What level of electricity access is required to enable and sustain poverty reduction?

ANNEX 1 –
LITERATURE REVIEW

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Issue date: 27/01/2015
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Acknowledgements:

The authors are grateful to all those who contributed to the preparation of this report. In particular we wish to thank our partners Mary Willcox and Louise Waters of PAC who contributed to the development of the methodology and advised on the integration of this literature review into the overall study.

Thanks are also due to the Research and Evidence Divisions Policy Research Fund, which covered the cost of this research, and in particular to Alistair Wray and Hayley Sharp of DFID for their guidance throughout the work.

We would also like to acknowledge our debt to the team at WB/ESMAP whose work in developing the Global Tracking Framework for defining and measuring energy access we have drawn on extensively to assess access levels achieved by programmes, households and enterprises.

Contents

1. Introduction and Objectives

Lack of access to electricity is seen as a major constraint to economic growth and increased welfare in developing countries. Poverty is the main barrier to access for the people who currently lack energy services and supplies but lack of energy access is also one of the main contributing factors to poverty (Practical Action, 2012). If the energy supply does not come together with income generation opportunities there is in fact a poverty trap: poor people cannot get enough income to pay for energy access which in turn keeps their productivity low, making energy access unaffordable (IDS, 2003). The provision of enough quantity and quality of reliable and affordable electricity – i.e. a sufficiently high level of electricity access - is an essential part of breaking this trap.

Energy is crucial for enterprises. It drives economic and social development by increasing productivity, incomes, and employment; reducing workloads and freeing up time for other activities; and facilitating the availability of higher-quality or lower-priced products through local production. However, electricity in poor communities is mainly used for lighting, mobile charging and TV, which keeps consumption levels low and concentrated in a few hours of the evening. On one side, this jeopardises the financial sustainability of electrification projects and on another side, it limits its income generation potential (Pueyo et al, 2013).

Policymakers are therefore concerned with maximising the productive uses of electricity to support sustained poverty reduction. But electricity is not a silver bullet. Most authors agree that electricity is a necessary but not sufficient condition for increased income generation and poverty reduction. The pre-existing conditions in the areas to be electrified play a big role in the number and magnitude of potential positive impacts. Additionally, businesses not only need access to electricity to improve their performance but a sufficient and reliable service (Pueyo et al, 2013).

Policymakers aiming to maximise the transformative power of electricity are interested in answering two questions:

1. What level of electricity access is required to enable and sustain poverty reduction?
2. Which other factors need to be in place for electricity to be used productively and lead to income generation?

Responding to Question 2, previous evidence has shown that areas most likely to use electricity for income generation are those more economically developed, with access to new markets or a large local purchasing market, a solid pre-existing industry, access to finance and resources and skilled entrepreneurs capable of innovating and reaching new markets. When these preconditions are not in place, integrated development programmes should address the gaps through, for example: improved infrastructures (water supply, roads, telecommunications), access to credit or subsidies to pay for connection fees and purchase end-use technologies, capacity building and technical assistance for enterprise creation and for upgrading enterprises through the use of electricity. As part of the project PRODUSE, a manual has been developed to support electrification practitioners to promote the productive use of electricity (Brüderle et al, 2011).

Responding to Question 1, previous evidence has shown that the quality and performance of hardware, in particular low quality equipment and installation of Solar Home Systems (SHSs) and poor performance and unreliability of grid electricity, is one of the main barriers to increased use of modern energy services by the poor (Watson et al, 2012). The quality, availability and reliability of supply are also linked to low connection rates. For productive activities these attributes are even more important than the price of electricity to increase connection and use as industry can face high costs as a result of voltage drops or blackouts (Pueyo et al, 2013). Our study will build on the findings of previous literature reviews.

This review aims to provide further light on the questions above by identifying the links between different levels of access to electricity and their impact on poverty reduction as reported by existing evidence based literature. We aim at finding regularities between different levels of access and their poverty impact, bearing in mind that electricity is only one, and not the most important of the elements required for sustained poverty reduction. Our study will therefore acknowledge the constraints or enabling factors that prevent or promote agricultural or industrial uses and analyse their role in the success or failure of different levels of access to promote sustained poverty reduction.

2. Background

2.1. Importance of electricity for poverty reduction

Since the 1990s, electrification has come back to the top of international donor's agendas as a key element of poverty reduction strategies. It is seen as a necessary condition to achieve the Millennium Development Goals- MDG (DFID, 2002) and many rural electrification projects use the MDG as their main justification, although without robust evidence to back it up. 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[1]. It comes, however, after a period of thorough questioning about its potential to contribute to poverty reduction.

Evidence from the World Bank in the 1990s showed that the intense electrification activity in developing countries during the 70s and early 80s had delivered low economic returns, low cost recovery and little evidence of an impact on industrial development, income generation and poverty eradication (IEG, 1994). This evidence showed that 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, leaving vast numbers of rural population in the dark.

A recent change in perspective from these disappointing results means that electrification is seen again as essential for poverty reduction. Investments in electrification are justified on the basis of high willingness to pay for energy services exceeding the long-run marginal cost of supply (World Bank, 2008), and the perception of electricity as a basic human need. Still, most donors and the private sector point at the need of cost recovery tariff levels and least cost supply to achieve financial sustainability. Also, new interventions need to be designed to maximise their impact for the poor and avoid previous failures, mainly: low connection rates; limited productive uses; and poorly designed subsidies that benefit the better off, put utilities under financial stress and jeopardise service quality and reliability.

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[1] http://www.sustainableenergyforall.org/

2.2. Results of recent related literature reviews

This literature review builds on the work of previous related reviews on the topic, each of them dealing with particular aspects of the electrification-poverty reduction causal chain. There are several literature reviews on the topic of the poverty impact of electricity (for example Suarez 1995, Brenneman and Kerf 2002, AEAT 2003, Willoughby 2002, Bernard 2010, Cook 2011). We will focus on the results of three recent and very relevant ones.

Firstly, 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 remove these effective?". The review included all types of modern energy services. Electricity was the most commonly discussed modern energy service, covered in 22 of their 41 reviewed articles. 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 installation 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 skill levels 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 donor's technical support; and poor managerial skills to provide adequate after-sales services. Watson et al (2012) show that evidence for interventions to overcome these barriers is less robust. The weakest evidence relates particularly to political and cultural barriers and associated interventions.

