IEEE Transactions on* 14.4: 1226–31	X				High
Calderon Cockburn, J. (2005) *Social Impact Evaluation Project: 'Fund for the Promotion of Micro Hydro Power Stations (MHSP)*', Lima, Peru: Intermediate Technology Development Group and IADB	X				High
Chen, P.-Y; Chen, S.-T *et al*. (2012) 'Energy Consumption and Economic Growth – New Evidence from Meta Analysis', *Energy Policy* 44: 245–55				X	High

Full reference	A	B	C	D	Quality
Cecelski, E. and Glatt, S. (1982) *The Role of Electrification in Development*, Washington, DC: The Center for Energy Policy Research			X		Moderate
Chakrabarti, S. and Chakrabarti, S. (2002) 'Rural Electrification Programme with Solar Energy in Remote Region – A Case Study in an Island', *Energy Policy* 30.1: 33–42		X	X		Moderate
Chandran, V.G.R.; Sharma, S. *et al.* (2010) 'Electricity Consumption-Growth Nexus: The Case of Malaysia', *Energy Policy* 38.1: 606–12			X		Low
Chen, S.-T.; Kuo, H.-I. *et al.* (2007) 'The Relationship between GDP and Electricity Consumption in 10 Asian Countries', *Energy Policy* 35.4: 2611–21				X	High
Chong, A. and Ferrara, E.L. (2009) 'Television and Divorce: Evidence from Brazilian Novellas', *Journal of the European Economic Association* 7.2–3: 458–68				X	Moderate
Chowdhury, S.K. (2010) 'Impact of Infrastructures on Paid Work Opportunities and Unpaid Work Burdens on Rural Women in Bangladesh', *Journal of International Development* 22.7: 997–1017			X		High
Clancy, J.; Winther, T. *et al.* (2001) *Gender Equity in Access to and Benefits from Modern Energy and Improved Energy Technologies,* World Development Report Background Paper, ENERGIA/NORAD/World Bank			X		High
Cook, C.C.; Duncan, T. *et al.* (2005) *Assessing the Impact of Transport and Energy Infrastructure on Poverty Reduction*, Manila: Asian Development Bank			X		Low
Costa, J.; Hailu, D. *et al.* (2009) *The Implications of Water and Electricity Supply for the Time Allocation of Women in Rural Ghana*, Working Paper 59, International Policy Centre for Inclusive Growth and United Nations Development Programme			X		Moderate
D'Agostino, A.L.; Sovacool, B.K. *et al.* (2011) 'And Then What Happened? A Retrospective Appraisal of China's Renewable Energy Development Project (REDP)', *Renewable Energy* 36.11: 3154–65			X		Moderate
Daka, K.R. and Ballet, J. (2011) 'Children's Education and Home Electrification: A Case Study in Northwestern Madagascar', *Energy Policy* 39.5: 2866–74		X	X		Low
Davis, M. (1998) 'Rural Household Energy Consumption: The Effects of Access to Electricity – Evidence from South Africa', *Energy Policy* 26.3: 207–17			X		Moderate
Dube, I. (2003) 'Impact of Energy Subsidies on Energy Consumption and Supply in Zimbabwe. Do the Urban Poor Really Benefit?', *Energy Policy* 31.15: 1635–45		X			Moderate

Full reference	A	B	C	D	Quality
Dinkelman, T. (2011) 'The Effects of Rural Electrification on Employment: New Evidence from South Africa', *American Economic Review* 101.7: 3078–3108		X			Low
Dinkelman, T. and Schulhofer-Wohl, S. (2012) *Migration, Congestion Externalities, and the Evaluation of Spatial Investments*, CEPR Discussion Paper DP9126, Rochester, NY: CEPR			X		High
Ferrer-Martí, L.; Garwood, A. *et al.* (2012) 'Evaluating and Comparing Three Community Small-Scale Wind Electrification Projects', *Renewable and Sustainable Energy Reviews* 16.7: 5379–90			X		High
Filippini, M. and Pachauri, S. (2004) 'Elasticities of Electricity Demand in Urban Indian Households', *Energy Policy* 32.3: 429–36			X		Low
Ghosh, S. (2002) 'Electricity Consumption and Economic Growth in India, *Energy Policy* 30.2: 125–29		X			High
Gibson, J. and Olivia, S. (2010) 'The Effect of Infrastructure Access and Quality on Non-Farm Enterprises in Rural Indonesia', *World Development* 38.5: 717–26				X	Moderate
Golam Ahamad, M. and Nazrul Islam, A.K.M. (2011) 'Electricity Consumption and Economic Growth Nexus in Bangladesh: Revisited Evidences', *Energy Policy* 39.10: 6145–50			X		High
Gonzalez-Eiras, M. and Rossi, M. A. (2007) *The Impact of Electricity Sector Privatization on Public Health,* Research Network Working Papers R-524, Washington, DC: Inter-American Development Bank				X	Moderate
Green, D. (2004) 'Thailand's Solar White Elephants: An Analysis of Fifteen Years of Solar Battery Charging Programmes in Northern Thailand', *Energy Policy* 32: 747–60			X		High
Grimm, M.; Hartwig, R. *et al.* (2011) *How Much Does Utility Access Matter for the Performance of Small and Micro Enterprises?*, Washington, DC: World Bank			X		Moderate
Grogan, L. and Sadanand, A. (2011) 'Rural Electrification and Employment in Poor Countries: Evidence from Nicaragua', *World Development* 43, 252–65			X		Moderate
GTZ and Agenchy, N. (2010) *Energizing Development Report on Impacts*, Eschborn: GTZ			X		High
Gunther, B.; Jörg, P. *et al.* (2012) *Fear of the Dark? – How Access to Electric Lighting Affects Security Attitudes and Night Time Activities in Rural Senegal*, Ruhr Economic Papers 369, Bochum, Germany: Ruhr-Universität Bochum (RUB)			X		Low
Gurung, A.; Gurung, O.P. *et al.* (2011) 'The Potential of a Renewable Energy Technology for Rural Electrification in Nepal: A Case Study from Tangting', *Renewable Energy* 36.11: 3203–10			X		High

Full reference	A	B	C	D	Quality
Gustavsson, M. and Ellegård, A. (2004) 'The Impact of Solar Home Systems on Rural Livelihoods. Experiences from the Nyimba Energy Service Company in Zambia', *Renewable Energy* 29.7: 1059–72			X		Low
Herman, R. and Gaunt, T. (2010) 'Probabilistic Interpretation of Customer Interruption Cost (CIC) Applied to South African Systems', 2010 IEEE 11th International Conference on Probabilistic Methods Applied to Power Systems (PMAPS), 14–17 June			X		Low
Herrin, A.N. (1983) *The Cagayan Valley Rural Electrification Project: An Impact Assessment*, Working Paper 83-04, Makati City: Philippine Institute of Development Studies	X				High
Hong, G.W. and Abe, N. (2012) 'Sustainability Assessment of Renewable Energy Projects for Off-Grid Rural Electrification: The Pangan – An Island Case in the Philippines', *Renewable and Sustainable Energy Reviews* 16.1: 54–64			X		High
Hosier, R.H. and Kipondya, W. (1993) 'Urban Household Energy Use in Tanzania: Prices, Substitutes and Poverty', *Energy Policy* 21: 454–73		X	X		Moderate
Ilskog, E. and Kjellström, B. (2008) 'And Then They Lived Sustainably Ever After? – Assessment of Rural Electrification Cases by Means of Indicators', *Energy Policy* 36.7: 2674–84		X			Moderate
Ilskog, E.; Kjellström, B. *et al.* (2005) 'Electrification Co-Operatives Bring New Light to Rural Tanzania', *Energy Policy* 33.10: 1299–1307		X			Moderate
Institute of Development Studies (2003) *Energy, Poverty and Gender: a Review of the Evidence and Case Studies in Rural China, A Report for the World Bank*, Brighton: IDS		X			Moderate
Jacobson, A. (2007) 'Connective Power: Solar Electrification and Social Change in Kenya', *World Development* 35.1: 144–62			X		Moderate
Jahangir Alam, M.; Ara Begum, I. *et al.* (2012) 'Energy Consumption, Carbon Emissions and Economic Growth Nexus in Bangladesh: Cointegration and Dynamic Causality Analysis', *Energy Policy* 45.C: 217–25		X	X		Moderate
Jamil, F. and Ahmad, E. (2010) 'The Relationship between Electricity Consumption, Electricity Prices and GDP in Pakistan', *Energy Policy* 38.10: 6016–25				X	Moderate
Jensen, R. and Oster, E. (2009) 'The Power of TV: Cable Television and Women's Status in India', *The Quarterly Journal of Economics* 124.3: 1057–94				X	High
Jumbe, C.B.L. (2004) 'Cointegration and Causality between Electricity Consumption and GDP: Empirical Evidence from Malawi', *Energy Economics* 26.1: 61–68			X		High