Pueyo et al (2013) undertook a literature review of "The evidence of benefits for poor people of increased renewable electricity capacity". They split the causal chain between electricity generation capacity and poverty impacts into four links, expressed as four research questions:

- What is the link between increased renewable electricity capacity and higher availability and reliability of supply?
- What is the link between increased availability and reliability of electricity and actual connection and use by the poor?
- What is the link between electricity consumption and poverty impacts? and
- What is the link between electricity consumption and economic growth at the macro level?

The last three questions are particularly relevant to the main question of this review.

This review concluded that, as regards the relationship between increased availability 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. 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 can face high costs as a result of voltage drops or blackouts. 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 which tend to be more evenly spread through the day. This 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; insufficient knowledge about what for and how to operate 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.

Regarding the relationship between electricity consumption and poverty impacts, the review concluded that 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. 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. There is also robust evidence of positive impacts for women's empowerment. Improvements in education are widely and consistently reported. Evidence is weak regarding health and environmental improvements facilitated by the use of electricity. 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. A compilation of quantitative estimates of several income and non-income impacts of electricity for households is provided as part of Pueyo et al, (2013).

As regards the causal relationship between electricity consumption and economic growth at the macro level, the review found the evidence to be 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 for growth (UNDP, 2012).

Attigah and Mayer-Tasch (2013), as part of the report "Productive use of energy-PRODUSE", carry out a literature review on "the impact of electricity access on economic development". They find that the micro-level literature on productive use impacts of electrification programmes is generally inconclusive, indicating that access to and use of electricity but medium and small enterprises "does not automatically lead to intended development results such as increased productivity, profits and income, and knowledge on the conditions under which this is the case are still sketchy". They point at the highly country-and context-specificity of impacts that prevents drawing definite conclusions. They also underline that quality of electricity supply is highly heterogeneous but rarely measured or described, and that the quality of the literature is very diverse.

2.3. Levels of access to electricity

Traditional definitions of electricity access as a binary variable (the existence or not of a connection to electricity) fail to capture the amount of energy services that this connection can provide as well as its adequacy and reliability. Because the poverty impacts that electricity can realise depend on how much and for what it is used, the amount and quality of the service are crucial for understanding its poverty reduction potential. Binary measurements of access cannot provide this information.

For this reason, we have used the definition and measurement of access to electricity along various dimensions related to potential electricity services, as proposed in the Global Tracking Framework (GTF) of the SE4ALL initiative (SE4ALL, 2013). This multi-tier measurement of access to electricity measures access to electricity supply using multiple tiers, defined by increasing levels of supply attributes, including quantity (peak available capacity), duration/availability (number of hours), reliability (unscheduled outages); quality (level and stability); health and safety (electrocution, air pollution, burning risk, drudgery); legality; affordability (ability of enterprise to operate without reductions in production due to energy costs); and convenience (time and effort to source energy). Higher attributes lead to higher tiers and more and more electricity services become feasible. The GTF proposal is technology neutral and only looks at the services enabled by electricity, regardless of whether it is provided through on-grid, off-grid or mini-grid solutions.

Definitions of tiers of access are provided for both household and productive uses. A draft version of the multi-tier framework of energy access for productive uses is provided in Figure 1.

Figure 1: Multi-tier framework of energy access for productive uses

Attributes		Tier-0	Tier-1	Tier-2	Tier-3	Tier-4	Tier-5
Relevant application needed but not used due to energy related issues		True	False	False	False	False	False
1. Capacity Amount of energy required to support different levels of power loads	Electricity	<1W <2Wh/day	1W-50W 2Wh-200Wh/day	50W-200W 200Wh-1.2kWh/day	200W-2KW >1.2kWh/day	2KW-10KW -	>10KW -
	Fuels	N.A.[8]					
	RM&TE	Capacity does not cover needs (<25%)	Capacity partially covers needs (25%-75%)		Capacity largely covers needs (75%-100%)		Capacity totally covers needs
2. Duration/Availability (% of usage hours/quantity) Average time*/quantity** primary energy source available divided by the average time/quantity required. *Hours per day for electricity and RM&TE **Liters/Kg per month for fuels		Less than 25%	25%-50%	50%-75%	75%-100%		100% + no constraints in extending operating hours
3. Reliability (unscheduled outages) Unscheduled outages/breakdowns in energy access greater than 5 hours per month have (i) no or little impact, (ii) moderate impact, or (iii) severe impact on business operations		>5 hr per month with Severe impact			>5 hr per month with Moderate impact		<5hr per month or No/little impact
4. Quality (level and stability) Voltage/temperature/power level, drops or fluctuations (if observed) have (i) no or little impact, (ii) moderate impact, or (iii) severe impact on business operations		Quality issues reported with Severe impact			Quality issues reported with Moderate impact		No quality issues reported or No or little impact
5. Health & Safety (electrocution, air pollution, burning risk, drudgery) The energy supply system (incl. electricity, fuels, energy conversion equipment) has in the past or is likely to cause electrocution, pollution (fumes/smoke), burns or physical harm from drudgery (in the respondent's opinion)		• Self-made non-BLEN solution • Manufactured non-BLEN solution used indoors w/o smoke extraction • Any solution that has or is likely to cause **severe**[9] damage		• Manufactured non-BLEN solution used outdoors or indoors with smoke extraction • Any solution that has or is likely to cause **moderate**[10] damage		• BLEN (or other non-fuel) solutions that have not caused and are not likely to cause any damage requiring medical treatment, time off work or reduction in lifespan	
6. Legality* Energy supply is obtained legally *only for electricity		Illegal			Legal		
7. Affordability Ability of enterprise to operate without reductions in production or hours resulting from energy costs		Significant and frequent reductions			Slight or occasional reductions		Energy costs do not generally cause reductions in business operations
8. Convenience (time & effort sourcing energy) The time and effort spent in sourcing energy and maintaining the supply equipment does not cause significant inconvenience and does not significantly impact the work/productive activity		Not convenient				Convenient	

Source: WB/ESMAP (unpublished)

The official version of the GTF supply tiers for household electricity access is provided in Figure 2.

Figure 2: Multi-tier framework of energy access for productive uses[2]

	TIER 0	TIER 1	TIER 2	TIER 3	TIER 4	TIER 5
Quantity (peak available capacity)	—	>1W	>50W	>200W	>2,000 W	>2,000 W
Duration of supply (hours)	—	>4	>4	>8	>16	>22
Evening supply	—	>2	>2	>2	4	4
Affordability (of a standard consumption package)	—	—	Affordable	Affordable	Affordable	Affordable
Legality	—	—	—	Legal	Legal	Legal
Quality (voltage)	—	—	—	Adequate	Adequate	Adequate

The uses that each quantity of electricity can provided are well known, and good examples are provided by the GTF report. For example, a very low power capacity system between 1 and 50W allows the use of lighting, small information and communication technologies (mobile phones, handheld computer devices, digital cameras, radio and small B&W TV); small tools such as saws or spinning wheels and a small table fan. Beyond 50W but lower than 500W capacity, electricity can enable the use of a much wider number of appliances, such as personal computers, printers and colour TVs, a small grain mill, drill machines, small water pumps, industrial sewing machines, domestic freezers/refrigerators and slow cookers. Between 500W and 2kW the uses are more diverse, including for example drilling machines, milling machines, domestic washing machines, tea dryers, hair dryers and portable steam generators. Examples of additional uses for a capacity between 2-10kW include central air conditioners, cold rooms, metal arc welding machines, pasteurisers, clothes irons, domestic water heaters and electric hobs. Very high power appliances of more than 10kW include industrial air conditioners, server rooms, central water heating systems, commercial catering ovens or an industrial forge. In addition to the quantity of electricity, reliability and voltage stability are key for many industries, such as the manufacture of microprocessors, tea processing or the food industry that requires refrigeration through the value chain of perishable products. Manufacturing companies may have to discard half-finished products if unscheduled outages stop the production process and electrical machines can break down due to voltage fluctuations.

In any case, whether or not electricity is actually used for the uses it enables depends not only on the quantity, quality, reliability and affordability of supply but on a set of enabling conditions, as will be discussed in this review.

[2] © International Energy Agency and World Bank, 2013.

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 highly diverse in the methodologies used and the topics analysed. 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 area 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 other forms, including Multilateral Development Banks’ and other donors’ impact evaluations, 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) describes 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.

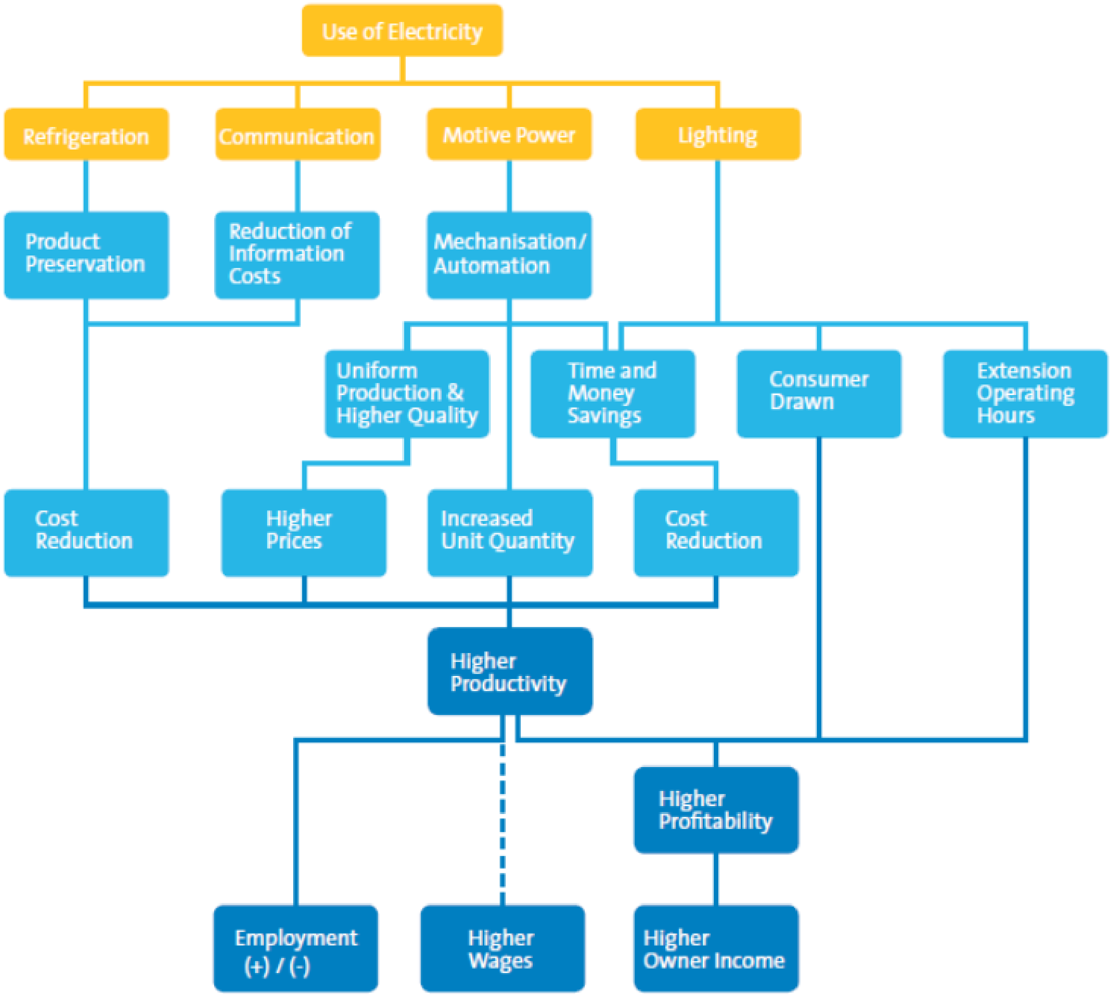
3.2. Conceptualising and interrogating the causal chain

A number of prominent publications and initiatives have made the case for the importance of electricity access for productive uses and the ensuing poverty reduction impacts. Most authors agree that electricity is a necessary but not sufficient condition for increased income generation and poverty reduction.

Although it is widely believed by policy-makers that electricity access is a prerequisite for promoting productive uses and economic development, there is little robust empirical evidence linking the provision of electricity and the creation of enterprises or the improved performance of existing ones. Figure 3 presents the steps between gaining electricity access and improved productive use; the relationship consists of several steps and many contextual factors in each step that greatly complicate evidence gathering and analysis. We may note that this figure does not include use of electricity for heating applications (cooking/water heating/

product heating/space heating), which could also lead to productive uses and income generation.