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Karekezi, S. and Majoro, L. (2002) 'Improving Modern Energy Services for Africa's Urban Poor', *Energy Policy* 30.11–12: 1015–28				X	High
Kebede, B.; Bekele, A. *et al.* (2002) 'Can the Urban Poor Afford Modern Energy? The Case of Ethiopia', *Energy Policy* 30.11–12: 1029–45		X	X		Low
Kemmler, A. (2007) 'Factors Influencing Household Access to Electricity in India', *Energy for Sustainable Development* 11.4: 13–20		X			High
Ketlogetswe, C.; Mothudi, T.H. *et al.* (2007) 'Effectiveness of Botswana's Policy on Rural Electrification', *Energy Policy* 35.2: 1330–37		X			Low
Khandker, S.R.; Barnes, D.F. *et al.* (2009a) *Welfare Impact of Rural Electrification: a Case Study from Bangladesh*, Policy Research Working Paper 4859, Washington, DC: World Bank		X			Low
Khandker, S.R.; Barnes, D.F. *et al.* (2009b) *Welfare Impact of Rural Electrification: Evidence from Vietnam*, Policy Research Working Paper 5057, Washington, DC: World Bank		X	X		High
Khandker, S.R.; Samad, H.A. *et al.* (2012) *Who Benefits Most from Rural Electrification?: Evidence in India*, Policy Research Working Paper 6095, Washington, DC: World Bank		X	X		High
Kirubi, C.; Jacobson, A. *et al.* (2009) 'Community-Based Electric Micro-Grids Can Contribute to Rural Development: Evidence from Kenya', *World Development* 37.7: 1208–21		X	X		High
Komatsu, S.; Kaneko, S. *et al.* (2011a) 'Are Micro-Benefits Negligible? The Implications of the Rapid Expansion of Solar Home Systems (SHS) in Rural Bangladesh for Sustainable Development', *Energy Policy* 39.7: 4022–31			X		High
Komatsu, S.; Kaneko, S. *et al.* (2011b) 'Non-Income Factors Behind the Purchase Decisions of Solar Home Systems in Rural Bangladesh', *Energy for Sustainable Development* 15.3: 284–92		X	X		Moderate
Kooijman-van Dijk, A.L. (2012) 'The Role of Energy in Creating Opportunities for Income Generation in the Indian Himalayas', *Energy Policy* 41.C: 529–36		X	X		Moderate
Kooijman-van Dijk, A.L. and Clancy, J. (2010) 'Impacts of Electricity Access to Rural Enterprises in Bolivia, Tanzania and Vietnam', *Energy for Sustainable Development* 14.1: 14–21			X		Moderate
Kouakou, A.K. (2011) 'Economic Growth and Electricity Consumption in Côte d'Ivoire: Evidence from Time Series Analysis', *Energy Policy* 39.6: 3638–44			X		Moderate
Kumar, S. and Rauniyar, G. (2011) *Is Electrification Welfare Improving?: Non-Experimental Evidence from Rural Bhutan*, Munich Personal RePEc Archive Paper 31482, Harvard University, Asian				X	Moderate

Full reference	**A**	**B**	**C**	**D**	**Quality**
Development Bank					
Kumar Narayan, P. and Singh, B. (2007) 'The Electricity Consumption and GDP Nexus for the Fiji Islands', *Energy Economics* 29.6: 1141–50				X	High
Laufer, D. and Schäfer, M. (2011) 'The Implementation of Solar Home Systems as a Poverty Reduction Strategy – A Case Study in Sri Lanka', *Energy for Sustainable Development* 15.3: 330–36			X		High
Lean, H.H. and Smyth, R. (2010) 'Multivariate Granger Causality between Electricity Generation, Exports, Prices and GDP in Malaysia', *Energy* 35.9: 3640–48			X		Low
Legros, G.; Rijal, K. *et al.* (2011) *Decentralized Energy Access Millennium Development Goals and the Analysis of the Development Benefits of Micro-Hydropower in Rural Nepal*, New York: United Nations Development Programme				X	High
Lorde, T. *et al*. (2010) 'The Importance of Electrical Energy for Economic Growth in Barbados', *Energy Economics* 32: 1411–20				X	High
Louw, K.; Conradie, B. *et al.* (2008) 'Determinants of Electricity Demand for Newly Electrified Low-Income African Households', *Energy Policy* 36.8: 2812–18			X		Moderate
Matly, M. (2003) *Rural Electrification in Indonesia and Sri Lanka: From Social Analysis to Reform of the Power Sector*, Washington, DC: World Bank		X			High
Meier, P.; Tuntivate, V. *et al.* (2010) *Peru: National Survey of Rural Household Energy Use. ESMAP Special Report 007/10*, Washington, DC: World Bank		X	X		Moderate
Meier, U.; Isaksen, J. *et al.* (2007) *Evaluation of Norwegian Power-Related Assistance. Final Report,* Oslo: Norwegian Agency for Development Cooperation		X	X		Moderate
Millinger, M.; Mårlind, T. *et al.* (2012) 'Evaluation of Indian Rural Solar Electrification: A Case Study in Chhattisgarh', *Energy for Sustainable Development* 16.4, 486–92			X		Low
Morimoto, R. and Hope, C. (2004) 'The Impact of Electricity Supply on Economic Growth in Sri Lanka', *Energy Economics* 26.1: 77–8			X		Low
Mozumder, P. and Marathe, A. (2007) 'Causality Relationship between Electricity Consumption and GDP in Bangladesh', *Energy Policy* 35.1: 395–402			X		Low
Mulder, P. and Tembe, J. (2008) 'Rural Electrification in an Imperfect World: A Case Study from Mozambique', *Energy Policy* 36.8: 2785–94				X	Moderate

Full reference	A	B	C	D	Quality
Munasinghe, M. (1988) 'The Economics of Rural Electrification Projects', *Energy Economics* 10.1: 3–17				X	Moderate
Neelsen, S. and Peters, J. (2011) 'Electricity Usage in Micro-Enterprises – Evidence from Lake Victoria, Uganda', *Energy for Sustainable Development* 15.1: 21–31			X		Moderate
Oakley, D.; Harris, P. *et al.* (2007) *Modern Energy – Impact on Micro-Enterprise,* AEA Energy and Environment, Report produced for the Department for International Development			X		Moderate
Obeng, G.Y. and Evers, H.D. (2010) 'Impacts of Public Solar PV Electrification on Rural Micro-Enterprises: The Case of Ghana', *Energy for Sustainable Development* 14.3: 223–31		X	X		Moderate
Obeng, G.Y.; Akuffo, F.O. *et al.* (2008) 'Impact of Solar Photovoltaic Lighting on Indoor Air Smoke in Off-Grid Rural Ghana', *Energy for Sustainable Development* 12.1: 55–61			X		Low
Obermaier, M.; Alexandre, S. *et al.* (2012) 'An Assessment of Electricity and Income Distributional Trends Following Rural Electrification in Poor Northeast Brazil', *Energy Policy* 49, 531–40			X		Moderate
Odhiambo, N.M. (2009a) 'Electricity Consumption and Economic Growth in South Africa: A Trivariate Causality Test', *Energy Economics* 31.5: 635–40			X		Moderate
Odhiambo, N.M. (2009b) 'Energy Consumption and Economic Growth Nexus in Tanzania: An ARDL Bounds Testing Approach', *Energy Policy* 37.2: 617–22		X	X		Moderate
Ozturk, I. and Acaravci, A. (2011) 'Electricity Consumption and Real GDP Causality Nexus: Evidence from ARDL Bounds Testing Approach for 11 MENA Countries', *Applied Energy* 88.8: 2885–92				X	High
Pandey, M.K. and Billinton, R. (2000) 'Electric Power System Reliability Criteria Determination in a Developing Country – an Investigation in Nepal', *Energy Conversion, IEEE Transactions on* 15.3: 342–47				X	Moderate
Pandey, M. and Billinton, R. (1999) 'Reliability Worth Assessment in a Developing Country – Commercial And Industrial Survey Results', *Power Systems, IEEE Transactions on* 14.4: 1232–37				X	Moderate
Pereira, M.G.; Freitas, M.A.V. *et al.* (2010) 'Rural Electrification and Energy Poverty: Empirical Evidences from Brazil', *Renewable and Sustainable Energy Reviews* 14.4: 1229–40	X				High
Pereira, M.G.; Vasconcelos Freitas, M.A. *et al.* (2011) 'The Challenge of Energy Poverty: Brazilian Case Study', *Energy Policy* 39.1: 167–75	X				High