Figure 3: Pathways from electricity to income generation



Source: Mayer-Tasch et al, 2013

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.

Against this background the review sought to provide an answer to the question:

"What level of electricity access is required to enable and sustain poverty reduction?"

To support a structured and rigorous review and provide meaningful conclusions this overall question has been broken down into a number of sub-questions that can link the intervention “provision of different levels of electricity access” with the impact “enabling and sustaining poverty reduction”. We proposed that the causal chain is split into two links:

1. **Under what circumstances do different levels of electricity access lead to productive uses?**
2. **Under what circumstances do productive uses enabled by electricity lead to income generation/poverty reduction?**

Firstly, the different “levels of electricity access” have been defined. For this we drew on the framework for measuring access to energy for productive uses currently under development as part of the Global Tracking Framework (GTF) for the SE4All initiative (2013).

Instead of the traditional binary approach, the GTF defines 6 tiers of energy access for productive uses. Tiers are defined not only in terms of access to energy supply but also in terms of energy applications for productive uses. Applications include: light, ICT and entertainment, motive power, space heating and cooling, product heating and water heating. What differentiates electricity from other primary sources of energy is that its productive use is always related to the ownership of appropriate electrical equipment.

Tiers of access are defined according to different levels of capacity, duration, availability, reliability (unscheduled outages), quality (level and stability), health and safety, legality, affordability and convenience.

Different tiers of access to electricity supply enable different applications and related productive uses. As a result of the productive use of electricity, several direct impacts could take place, such as:

- Lower costs of production, due to less labour needed, lower costs of energy, the preservation of products for a longer time, the reduction of information costs
- Improved access to product markets, which may translate into higher sales volumes and/or prices
- Higher quality of products and services, which may translate into higher prices
- Increased volume of production and/or range of products
- Development of new enterprises
- Attraction of additional consumers
- Extension of operating hours, which may translate into higher production or sales

In addition to these direct impacts, electricity may contribute to indirect impacts, mainly higher profitability and income for the owner of the businesses, higher employment and higher wages, which may be expected to . Increases in income for poor people would contribute to raise them out of poverty reduction.

However, access to electricity supply is not enough to trigger productive uses. These depend on a number of other enabling factors, such as:

- Financial situation of businesses.
- Appliances/equipment ownership. 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 what for and how to use electrical machines. The physical availability of suitable equipment in the locality is also an important factor.
- Pre-existing productive activities. The local industry and agriculture businesses can create a significant, relatively steady initial demand for electricity and contribute to an important share of its initial costs.
- Skills to identify the new business opportunities created by electricity, to use electrical equipment efficiently and to find and access new markets for the new products and services provided.
- Markets for the additional production. 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.
- Integrated development programs. These include roads that allow access to external markets, access to credit to purchase end-use technologies, training programs 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.
- User awareness and time. It takes time for users to learn about the different services that electricity can provide. Experience shows that low electricity consumption levels after electrification give way to higher consumption after a few years.

To achieve meaningful conclusions regarding the linkage between provision of improved electricity supply and impacts on poverty it has been therefore necessary to establish which factors enable utilisation of available electricity access for productive purposes, and which factors contribute to these productive uses leading to additional income generation.   The synthesis of the literature looked at these issues by questioning each paper on whether or not electricity had led to income generation or other variables such as increased productivity, poverty reduction, employment, etc. When these impacts were reported, we looked at the mechanisms through which improvements had taken place and the specific productive activities that had enabled them, if any.

3.3. Searches

3.3.1. Approach

The search for the relevant literature was conducted in five ways:

- Identifying the relevant studies from IDS (2013) previous literature review on "The evidence of benefits for poor people of increased renewable electricity capacity". Out of the 140 studies considered as relevant for the previous study, we selected those dealing with income-related impacts of electricity or identifying productive uses of electricity.
- Update of searches from IDS previous literature review. The previous review only covers studies up to 2013. We extended the previous searches to include also studies published in 2013 and 2014.
- New searches. We searched databases with a new search string specifically related to productive uses of electricity for development or poverty reduction.
- Snowballing. We identified the key literature referred to in recent publications on the productive uses to electricity, mainly reports published in 2013 as part of the project "Productive Use of Energy - PRODUSE"[3].
- Incorporating relevant studies identified by PAC and TERI, particularly those related to electricity access interventions in India and Kenya.

3.3.2. 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

[3] www.produse.org/

In addition to articles extracted from bibliographic databases, our review also included 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.

3.3.3. Search strings

Each of the databases above was questioned for a string of search terms included in Appendix A.

The search strings used for this review built on the recent experience of IDS in undertaking a literature review of the "evidence of benefits for poor people of increased renewable electricity capacity". In that review, IDS identified the different steps linking electricity capacity to poverty impacts. These included, among others, the relationship between increased availability and reliability of electricity and actual consumption by the poor, and the relationship between electricity consumption and poverty impacts. The findings of the previous review on these relationships were highly relevant for the proposed literature review but mainly covered results up to 2013.

Drawing from existing database and literature, the current study expanded the search databases to include recent studies and publications which were published in 2013 and 2014. By doing so, the search process and literature review aimed to ensure that all up to date studies and evidence were included in this review given the scope of the research question.

We also carried new searches, not restricted to the last two years, to make sure that we did not omit literature related to the productive uses of electricity and its impact on poverty reduction and development.

3.4. Study inclusion criteria

3.4.1. Relevance

We included those studies that provided an answer to the leading question of our review and its two related sub-questions:

"What level of electricity access is required to enable and sustain poverty reduction?"

1. **Under what circumstances do different levels of electricity access lead to productive uses?**
2. **Under what circumstances do productive uses enabled by electricity lead to income generation/poverty reduction?**

3.4.2. Electricity systems

Electricity is a homogeneous service and its effects on poverty are expected to be similar regardless of the generation source. Therefore the impact of electricity was taken into account regardless of how it was generated. We classified studies as on-grid, mini-grids and stand-alone systems, and for the last two we also indicated if they use renewable or non-renewable sources.

3.4.3. Definition of levels of electricity access

We classified the different levels of electricity supply based on the Global Tracking Framework for energy access for defining and measuring energy access for productive uses, still under development, but provided in a draft version by Practical Action.

The draft framework for defining and measuring energy access for productive uses defines 6 possible tiers of access according to 8 attributes. For each attribute, a tier is assigned based on the respondents answer. The lowest of the tiers is applied to obtain the overall tier rating for the application. The 8 attributes used to evaluate the level of access are: peak available capacity (watts or kWh/day, depending on generation type), duration (hours), reliability (unscheduled outages), quality (level and stability), health and safety (electrocution, air pollution, burning risk, drudgery), legality, affordability and convenience.

The framework also defines 6 types of productive use applications: lighting, ICT & entertainment, motive power, space heating, product heating and water heating.

3.4.4. Definition of poverty

The aim of this study is to assess how electricity supply can enable and sustain poverty reduction. We understand that a sustained poverty reduction is only possible through electricity uses that enable income generation. Therefore, we narrowed down our target studies to include only those that refer to the productive use of electricity. Productive use of electricity were examined vis-à-vis its impact on income generation on the household and enterprise levels. Poverty reduction was therefore examined in terms of productivity, competitiveness, employment generation, enterprise revenue, sustainability of enterprises and overall impact on household income and expenditures. The impact of electricity on other important dimensions of poverty, such as health, education, women's empowerment and welfare have not been part of this literature review, due to time and budget constraints and because they were extensively covered in a recent literature review by Pueyo et al (2013).

3.4.5. Macro or micro-level

Macro-level literature looks at causality between electricity consumption and economic growth, productivity growth or poverty reduction at the country or regional level. Good reviews of this literature are provided in PRODUSE (2013) and IDS (2013). We did not focus on macro-level literature because existing studies take electricity consumption or infrastructure investments as their explanatory variable, without taking into account different levels of electricity access. They could not therefore provide an answer to the question that this study aimed to clarify.

Our review looked at literature examining the impacts of electricity at the micro-level. Our focus was therefore on studies that were able to link specific electrification interventions to business performance, income generation and poverty reduction through household and enterprise surveys or case studies. Ideally, studies at the micro-level were able to provide some information on the level of access to electricity according to all or some criteria included in the GTF: quantity, reliability, quality, affordability, availability, legality, convenience and health and safety.

3.4.6. Geographical scope

Following the 2010 bilateral aid review, DFID's 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. Therefore we proposed to consider evidence from all developing countries (i.e. low-income or middle-income countries, as defined by the World Bank).

3.4.7. 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 has been the case at the level of a household or at the economy-wide level. When reviewed studies explicitly included it, we detailed the time of the intervention analysed. However many studies only referred to the impacts of "electrification" without indicating when electricity was made available.

3.4.8. Methodological approach

Following DFID's terminology (DFID, 2013), we only included 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 'randomized 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 counter-factual 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, not such studies have been found on the poverty impacts of access to electricity. This is due to the difficulty of randomly allocating access to electricity, given the high up-front costs of grid extension and off-grid systems, which requires some planning.

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.

3.4.9. 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 to be 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 indicated 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 to be found by databases delivering a large number of results were screened for relevance. A first screening by title allowed for the reduction of the studies.

The selected 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 undertaken for relevance assessment. 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 reviewed is 71 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 Table 1.

Table 1: 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 'signpost' the reader throughout
	The conclusions are clearly based on the study's results

Source: DFID, 2003

In addition to DfID's principles, we 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 took into account confounding factors that may be causing benefits for the poor apart from electricity (control variables); defined an appropriate and credible comparison group (the counterfactual); chose a representative sample; in the case of panels there was a pre-intervention baseline survey so that differences between control and treated could be assessed; corrected for potential endogeneity of the electrification variable; and justified the selection of particular specification methods. The highest quality studies consisted of quasi-experimental approaches with non-random treatment assignment that had a proper argumentation about how selection bias is controlled for. Some high quality approaches were:

- 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 Difference (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 determine treatment is actually exogenous.
- OLS provided that it contains some argument or additional techniques to assess selection bias, omitted variable bias, etc.

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

Qualitative studies meeting DfID principles of high quality and showing causality were also considered as high quality. As per IDS literature review (2013);

> “Descriptive literature can provide more in-depth insights on the links between electricity and income generation. 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.”

Even though high quality studies will be given more weight, all studies are considered in our synthesis.

3.7. Data extraction strategy

All studies passing the title screening were stored in information management software (Mendeley and EndNote). The screening at abstract/full text level was recorded in an Excel spreadsheet. For each included paper, descriptive information was recorded in an Excel spreadsheet. A data extraction form showing all fields considered is presented in Table 2:

Table 2: Data Extraction Form

General information	Full bibliographic reference
Year of publication	Year
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
Method	• Quantitative • Qualitative • Both
Quality	• High • Moderate • Low
Sophistication of the analysis	• Describes impacts • Quantifies impacts • Tests causality
Time between intervention and analysis of impacts	Years

Geographical coverage		(Detail countries)
Households or businesses		• Households • Businesses • Both
Electricity system		• Grid extension • Mini-grids • Stand-alone systems
Energy source		• Wind • Hydro • Biomass • Solar PV • Fossil fuels • Human/animal power
Tiers of electricity supply	Capacity	Grid/mini-grid/fossil-fuel powered systems: • Tier 0 - < 1W • Tier 1 - 1W - 50W • Tier 2 - 50W - 200W • Tier 3 - 200W - 2kW • Tier 4 - 2kW - 10kW • Tier 5 - >10kW • Standalone systems (not fossil-fuel powered): • Tier 0 - < 2Wh/day • Tier 1 - 2Wh – 200Wh/day • Tier 2 - 200Wh – 1.2kWh/day • Tier 3 - > 1.2kWh/day
	Duration/ availability	Number of hours per day available vs. number of hours required[4]
	Reliability	• 5 hours per month unscheduled interruption with severe impact (Tier 2) • 5 hours per month unscheduled interruption with moderate impact (Tier 4) • < 5 hours per month unscheduled interruption or no/little impact (Tier 5)

[4] If information on number of hours for which electricity is required is not available, it is assumed to be 8 hrs/day