Full reference	A	B	C	D	Quality
Peters, J. and Vance, C. (2010) 'Rural Electrification and Fertility – Evidence from Côte d'Ivoire', *The Journal of Development Studies* 47.5: 753–66			X		Moderate
Peters, J; Harsdorff, M. *et al.* (2009) 'Rural Electrification: Accelerating Impacts with Complementary Services', *Energy for Sustainable Development* 13.1: 38–42			X		Low
Peters, J.; Vance, C. *et al.* (2011) 'Grid Extension in Rural Benin: Micro-Manufacturers and the Electrification Trap', *World Development* 39.5: 773–83			X		High
Ramcharran, H. (1990) 'Electricity Consumption and Economic Growth in Jamaica', *Energy Economics* 12.1: 65–70			X		High
Ranganathan, V. (1998) 'Long-Term Impact of Rural Electrification: A Study in UP and MP', *Economic and Political Weekly* 33.50: 3181–84		X			Low
Reddy, V.R.; Uitto, J.I. *et al.* (2006) 'Achieving Global Environmental Benefits through Local Development of Clean Energy? The Case of Small Hilly Hydel in India', *Energy Policy* 34.18: 4069–80				X	Moderate
Rud, J.P. (2012) 'Electricity Provision and Industrial Development: Evidence from India', *Journal of Development Economics* 97.2: 352–67			X		Low
Sebri, M. and Abid, M. (2012) 'Energy Use for Economic Growth: A Trivariate Analysis from Tunisian Agriculture Sector', *Energy Policy* 48.C: 711–16			X		Low
Sengendo, M. (2005) *Institutional and Gender Dimensions of Energy Service Provision for Empowering the Rural Poor in Uganda*, output of the Collaborative Research Group on Gender and Energy (CRGGE) ENERGIA International Network on Gender and Sustainable Energy and the United Kingdom Department for International Development (DFID) KaR research project R8346 on 'Gender as a Key Variable in Energy Interventions'				X	High
Shahbaz, M. and Lean, H.H. (2012) 'The Dynamics of Electricity Consumption and Economic Growth: A Revisit Study of their Causality in Pakistan', *Energy* 39.1: 146–53				X	High
Sharma, S.S. (2010) 'The Relationship Between Energy and Economic Growth: Empirical Evidence from 66 countries', *Applied Energy* 87.11: 3565–74			X		Low
Shiu, A. and Lam, P.-L. (2004) 'Electricity Consumption and Economic Growth in China', *Energy Policy* 32.1: 47–54				X	High
Sokari-George, E.; Emeruem, J.O. *et al.* (1991) 'Rural Electrification: A Study of Socio-Economic and Fertility Change in Rivers State, Nigeria', *African Study Monographs* 12.4: 167				X	Moderate

Full reference	A	B	C	D	Quality
Sovacool, B.K.; D'Agostino, A.L. *et al.* (2011) 'Gers Gone Wired: Lessons from the Renewable Energy and Rural Electricity Access Project (REAP) in Mongolia,' *Energy for Sustainable Development* 15.1: 32–40				X	Moderate
Sovacool, B.K.; Bambawale, M.J. *et al.* (2011) 'Electrification in the Mountain Kingdom: The Implications of the Nepal Power Development Project (NPDP)', *Energy for Sustainable Development* 15.3: 254–26			X		Low
Squalli, J. (2007) 'Electricity Consumption and Economic Growth: Bounds and Causality Analyses of OPEC Members', *Energy Economics* 29.6: 1192–1205			X		Low
Talha Yalta, A. and Cakar, H. (2012) 'Energy Consumption and Economic Growth in China: A Reconciliation', *Energy Policy* 41.C: 666–75			X		Low
Tang, C.F. (2008) 'A Re-Examination of the Relationship between Electricity Consumption and Economic Growth in Malaysia', *Energy Policy* 36.8: 3077–85				X	Moderate
Thom, C. (2000) 'Use of Grid Electricity by Rural Households in South Africa', *Energy for Sustainable Development* 4.4: 36–43				X	High
Tobich, R. (2008) *Impact Assessment of NORAD-Funded Rural Electrification Interventions in Northern Namibia, 1990–2000*, Oslo: Norwegian Agency for Development Cooperation (NORAD)				X	Moderate
UNDP (2012) *Integrating Energy Access and Employment Creation to Accelerate Progress on the Millennium Development Goals in Sub-Saharan Africa*, New York: UNPD		X			Low
UNDP and ESMAP (2004) *The Impact of Energy on Women's Lives in Rural India*, New York			X		Moderate
UNDP and World Bank (2002) *Rural Electrification and Development in the Philippines: Measuring the Social and Economic Benefits*, New York: UNDP and World Bank Energy Sector Management Assistance Programme (ESMAP)			X	X	High
Urmee, T. and Harries, D. (2011) 'Determinants of the Success and Sustainability of Bangladesh's SHS Programme', *Renewable Energy* 36.11: 2822–30		X	X		Moderate
Van Harte, M.A.; Gaunt, C.T. *et al.* (2005) 'Introducing Reliability Based Distribution Network Planning in South Africa', 18th International Conference and Exhibition on Electricity Distribution, 6–9 June			X		Moderate
Wolde-Rufael, Y. (2006) 'Electricity Consumption and Economic Growth: a Time Series Experience for 17 African Countries', *Energy Policy* 34.10: 1106–14		X	X		Moderate

Full reference	**A**	**B**	**C**	**D**	**Quality**
Wolde-Rufael, Y. (2004) 'Disaggregated Industrial Energy Consumption and GDP: The case of Shanghai, 1952–1999', *Energy Economics* 26.1: 69–75	X				High
World Bank (2008a) *Project Assessment Report Lao People's Democratic Republic Southern Provinces Rural Electrification Project. Credit 3047*, Washington, DC: Sector Thematic and Global Evaluation Division, Independent Evaluation Group, World Bank				X	Moderate
World Bank (2008b) *The Welfare Impact of Rural Electrification: A Reassessment of the Costs and Benefits*, Washington, DC: World Bank				X	Moderate
World Bank (1995) *Rural Electrification: A Hard Look at Costs and Benefits*, Washington, DC: World Bank		X	X		High
Yadoo, A. and Cruickshank, H. (2010) 'The Value of Cooperatives in Rural Electrification', *Energy Policy* 38.6: 2941–47		X	X		High
Yang, M. (2003) 'China's Rural Electrification and Poverty Reduction', *Energy Policy* 31.3: 283–95			X		Moderate
Yoo, S.H. (2006) 'The Causal Relationship between Electricity Consumption and Economic Growth in the ASEAN countries', *Energy Policy* 34.18: 3573–82		X			Low
Yoo, S.-H. and Kim, Y. (2006) 'Electricity Generation and Economic Growth in Indonesia', *Energy* 31.14: 2890–99			X		Moderate
Yoo, S.-H. and Kwak, S.-Y. (2010) 'Electricity Consumption and Economic Growth in Seven South American Countries', *Energy Policy* 38.1: 181–88				X	Moderate
Yuan, J.; Zhao, C. *et al.* (2007) 'Electricity Consumption and Economic Growth in China: Cointegration and Co-Feature Analysis', *Energy Economics* 29.6: 1179–91				X	Moderate
Yuan, J.-H.; Kang, J.-G. *et al.* (2008) 'Energy Consumption and Economic Growth: Evidence from China at both Aggregated and Disaggregated levels', *Energy Economics* 30.6: 3077–94				X	Moderate
Zahnd, A. and Kimber, H.M. (2009) 'Benefits from a Renewable Energy Village Electrification System', *Renewable Energy* 34.2: 362–68				X	Moderate
Abosedra, S.; Dah, A. *et al.* (2009) 'Electricity Consumption and Economic Growth, the Case of Lebanon', *Applied Energy* 86.4: 429–32				X	Moderate
African Development Bank (2011) *Benin: Project for the Electrification of 17 Rural Centres, Project Performance Evaluation Report (PPER)*, Operations Evaluation Department			X		Low

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Dent, C.J.; Bialek, J.W.; Coolen, F.P.A.; Power, M.; Smith, P.; Richards, A.W. and Zachary, S. (2012) 'Guest Editorial: Risk and Reliability Modelling of Energy Systems, Proc. IMechE Part O', *Journal of Risk and Reliability* 226.1: 3–5

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Appendices

Appendix 1 Search terms

Table A1 Search terms

Interventions	**Uses**	**Poverty outcomes**	**Geography**	**Low-carbon technologies**
Electrification	Access	Poverty	Developing* countr*	Hydro
Electricity	Consum*	Poverty reduction	Southern countr*	Solar
Energy	Use	Poor households	Low income countr*	Wind
Generation	Demand	Benefits	Poor countr*	Renewable energ*
Capacity	Light* or illuminate*	Health	Underdeveloped countr*	Clean energ*
Network	Refrigerat*	Education	Sub-Saharan Africa	Biomass energy*
Grid	Heat*	Livelihood*	Africa	Energy efficien*
Mini-grid	Freez* or cool	Employment	South East Asia	Clean energy*
Stand-alone	Communication OR radio OR television OR TV or OR ICT OR internet	Gender	Latin America	Sustainable energy*
Extension	*phone charg*	Labour	China	
	Cook*	Development	India	
	Pump*	Econom*	Brazil	
	Food storage	Growth	(country disaggregation)	
	Energy services	Income	Rural	
	Useful work	Wealth		
		Turnover		
		Productivity		
		Industr*		
		Study		
		Women		
		Girls		
		Information		
		Knowledge		
		Welfare		
		Impact		
		Evaluation		

Appendix 2 Search strings

A. What is the link between increased renewable energy generation capacity and higher availability and reliability of supply?