Tiers of electricity supply (continued)	Quality	• High (Tier 5) - No problems of low or fluctuating voltage or frequency • Moderate (Tier 4) - Problems of low or fluctuating voltage or frequency with little/moderate impact • Low (Tier 2) - problems of low or fluctuating voltage or frequency
	Legality	• Legal (Tier 5) • Illegal (Tier 2)
	Affordability	• Affordable (Tier 5) - the cost of electricity does not generally cause reductions in business operations • Semi-affordable (Tier 4) - Slight or occasional reductions in business operations • Not affordable (Tier 2) - The cost of electricity causes significant and frequent reductions in business operations
Level of access[5]	• Tier 0 • Tier 1 • Tier 2 • Tier 3 • Tier 4 • Tier 5	
Applications	• Lighting • ICT & Entertainment • Motive power (including cooling) • Space heating • Product heating • Water heating	
Type of business	• Agriculture (mainly irrigation) • Services (multiple choice of activities) • Manufacture (multiple choice of activities)	

[5] The overall level of access is derived from the lowest ranking assigned to any one of the attributes above

Impacts of productive use of electricity	• Lower production costs • Better product/service quality • Extension of operating hours • More consumers attracted • Increased production • Higher revenues • Higher productivity • Higher income • Higher wages of employees • Increased employment • Creation of new enterprises • Higher investment
Negative impacts of productive uses of electricity	• Crowding-out effects- No net income generation • Increased debt • Financial problems • Inequity • Less employment • Lower wages • Other
Factors that enable income-related impacts of productive uses	• Users' income • Affordability of connection fee • Ability to pay for appliances/equipment • Access to finance • Electricity essential for operation • Access to external markets • Size of the local market • Pre-existing productive activities • Other infrastructures: roads, telecoms • Skills of users • Services to support business creation • Location close to exploitable resources • Control over monthly bill • Other (detail)

In addition to the excel database, a short summary of each study was recorded in Word format, providing the following information:

- Brief description of the methodology and comment about quality/reliability of results
- Tier of access to electricity and assumptions made to determine it
- How does the quality of electricity supply promote or prevent productive uses and income generation?
- Does access to electricity lead to increased income generation?
- How does income generation happen?

- What are the constraining or enabling factors for income generation through electricity?

3.8. Data synthesis and presentation

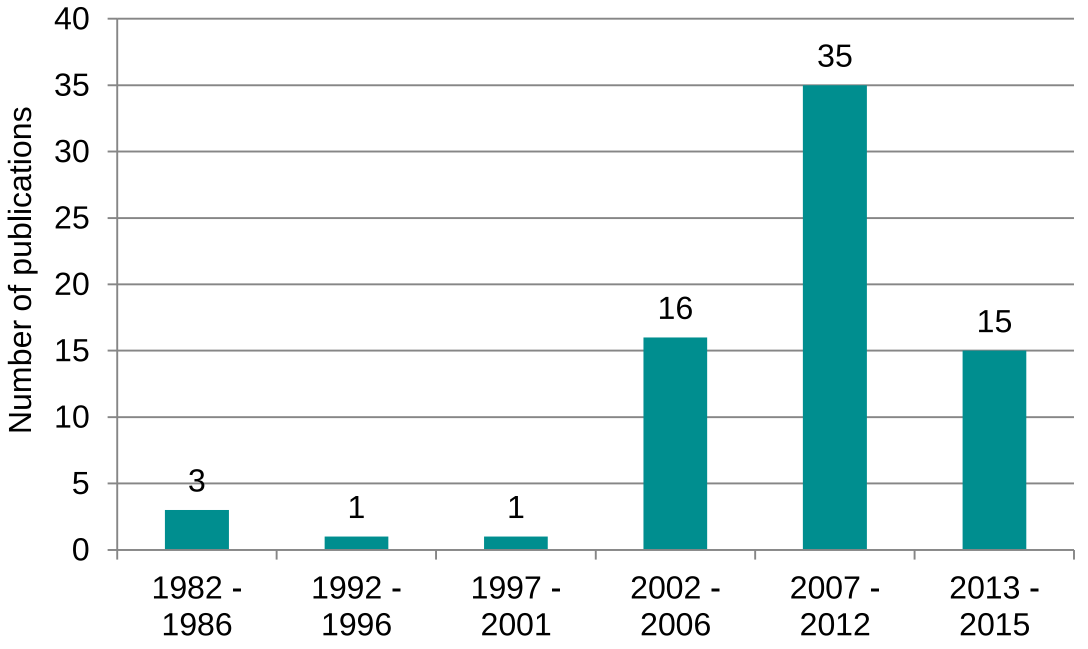
The synthesis provides a high level description of the existing literature, the details of the included studies and explores regularities in evidence as regards:

- Different levels of access to electricity and increases in productive activity;
- Increases in productive activity and poverty related impacts;
- Different levels of access to electricity and poverty related impacts.

4. Survey of the Literature Reviewed

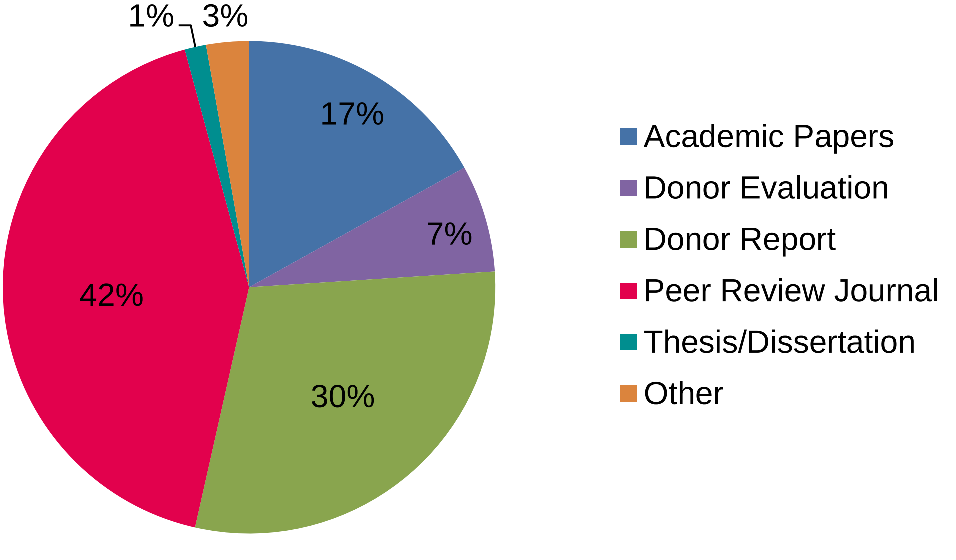
In total 71 studies were reviewed. The graph indicates that the majority of the studies included in the review covered the last 10 years (2004-2014), with a main concentration for studies between 2007 and 2012. Very few studies cover the period between 1982 and 2001, even though no time constraints were placed in our search.