This exercise will be done by Chris Dent from the University of Durham and has not followed the same systematic approach to searches as the rest of the questions. The review has been based on contacts of the author from a seminal study on power systems analysis for developing countries.

B. What is the link between higher availability and reliability of electricity and increased connection rates and actual consumption by households and firms?

- Impact AND Evaluation AND Electrification
- Electrification AND Generation OR Capacity OR Network OR Grid OR Mini-grid OR Stand-alone OR Extension AND Access OR Consumption OR Use OR Demand OR Light OR illuminate OR Refrigerate OR Heating OR Freezing OR cooling OR Communication OR radio OR television OR TV OR ICT OR internet OR phone charging OR Cooking OR Pumping OR Food storage OR Energy services OR Useful work
- If we obtain too many entries or find out that the results include many studies from developed countries we can reduce results by introducing geographical search terms AND Developing countr* OR Southern countr* OR Low income countr* OR Poor countr* OR Underdeveloped countr* OR Sub-Saharan Africa OR Africa OR South East Asia OR Latin America OR Rural
- We can also introduce geographical search terms including every low and middle income country

C. Once households and firms get a connection and start consuming electricity, what is the evidence of the impacts of this consumption for the poor?

- Electricity AND Poverty OR Poverty reduction OR Poor households OR Benefits OR Health OR Education OR Livelihood* OR Employment OR Gender OR Labour OR Development OR Economic OR Growth OR Income OR Wealth OR Turnover OR Productivity OR Industry OR Study OR Women OR Girls OR Information OR Knowledge OR Welfare OR Microenterprise
- As before, if we obtain too many entries or find out that the results include many studies from developed countries we can reduce results by introducing geographical search terms: AND Developing* countr* OR Southern countr* OR Low income countr* OR Poor countr* OR Underdeveloped countr* OR Sub-Saharan Africa OR Africa OR South East Asia OR Latin America OR Rural
- We can also introduce geographical search terms including every low and middle income country

D. What is the link between electricity capacity or consumption and economic growth at a macro level?

- Electri* AND Economic growth

IDEAS

1 Impact Evaluation Electrification
2 Electricity AND Access OR Consumption OR Use OR Demand and poverty
3 Electricity AND (Generation OR Capacity OR Network OR Grid OR Mini-grid OR Stand-alone OR Extension) AND (Access OR Consum* OR Use* OR Demand OR Light* OR illuminate* OR Refrigerat* OR Heat* OR Freez* OR cool OR Communication OR radio OR television OR TV OR ICT OR internet OR *phone charg* OR Cook* OR Pump* OR Food storage OR (Modern) Energy services OR Useful work)

JOLIS

1 Evaluation and electrification
2 Electricity and development or poverty and impact

JOLISPLUS

1 Electrification AND (Generation OR Capacity OR Network OR Grid OR Mini-grid OR Stand-alone OR Extension) AND (Access OR Consumption OR Use OR Demand OR Light OR illuminate OR Refrigerate OR Heating OR Freezing OR cooling OR Communication OR radio OR television OR TV OR ICT OR internet OR phone charging) AND developing countries
2 Electrification AND (Poverty OR Poverty reduction OR Poor households OR Benefits OR Health OR Education OR Livelihood* OR Employment OR Gender OR Labour OR Development OR Economic OR Growth OR Income OR Wealth OR Turnover OR Productivity OR Industry OR Study OR Women OR Girls OR Information OR Knowledge OR Welfare)

GOOGLE SCHOLAR

1 Electri* AND (Generation OR Capacity OR Network OR Grid) AND (Poverty OR Poverty reduction OR Poor households OR Benefits OR Health OR Education OR Livelihood* OR Employment OR Gender OR Labour OR Development OR Economic OR Growth OR Income OR Wealth)

SCIENCE DIRECT

1 (Electri* and Impact) and (Poverty OR Poverty reduction OR Poor households OR Benefits OR Health OR Education OR Livelihood* OR Employment OR Gender OR Labour OR Development OR Economic OR Growth OR Income OR Wealth OR Turnover OR Productivity OR Industry OR Study OR Women OR Girls)
2 (Electri* and Evaluation) and (Poverty OR Poverty reduction OR Poor households OR Benefits OR Health OR Education OR Livelihood* OR Employment OR Gender OR Labour OR Development OR Economic OR Growth OR Income OR Wealth OR Turnover OR Productivity OR Industry OR Study OR Women OR Girls)
3 (rural electrification) and (Poverty OR Poverty reduction OR Poor households OR Benefits OR Health OR Education OR Livelihood* OR Employment OR Gender OR Labour OR Development OR Economic OR Growth OR Income OR Wealth OR Turnover OR Productivity OR Industry OR Study OR Women OR Girls)
4 TITLE-ABSTR-KEY (electri* and economic growth) and (Developing* countr* OR Southern countr* OR Low income countr* OR Poor countr*)

5 Energy Access AND (Poverty OR Poverty reduction OR Poor households OR Benefits OR Health OR Education OR Livelihood* OR Employment OR Gender OR Labour OR Development OR Economic OR Growth OR Income OR Wealth OR Turnover OR Productivity OR Industry OR Study OR Women OR Girls OR Information OR Knowledge OR Welfare):

DFID

1 Search by theme: Infrastructure/Energy/Electrification/Access to Energy/Electricity.

BLDS

1 Impact Evaluation Electrification
2 Electricity and Development

IEA

1 Electrification/electricity

UNDP

1 Electrification/Electricity

ELDIS

1 Electrification /Electricity

PROQUEST DISSERTATION DATABASE

1 Rural electrification
2 Electri* and development and poverty

WORLD BANK DATABASE

1 Impact Evaluation Electrification (375 results, only a few relevant)
2 Electricity AND Access OR Consumption OR Use OR Demand and poverty

(93 results)

Appendix 3 Data extraction form

General information	Full bibliographic reference
Reviewer	Name of reviewer
Year of publication	Year
Review question (s) addressed	A B C D
Publication type	Peer review journal article Academic paper MDB evaluation report MDB report Thesis/dissertation Other
Research design	P&E; EXP P&E; OBS-AN P&E; OBS-DES
Quality	High Moderate Low
Comment on quality	
Description of method	
Sophistication of the analysis (for questions C and D)	Describes impacts Quantifies impacts Tests causality
Sample size	With intervention Without intervention Total
Geographical coverage	(Detail countries)
Period	
Sampling method	
Households or businesses	Households Businesses Both
Intervention	On-grid generation capacity Off-grid generation capacity Expanding or improving grid Subsidies, financial services or management through cooperatives Other (awareness and training, support to buying appliances)
Time of intervention	

(Cont'd.)

Appendix 3 (cont'd.)

Generation technology	Solar home systems Wind Solar PV Hydro Biomass Fossil-fuel based
Definition of access	
Factors that influence connection **(Question B)**	Income Connection fee Appliances/equipment cost and ability to pay for them Electricity tariffs Access to finance Previous kerosene and LPG consumption Quality/reliability of supply Electricity essential for operation Characteristics other than income (age, educ. level, occupation, neighbourhood elec. rates...) Other
Estimation of factors that determine connection likelihood **(Question B)**	Yes/no (included in the description of the study)
Factors that influence use **(Question B)**	Income HH/financial situation of business Electricity tariffs Appliances/equipment ownership Price of alternatives Previous kerosene consumption Quality and reliability of supply/good systems maintenance Access to credit Knowledge how to operate equipment/ preferences Control over monthly bill Use for income generation Occupation Other/ Comments
Electricity consumption elasticities **(Question B)**	Yes/no (detailed in the description of the study

(Cont'd.)

Appendix 3 (cont'd.)

Main uses of electricity in households and social services (Question C)	Household Light Radio and TV Mobile charging Iron Washing machine Refrigeration Ventilation Water pumps Cooking Street lights Community services Internet Music equipment Comments/other
Main productive uses (Question C)	Water pumps and Irrigation units Agriculture processing Food processing Lighting workspace Welding and carpentry Printing Industry (other uses) Telecommunications Lighting for service activities Hospitality and shops Battery charging centres Services (other uses) Comments/other
Definition of poverty (Question C)	
Quantification of impacts on poverty or power consumption elasticity of impacts (Question C)	Yes/No

(Cont'd.)

Appendix 3 (cont'd.)