Figure 4: Studies per publication date



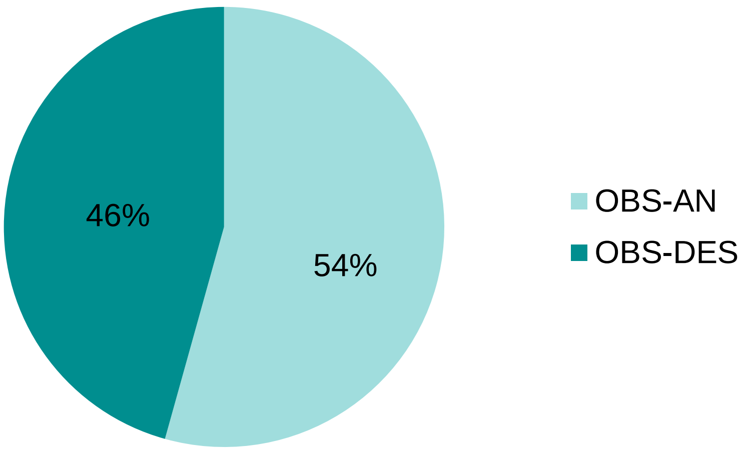
The majority of the publications are from peer reviewed journals (42%) and donor reports including impact evaluations (30%).

Figure 5: Studies per type of publication



Methodologically, there is a balanced representation of analytical and descriptive literature.

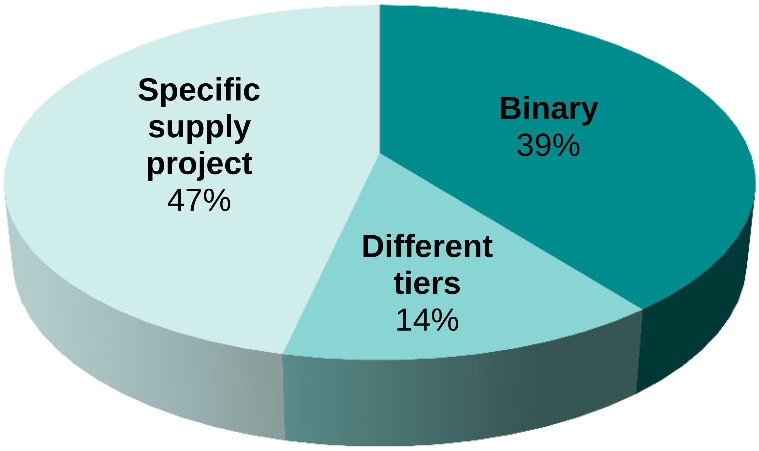
Figure 6: Studies per research design



Given the large scope of the literature review, to facilitate the synthesis process, each paper was classified under one of 3 main categories:

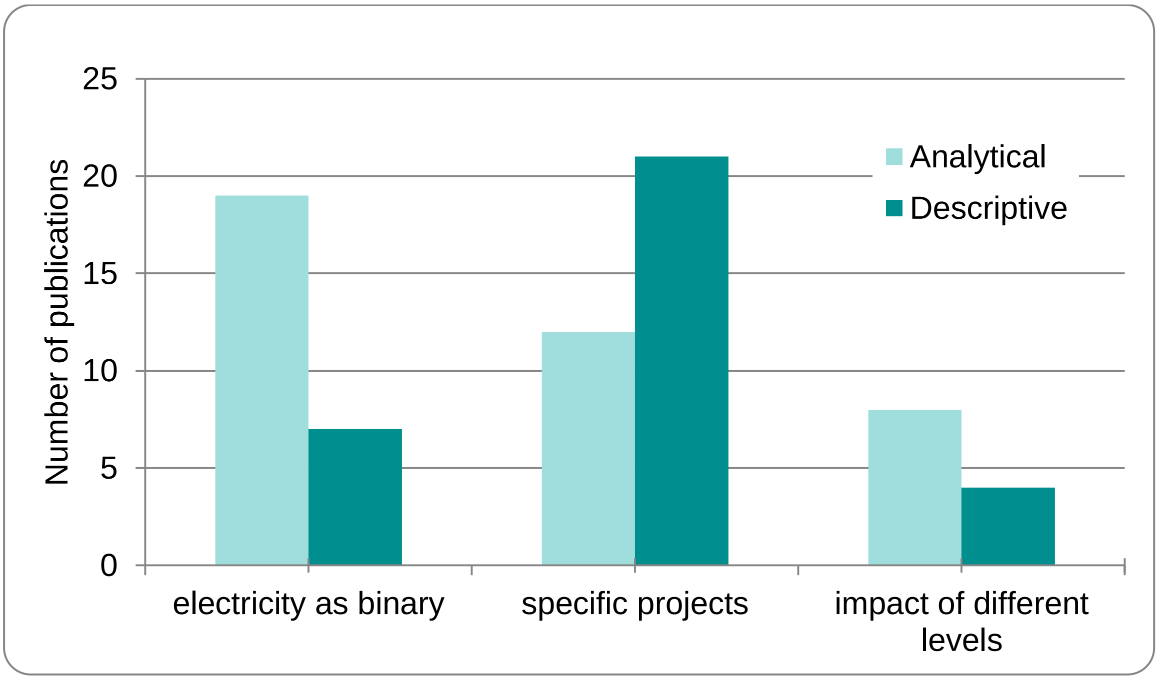
- Binary. These consider access to electricity as a binary variable: yes or no, without taking into account the different levels/qualities of supply of the population analysed. Also, they base their analysis on large surveys or multiple case studies with population likely to have different levels of access. Therefore, a specific tier of access cannot be assumed for our analysis.
- Project- or community-specific. Look at the impacts of particular electrification projects or on a particular community or communities. Most of them consider electricity access as binary, but often they provide some information about the capacity of the systems, the energy services provided, the availability or reliability of supply that allow us to deduce a specific tier of access.
- Different tiers. This literature acknowledges that different levels of access to electricity can achieve different poverty impacts and describe or quantify these. It is the smallest group, as literature has traditionally ignored that access to electricity is not homogenous, and that different levels of access can enable different uses and hence achieve different poverty impacts.