Poverty impacts for households (Question C)	Improved quality of life Employment (more time allocated to income-earning activities) Education (more time allocated to study, time for a break, teachers prepare better their lectures) Household productivity – more hours and more flexibility Communications and access to information Safety (less fire and burns, outdoor light) Improved social services: health, education, etc. Improved health (eyesight, less physical effort, air pollution, fertility, etc.) Energy cost savings Increased income Energy poverty Increased land value Gender equality Social benefits: socialise, feel included in community Environmental benefits (GHG emissions, deforestation) Improved livelihoods Comments/other
Impacts for productive activities (Question C)	Creation of enterprises Reduced cost Firm profits Increased productivity Increased revenues Extended working hours Increased investment Increased employment Better product/service quality Better work quality Comments/other
Enabling factors (Question C)	Access to external markets Size of local market Employment opportunities Other infrastructures/services for productive uses Skills, training Location close to exploitable resource Gender-related interventions Other
Gender differentiation (Question C)	Yes/No

(Cont'd.)

Appendix 3 (cont'd.)

Negative poverty impacts (Question C)	Longer working days Less leisure time Time spent on TV (less time for study, damage to identity...) Lost business for those with no electricity Debt for connected businesses Financial difficulties for national utility Environmental problems: battery disposal Inequity Other (detail)
Number of observations (Question D)	
Dependent variable (Question D)	
Independent variable (Question D)	
Direction of causality (Question D)	No causality GDP to electricity Electricity to GDP Bi-directional causality
Approach for causality test (Question D)	
Bivariate/multivariate (Question D)	Bivariate Multivariate

Appendix 4 DFID principles of high-quality studies

Principles of quality	Associated principles
Conceptual framing	The study acknowledges existing research The study constructs a conceptual framework The study poses a research question The study outlines a hypothesis
Openness and transparency	The study presents or links to the raw data it analyses The author recognises limitations/weaknesses in her work
Appropriateness and rigour	The study identifies a research design The study identifies a research method The study demonstrates why the chosen design and method are good ways to explore the research question
Validity	The study has demonstrated measurement validity The study is internally valid The study is externally valid
Reliability	The study demonstrates measurement reliability The study demonstrates that its selected analytical technique is reliable
Cogency	The author 'signposts' the reader throughout The conclusions are clearly based on the study's results

Source: DFID (2013).

Appendix 5 Power systems reliability analysis in developed countries, and contrasts with developing countries

Power system reliability analysis methods for developed country systems are well established, having been used widely both in academia and industry since the development of modern digital computers. A survey of key issues in and textbook treatments of the subject may be found in Dent *et al.* (2012).

A typical analysis for a given system would consist of the following stages:

1. Estimate probabilistic representations inputs such as demand, available generating capacity and network component availability at all relevant locations.
2. Define model outputs, e.g. 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 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 intermittent sources):

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

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

- ***Data availability.*** Most developed country electricity supply 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. As discussed in the papers by Pandey and Billinton (1999, 2000) good data on the state of networks, reliability and number of consumers may not always be available in developing countries[18] – 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 round 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 in the outputs some consideration of how a limited supply is shared between customers or between classes of use.)

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

Appendix 6 Summary of papers Question D

Reference	Country	Period	Nr. obs.	Dep. var.	GDP	Approaches	Outcome
Abosedra et al. (2009)	Lebanon	Jan 1995–Dec 2005	132	EC	TI	Standard Granger/Hsiao's	EC ==> GDP
Akinlo (2009)	Nigeria	1980–2006	27	EC	Real GDP	VECM	EC ==> GDP
Altinay and Karagol (2005)	Turkey	1950–2000	51	EC	Real GDP	Modified Wald Test	EC ==> GDP
Aqeel and Butt (2001)	Pakistan	1955/56–1995/96	41	EC	GDP and EG	Standard Granger/Hsiao's	EC ==> GDP
Bildirici and Kayikçi (2012)	Armenia	1999–2009	21	EC p/c	Real GDP p/c	VECM	EC <==> GDP
	Azerbaijan	1999–2009	21	EC p/c	Real GDP p/c	VECM	EC <==> GDP
	Georgia	1999–2009	21	EC p/c	Real GDP p/c	VECM	EC <==> GDP
	Kazakhstan	1999–2009	21	EC p/c	Real GDP p/c	VECM	EC <==> GDP
	Kyrgyzstan	1999–2009	21	EC p/c	Real GDP p/c	VECM	EC <==> GDP
	Moldova	1999–2009	21	EC p/c	Real GDP p/c	VECM	EC <==> GDP
	Republic of Belarus	1999–2009	21	EC p/c	Real GDP p/c	VECM	EC <==> GDP
	Russian Federation	1999–2009	21	EC p/c	Real GDP p/c	VECM	EC <==> GDP
	Tajikistan	1999–2009	21	EC p/c	Real GDP p/c	VECM	EC <==> GDP
	Ukraine	1999–2009	21	EC p/c	Real GDP p/c	VECM	EC <==> GDP
	Uzbekistan	1999–2009	21	EC p/c	Real GDP p/c	VECM	EC <==> GDP
Chandran et al. (2010)	Malaysia	1971–2003	33	EC	Real GDP	VECM	EC ==> GDP
Chen et al. (2007)	China	1971–2001	31	EC	Real GDP	VECM	EC <≠≠> GDP
	India	1971–2001	31	EC	Real GDP	VECM	EC <≠≠> GDP
	Indonesia	1971–2001	31	EC	Real GDP	VECM	EC ==> GDP
	Malaysia	1971–2001	31	EC	Real GDP	VECM	EC <== GDP
	Philippines	1971–2001	31	EC	Real GDP	VECM	EC <== GDP
	Thailand	1971–2001	31	EC	Real GDP	VECM	EC <≠≠> GDP
Ghosh (2002)	India	1950/51–1996/97	47	EC p/c	real GDP p/c	Standard Granger/Hsiao's	EC <== GDP
Golam Ahamad and Nazrul Islam (2011)	Bangladesh	1971–2008	38	EC p/c	real GDP p/c	VECM	EC <==> GDP
Jahangir Alam et al. (2012)	Bangladesh	1972–2006	36	EC p/c	Real GDP p/c	VECM	EC <==> GDP
Jamil and Ahmad (2010)	Pakistan	1960–2008	49	EC p/c	Real GDP	VECM	EC <== GDP

Abbreviations: AVA, Agricultural Value Added; EC, Electricity Consumption; EG, Employment Growth; EP, Electricity Production; ER, Electrification Rate; GDP, Gross Domestic Product; GNP, Gross National Product; MO, Manufacturing Output; p/c, Per Capita; TI, Total Imports; VECM, Vector Error Correction Model.
(Cont'd.)

Appendix 6 (cont'd.)

Reference	Country	Period	Nr. obs.	Dep. var.	GDP	Approaches	Outcome
Jumbe(2004)	Malawi	1975–1999	25	EC	Real GDP	Standard Granger/Hsiao's	EC <==> GDP
Kouakou (2011)	Côte d'Ivoire	1971–2008	38	EC p/c	Real GDP p/c	VECM	EC ==> GDP
Narayan and Singh (2007)	Fiji	1971–2002	32	EC	real GDP	VECM	EC ==> GDP
Lean and Smyth (2010)	Malaysia	1970–2008	39	EP p/c	Real GDP p/c	Modified Wald Test	EC <== GDP
Morimoto and Hope (2004)	Sri Lanka	1960–1988	35	EP	Real GDP	Standard Granger/Hsiao's	EC ==> GDP
Mozumder and Marathe (2007)	Bangladesh	1971–1999	29	EC p/c	Real GDP	VECM	EC <== GDP
Odhiambo (2009a)	South Africa	1971–2008	38	EC p/c	Real GDP p/c	VECM	EC <==> GDP
Odhiambo (2009b)	Tanzania	1971–2006	36	EC p/c	Real GDP p/c	VECM	EC <≠≠> GDP
Ozturk and Acaravci (2011)	Egypt	1971–2006	36	EC p/c	Real GDP p/c	VECM	EC ==> GDP
Ramcharran (1990)	Jamaica	1970–1986				OLS	No causality check
Rud (2012)	India	1965–1984	20	ER	MO	Other	EC ==> GDP
Sebri and Abid (2012)	Tunisia	1980–2007	28	EC p/c	AVA	VECM	EC ==> GDP
Shahbaz and Lean (2012)	Pakistan	1972–2009	38	EC p/c	Real GDP p/c	VECM	EC <==> GDP
Sharma (2010)	Multi-country					Panel data	No causality check
Shiu and Lam (2004)	China	1971–2000	30	EC	Real GDP	VECM	EC ==> GDP
Squalli (2007)	Algeria	1980–2003	24	EC p/c	Real GDP	Modified Wald Test	EC <== GDP
	Indonesia	1980–2003	24	EC p/c	Real GDP	Modified Wald Test	EC ==> GDP
	Iraq	1980–2003	24	EC p/c	Real GDP	Modified Wald Test	EC <== GDP
	Iran	1980–2003	24	EC p/c	Real GDP	Modified Wald Test	EC <==> GDP
	Libya	1980–2003	24	EC p/c	Real GDP	Modified Wald Test	EC <== GDP
	Nigeria	1980–2003	24	EC p/c	Real GDP	Modified Wald Test	EC ==> GDP
	Venezuela	1980–2003	24	EC p/c	Real GDP	Modified Wald Test	EC ==> GDP

Abbreviations: AVA, Agricultural Value Added; EC, Electricity Consumption; EG, Employment Growth; EP, Electricity Production; ER, Electrification Rate; GDP, Gross Domestic Product; GNP, Gross National Product; MO, Manufacturing Output; p/c, Per Capita; TI, Total Imports; VECM, Vector Error Correction Model.
(Cont'd.)

Appendix 6 (cont'd.)

Reference	Country	Period	Nr. obs.	Dep. var.	GDP	Approaches	Outcome
Talha Yalta and Cakar (2012)	China	1971–2007	37	EC	Real GDP	Other	EC <≠≠> GDP
Tang (2008)	Malaysia	1972Q1–2003Q4	136	EC p/c	Real GNP p/c	Modified Wald Test	EC <==> GDP
Wolde-Rufael (2004)	Shanghai, China	1952–1999	48	EC	Real GDP	Modified Wald Test	EC ==> GDP
Wolde-Rufael (2006)	Algeria	1971–2001	31	EC p/c	Real GDP p/c	Modified Wald Test	EC <≠≠> GDP
	Benin	1971–2001	31	EC p/c	Real GDP p/c	Modified Wald Test	EC ==> GDP
	Cameroon	1971–2001	31	EC p/c	Real GDP p/c	Modified Wald Test	EC <== GDP
	Congo D.R.	1971–2001	31	EC p/c	Real GDP p/c	Modified Wald Test	EC ==> GDP
	Congo Rep.	1971–2001	31	EC p/c	Real GDP p/c	Modified Wald Test	EC <≠≠> GDP
	Egypt	1971–2001	31	EC p/c	Real GDP p/c	Modified Wald Test	EC <==> GDP
	Gabon	1971–2001	31	EC p/c	Real GDP p/c	Modified Wald Test	EC <==> GDP
	Ghana	1971–2001	31	EC p/c	Real GDP p/c	Modified Wald Test	EC <== GDP
	Kenya	1971–2001	31	EC p/c	Real GDP p/c	Modified Wald Test	EC <≠≠> GDP
	Morocco	1971–2001	31	EC p/c	Real GDP p/c	Modified Wald Test	EC <==> GDP
	Nigeria	1971–2001	31	EC p/c	Real GDP p/c	Modified Wald Test	EC <== GDP
	Senegal	1971–2001	31	EC p/c	Real GDP p/c	Modified Wald Test	EC <== GDP
	South Africa	1971–2001	31	EC p/c	Real GDP p/c	Modified Wald Test	EC <≠≠> GDP
	Sudan	1971–2001	31	EC p/c	Real GDP p/c	Modified Wald Test	EC <≠≠> GDP
	Tunisia	1971–2001	31	EC p/c	Real GDP p/c	Modified Wald Test	EC ==> GDP
	Zambia	1971–2001	31	EC p/c	Real GDP p/c	Modified Wald Test	EC <== GDP
	Zimbabwe	1971–2001	31	EC p/c	Real GDP p/c	Modified Wald Test	EC <== GDP
	Indonesia	1971–2002	32	EC p/c	Real GDP p/c	Standard Granger/Hsiao's	EC <== GDP

Abbreviations: AVA, Agricultural Value Added; EC, Electricity Consumption; EG, Employment Growth; EP, Electricity Production; ER, Electrification Rate; GDP, Gross Domestic Product; GNP, Gross National Product; MO, Manufacturing Output; p/c, Per Capita; TI, Total Imports; VECM, Vector Error Correction Model.
(Cont'd.)

Appendix 6 (cont'd.)

Reference	Country	Period	Nr. obs.	Dep. var.	GDP	Approaches	Outcome
Yoo (2006)	Malaysia	1971–2002	32	EC p/c	Real GDP p/c	Standard Granger/Hsiao's	EC <==> GDP
	Thailand	1971–2002	32	EC p/c	Real GDP p/c	Standard Granger/Hsiao's	EC <== GDP
Yoo and Kwak (2010)	Argentina	1975–2006	32	EC p/c	Real GDP p/c	Standard Granger/Hsiao's	EC ==> GDP
	Brazil	1975–2006	32	EC p/c	Real GDP p/c	Standard Granger/Hsiao's	EC ==> GDP
	Chile	1975–2006	32	EC p/c	Real GDP p/c	Standard Granger/Hsiao's	EC ==> GDP
	Colombia	1975–2006	32	EC p/c	Real GDP p/c	Standard Granger/Hsiao's	EC ==> GDP
	Ecuador	1975–2006	32	EC p/c	Real GDP p/c	Standard Granger/Hsiao's	EC ==> GDP
	Peru	1975–2006	32	EC p/c	Real GDP p/c	Standard Granger/Hsiao's	EC <≠≠> GDP
	Venezuela	1975–2006	32	EC p/c	Real GDP p/c	Standard Granger/Hsiao's	EC <==> GDP
Yoo and Kim (2006)	Indonesia	1971–2002	32	EP	Real GDP	Standard Granger/Hsiao's	EC <== GDP
Yuan et al. (2007)	China	1978–2004	27	EC	Real GDP	VECM	EC ==> GDP
Yuan et al. (2008)	China	1963–2005	43	EC	Real GDP	VECM	EC <==> GDP

Abbreviations: AVA, Agricultural Value Added; EC, Electricity Consumption; EG, Employment Growth; EP, Electricity Production; ER, Electrification Rate; GDP, Gross Domestic Product; GNP, Gross National Product; MO, Manufacturing Output; p/c, Per Capita; TI, Total Imports; VECM, Vector Error Correction Model.

Appendix 7 Multinomial logit model

Analysis with Multinomial Logit

The four different possibilities in the causality analysis lead Chen, Chen *et al.* (2012) to use a multinomial logit model. In the multinomial logit the dependent variable is categorical and the categories are not ordered in a hierarchical way, although they exclude each other.

Multinomial logit is then used when there are more than two possible outcomes. Let's simplify the model to the three options specification in order to make it simpler and then we can extend it to the general case of n possible outcomes.

We assume that $y_{ij} = 1$ if the i-th country happens to have outcome e or $y_{ij} = 0$ otherwise, where e = 1, 2, 3. Prob [y_{ij}] = π_{ij} and all probabilities should add up to one, and therefore $\pi_{i1} + \pi_{i2} + \pi_{i3} = 1$.

The different probabilities in the multinomial logit are given by (assuming a simple model like $\alpha_j + \beta_j X_i$)

$$\pi_{i1} = \frac{e^{(\alpha_1+\beta_1X_i)}}{e^{(\alpha_1+\beta_1X_1)}+e^{(\alpha_2+\beta_2X_2)}+e^{(\alpha_3+\beta_3X_3)}}$$ for category 1.

$$\pi_{i2} = \frac{e^{(\alpha_2+\beta_2X_i)}}{e^{(\alpha_1+\beta_1X_1)}+e^{(\alpha_2+\beta_2X_2)}+e^{(\alpha_3+\beta_3X_3)}}$$ for category 2

$$\pi_{i3} = \frac{e^{(\alpha_3+\beta_3X_i)}}{e^{(\alpha_1+\beta_1X_1)}+e^{(\alpha_2+\beta_2X_2)}+e^{(\alpha_3+\beta_3X_3)}}$$ for category 3.

In a more general form, the probabilities can be expressed as

$$\pi_{ij} = \frac{e^{(\alpha_j+\beta_jX_i)}}{\sum_j^k e^{(\alpha_j+\beta_jX_i)}}$$

where k is the number of categories, in our illustrating simplification k = 3.

One of the potential problems of the model is that different parameterisations can lead to different probabilities. This is solved through the Theil Normalisation. This consists basically in setting α_j and β_j equal to 0. Normally, the normalisation is done with the first category and this is the way that can be found in econometric software. Thus, $\alpha_1 = 0$ and $\beta_1 = 0$. Given that any number to the power of zero is equal to one, the different probabilities will now be expressed as:

$$\pi_{i1} = \frac{1}{1+e^{(\alpha_2+\beta_2X_2)}+e^{(\alpha_3+\beta_3X_3)}}$$ for category 1.

$$\pi_{i2} = \frac{e^{(\alpha_2+\beta_2X_i)}}{1+e^{(\alpha_2+\beta_2X_2)}+e^{(\alpha_3+\beta_3X_3)}}$$ for category 2

$$\pi_{i3} = \frac{e^{(\alpha_3+\beta_3X_i)}}{1+e^{(\alpha_2+\beta_2X_2)}+e^{(\alpha_3+\beta_3X_3)}}$$ for category 3.

The first category is then called the normalised category although the normalization can be done on any of them. The condition that all probabilities add up to one is still held.

Log odds ratios and Marginal Effects

For illustrative purposes we will drop the i subscript in order to explain how to find the log odds ratios and marginal effects.

In the case of the different combinations of the log odds ratios, they can be expressed with respect to any of the categories. They can be expressed, for example:

$$\ln\left(\frac{\pi_2}{\pi_1}\right) = \alpha_2 + \beta_2 X$$ for the second category;

$$\ln\left(\frac{\pi_3}{\pi_1}\right) = \alpha_3 + \beta_3 X$$ for the third category; and

$$\ln\left(\frac{\pi_3}{\pi_2}\right) = \ln\left(\frac{\pi_3}{\pi_1}\right) - \ln\left(\frac{\pi_2}{\pi_1}\right) = \alpha_3 + \beta_3 X \quad - \alpha_2 + \beta_2 X \quad = \ln\left(\frac{\pi_3}{\pi_1}\right)$$
$$= (\alpha_3 - \alpha_2) + (\beta_3 X \quad - \beta_2 X \quad)$$

The intercepts and coefficients of $\ln\left(\frac{\pi_2}{\pi_1}\right)$ and $\ln\left(\frac{\pi_3}{\pi_1}\right)$ should be interpreted with respect to the normalised category, 1.

In the case of the marginal effects, the interest is the answer to the question of what is the effect of a small change in X on the likelihood of an event occurring. This is found just doing the first derivative of the probability of the event with respect to X. For the non-normalised categories, the general equation would be:

$$\frac{\delta \pi_j}{\delta X} = \pi_j[\beta_j - \sum_k \beta_k \pi_k]$$

In the case of the marginal probability of the normalised first category (π_1),the effect is calculated by:

$$\frac{\delta\pi_1}{\delta X} = \pi_1[0 - \beta_2\pi_2 - \beta_3\pi_3]$$

where π_2 and π_3 can be estimated as the average proportions in these categories.

The parameters of the multinomial logit are estimated through maximum likelihood estimation, substituting the probability π_{ij} for its expressions above described, after the Theil Normalisation has been done:

$$L = \sum_{i}^{n}\sum_{j}^{k} Y_{ij}\ln(\pi_{ij})$$

The Independence of Irrelevant Alternatives (IIA) assumption

This is a strong assumption which implies that the probability ratio of any alternative is independent of irrelevant alternatives. In other words, the probabilities of all categories should change in the same proportion with the inclusion of an extra alternative or the deletion of one of them and thus the log odds ratios should not change with the insertion/deletion of this alternative.

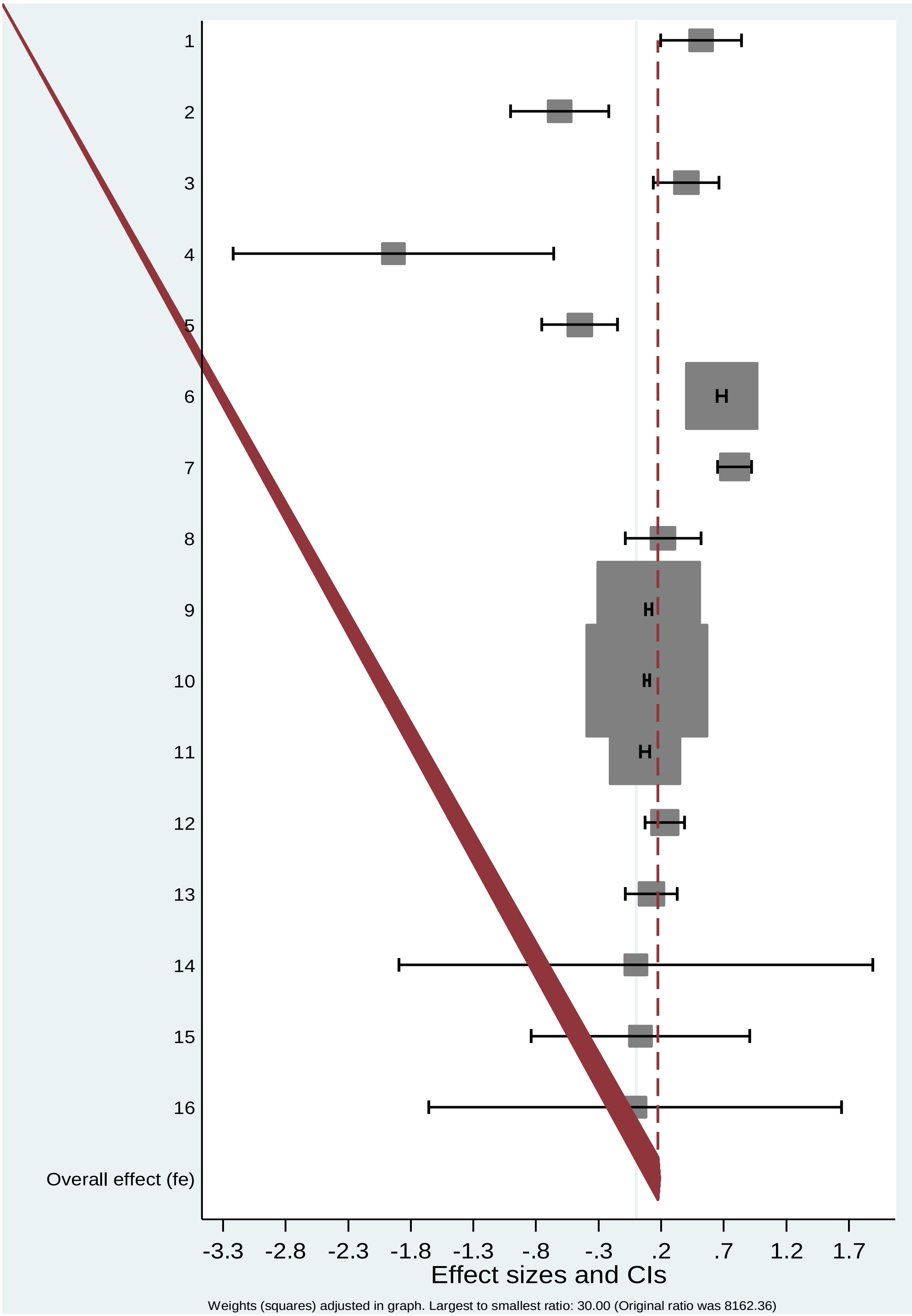
The great importance of the assumption makes it necessary to be tested. The Hausman and McFadden (1984) test has been one of the most widely used. However, there are some drawbacks about this test as the outcomes might be different when we omit different categories. Also, it is possible that the test yields negative values, which are not easy to interpret. To avoid this problem an additional Small-Hsiao test will be run, which always results into positive values.

Appendix 8 Fixed effect approach

Table A2 Fixed effects approach outcomes

Study	Obs	Country/ies	Regression /spec	Effect	95% confidence interval		Per cent weight
Bildirici and Kayikçi (2012)	84	Group 1	FMOLS	0.52	0.196	0.844	0.17
Bildirici and Kayikçi (2012)	84	Group 2	FMOLS	–0.61	–1.002	–0.218	0.12
Bildirici and Kayikçi (2012)	63	Group 3	FMOLS	0.4	0.138	0.662	0.26
Bildirici and Kayikçi (2012)	84	Group 2	ARDL	–1.94	–3.22	–0.66	0.01
Bildirici and Kayikçi (2012)	63	Group 3	ARDL	–0.45	–0.753	–0.147	0.2
Chandran *et al.* (2010)	33	Malaysia	Spec 1	0.683	0.646	0.72	13.26
Chandran *et al.* (2010)	33	Malaysia	Spec 2	0.787	0.651	0.923	0.99
Jumbe (2004)	25	Malawi	OLS	0.216	–0.085	0.517	0.2
Narayan and Singh (2007)	32	Fiji	OLS	0.1	0.075	0.125	29.37
Narayan and Singh (2007)	32	Fiji	FMOLS	0.086	0.065	0.107	41.37
Narayan and Singh (2007)	32	Fiji	ARDL	0.071	0.034	0.109	12.85
Ramcharran (1990)	17	Jamaica	OLS	0.23	0.072	0.388	0.73
Sharma (2010)	320	Latin & Caribbean	Electricity consumption	0.121	–0.085	0.328	0.43
Sharma (2010)	400	Africa & M. East	Electricity consumption	–0.002	–1.897	1.893	0.01
Sharma (2010)	320	Latin & Caribbean	Electricity consumption	0.035	–0.839	0.909	0.02
Sharma (2010)	400	Africa & M. East	Electricity consumption	–0.007	–1.656	1.641	0.01
			Overall effect	0.175	0.162	0.189	100

Figure A1 Forest graph fixed effect approach



Appendix 9 Guidelines for the design of robust impact evaluations of electrification on poverty using experimental and quasi-experimental approaches

Experimental methods for measuring impact of access and consumption of electricity

The ideal design would randomise across a variety of different village types throughout the country or regions on the continent in order to control for different macroeconomic and geographic factors and community characteristics and hence estimate results that have external validity. However this is often not practical because projects are usually targeted at a particular cause – usually the decision to increase pro-poor access to electricity, or to provide access to electricity in the most cost-effective way.

Assuming that projects need to be targeted in some way and depending on budget, an impact evaluation could be set up to *randomise* across *eligible communities*. In this situation, the number of eligible communities must be greater than the number of communities that can be funded. Eligibility characteristics should be determined by the project objectives, and may likely include indicators such as poverty indices in the case of pro-poor access to electricity projects, and population density and income in the case of cost-effective projects. When the programme can randomly assign treatment based on eligibility, a robust estimate of the counterfactual can be established and the impact measured will be inferred for all possible eligible communities. Please note, the impact measured will not be causal for all communities within the country or region as there is an eligibility requirement. A lottery can be used to decide which communities among the equally eligible population receive the programme. This is also the most fair and transparent way to select communities. The randomisation process in itself will produce two groups that have a high probability of being statistically identical, or more specifically, have statistically equivalent averages for all of their characteristics. Baseline data can be used to test this assumption empirically through the use of independent sample t-tests of equal means on observable characteristics such as population characteristics, access to roads, distance to market nodes, size of local market, economic activity in the village, market integration, current energy sources, household characteristics, access to resources, geographic characteristics, social services and institutions in the community.

Alternatively, if the programme needs to be gradually phased into many communities until it covers the entire eligible population, then the evaluation could be conducted through a *phase-in randomisation* in which communities are randomly allocated to different phase-in stages in order to give each eligible community the same chance of receiving treatment in the first phase or in a later phase. This is often referred to as the *pipeline comparison method* or the *phase-in approach.* So long as the last community has not yet been phased into the programme by the time of the endline survey for the first community, it will serve as a valid control group to estimate a counterfactual. Paired matching must also be conducted based on observable characteristics collected at the baseline to further ensure that the communities within the first phase of electrification were sufficiently similar ex-ante to those in the later phase. This is the approach used by the forthcoming Chemin and De Laat study in Kenya. We include this as the second-best option because contamination of the control group is more likely than in pure randomisation, because the control group (i.e. the community receiving the electrification last) may anticipate the project and make choices they would not have otherwise made if they did not expect to receive electricity at a later stage. Phase-in approaches work best only in treatments where waiting for treatment is simply not an option (for example, waiting for access to health services with a sick child). Furthermore, the government may want to prioritise which communities receive treatment first for specific reasons such as cost-recovery, which will create a selection bias.

Yet another method, if randomisation or pipeline comparison method is not possible, is *regression discontinuity design (RDD).* As with the other methods, it produces an estimate of the counterfactual through explicit programme assignment rules. It is an adequate method if the programme uses a continuous index to rank potential communities, such as a poverty index, whereby the cut-off point along the index determines whether or not potential communities receive the treatment (i.e. connection to the grid). Then, the communities just above the eligibility threshold are compared against the communities just below the eligibility threshold. However, this is not encouraged if few communities lie just above and just below the threshold, as the outcome assessed is only the local average impact around the eligibility cut-off. The estimate cannot be generalised to communities whose scores on the index are further away from the cut-off, because eligible and ineligible communities will no longer be similar. An average treatment effect for all programme participants then cannot be estimated.

Quasi-experimental methods for measuring impact of access and consumption of electricity

The three previous methods may not be possible if the programme assignment rules are less clear or there are no eligibility rules to determine communities that will be electrified. In this case, *difference-in-differences*, and *matching* techniques can be employed. They require much stronger assumptions than the randomised selection methods and hence are generally less robust. Although not used often in the quasi-experimental studies reviewed in this report, *Difference-in-differences* is the most robust quasi-experimental approach. Simply put, it compares the changes in outcomes over time between a treated community and a community that is not treated. Instead of simply taking a before-and-after estimate of the impact of the project in a community, difference-in-differences compares the before-and-after outcomes for the community that received the project (the first difference) and the before-and-after outcomes for the community that did not receive the project but was exposed to the same set of economic and environmental conditions. Then the difference between the difference in outcomes for the treated and the comparison is calculated. This controls for factors that are constant over time, as well as factors that are time-varying. However, the comparison group must accurately represent the change in outcomes that would have been experienced by the treatment group in order to be valid and must be subject to the same environmental and economic conditions.

Matching is the most common method used in the studies measuring causality at the micro-level reviewed by this report. The method uses observed characteristics identified through the baseline survey to construct a control community and is often used to deal with the problem of selection bias when estimating the impacts of treatments such as access to electricity in the community, household connection, privatisation of the electricity sector, and access to reliable electricity. Every treated community is matched to a control community based on observable characteristics that determine selection similar to the criteria mentioned in previous methods. However, it may be difficult to match on many characteristics, known as the curse of dimensionality, in which case the *propensity score matching* method is employed to try to match each enrolled community to a non-enrolled community based on similar scores of *probabilities* that a community will receive the project. The difference in outcomes between the matched comparison communities produces an estimated impact of the programme (for papers using PSM, see Banerjee *et al*. 2011; Khandker *et al*. 2012; Khandker *et al*. 2009a; Khandker *et al*. 2009b; Peters *et al*. 2011; Bensch *et al*. 2010; Komatsu *et al*. 2011b).

The dependent variable of these models is the connection status and several factors are tested for their impact on increasing the probability of connection. The selected covariates to be included in the probit model for their use in the matching process must be non-responsive to the connection status but must be able to affect both the decision to connect and the outcome variable. Hence probit models used for PSM do not include income, upfront costs, and tariffs as covariates, although they are likely to significantly affect the propensity to connect. As mentioned in the literature review, factors that are used in probit models for determining the probability of households to connect to the grid include: age of household head, sex of household head, education, household size, log of household landholding, price of other fuels, geographic characteristics, materials of house construction, availability of electricity, price of electricity, income, and ownership of appliances. Factors used in studies evaluated by this report that determine the probability of businesses to connect to the grid include: the entrepreneur’s age and gender and the quantity of the investment for firm creation.

However, matching does not control for unobservables and hence is much less robust and it requires large samples and extensive background characteristics. It can be combined with other techniques such as *difference-in-differences,* which accounts for time-invariant, unobserved heterogeneity.

Appendix 10 Baseline and endline survey criteria and indicators

Table A3 Baseline survey indicators

Criteria	Indicators
General population characteristics (not affected by treatment in the short to medium term)	Number of inhabitants Average age of village member Gender ratio Life expectancy Crime rates Average household size Head of household gender Quality of average dwelling Average size of landholding
Village extension	Km^2 (to estimate population density)
Access to roads	Access to all-weather roads
Distance to population/market nodes	Details of population, income levels and distance from the community of closer medium/large towns Distance to the grid, or to the nearest grid-connected community
Size of the local market	Income levels of the community
Economic activity	Describe what is the main source of income for the community, providing estimated income figures for: Services (including tourism): total income and share of micro, SME and large enterprises Industry: total income and share coming from micro, small, medium and large enterprises Agriculture: size of landholding, crops, income Livestock: type and size of herd, private or communal grazing areas, income Fishing: income Other
Market integration	Which per cent of the community output is exported (nationally and internationally) for: Services (tourism) Industry Agriculture Fishing Other
Current energy sources	What is the prevalent source of energy for lighting and operation of appliances such as radio, TV, irrigation pumps (if relevant), refrigeration, cooking, etc? Average price of primary fuel Any stand-alone electricity systems currently in place? Are they for public institutions, industry or households?

(Cont'd.)

Table A3 (cont'd.)

Criteria	Indicators
Access to resources	Tourism Agriculture Mining Natural resource endowment Per cent of lands, water, and grazing fields that are communal ICT (i.e. mobile network access) Access to loans: availability, number of institutions in community Access to micro-finance: availability of micro-finance, number of institutions in community
Geography characteristics	Average rainfall Altitude
Social services and institutions in the community	Does the community have: School Health centre Bank Post office Police force Experience with collective management systems for natural resources?
Business performance	Number of micro, small, medium and large enterprises in the community Working hours Employment Investment Revenues Productivity Profit
Household health	Cough incidence Respiratory ailments Eye irritation Headache Gastrointestinal problems Low birth weight and child mortality
Household income	Income per capita Farm income Non-farm income Expenditure Estimated per cent of population below the poverty line Employment in paid work
Household education	Years of schooling completed Study time (min/day) School enrolment

(Cont'd.)

Table A3 (cont'd.)

Criteria	Indicators
Women's time allocation	Women's time in income generation Women's time studying Women's leisure time Women's time in unpaid work Women's time cooking Women's fuel collection time Women's hours fetching water
Women empowerment	Participation in decisions on education and health index Independent decision-making on fertility Independent decision-making about children Share of women separated or divorced Acceptability of spousal abuse, son preference, autonomy and fertility.
Fertility	Number of children born in the last 5 years Contraceptive prevalence rate Number of children
Deforestation	Deforestation rate
Household appliance ownership	Number of mobile phones Number of TVs Number of electric lights Number of laptops, etc.

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