Figure 7: Studies per types of analysis



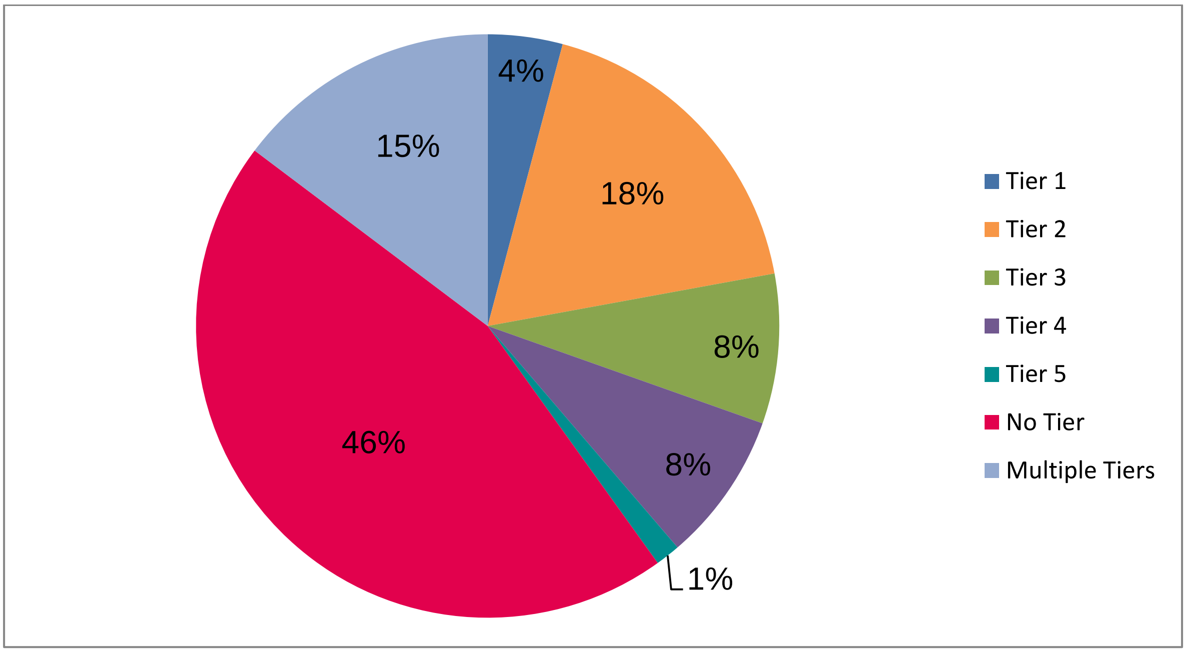
Studies that treat electricity as a binary variable and focus on large samples for their analysis use predominantly analytical approaches. Studies focusing on specific communities or electrification projects tend to use descriptive approaches and those that acknowledge the different impacts that different levels of access can achieve are also mostly quantitative.

Figure 8: Research design per type of analysis



Most papers included in the review did not contain enough information to allow us to deduce a tier of electricity access (46%), while others included several case studies or samples representing multiple tiers of access to electricity (15%). The remaining papers were divided amongst the different tiers as shown in the figure, with most papers representing tiers 2 (18%) and tier 3 (8%).

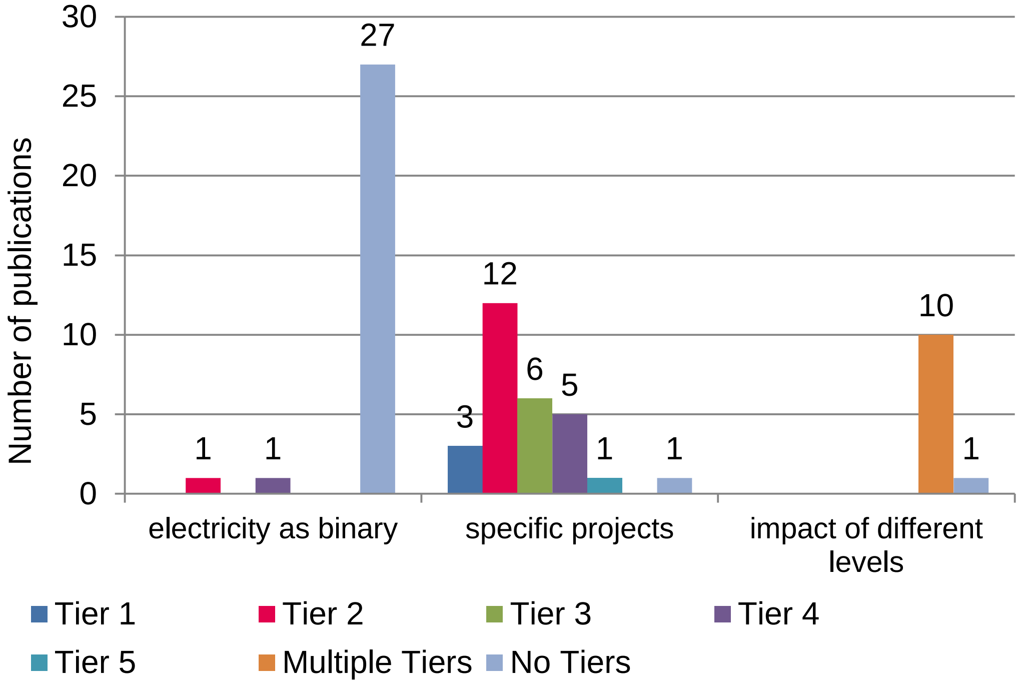
Figure 9: Tiers of electricity identified for the reviewed papers



Consistent with our classification of papers in three groups, those that treat electricity access as a binary variable and study their impact on large samples or case studies, usually don't allow us to infer a specific tier[6]. Studies looking at the impact of specific electrification projects or on specific communities allow us to deduce tiers and show tiers of access 2 and 3 as the most frequently reported. Finally, studies that acknowledge the different impacts of different levels of supply tend to provide information on several tiers.

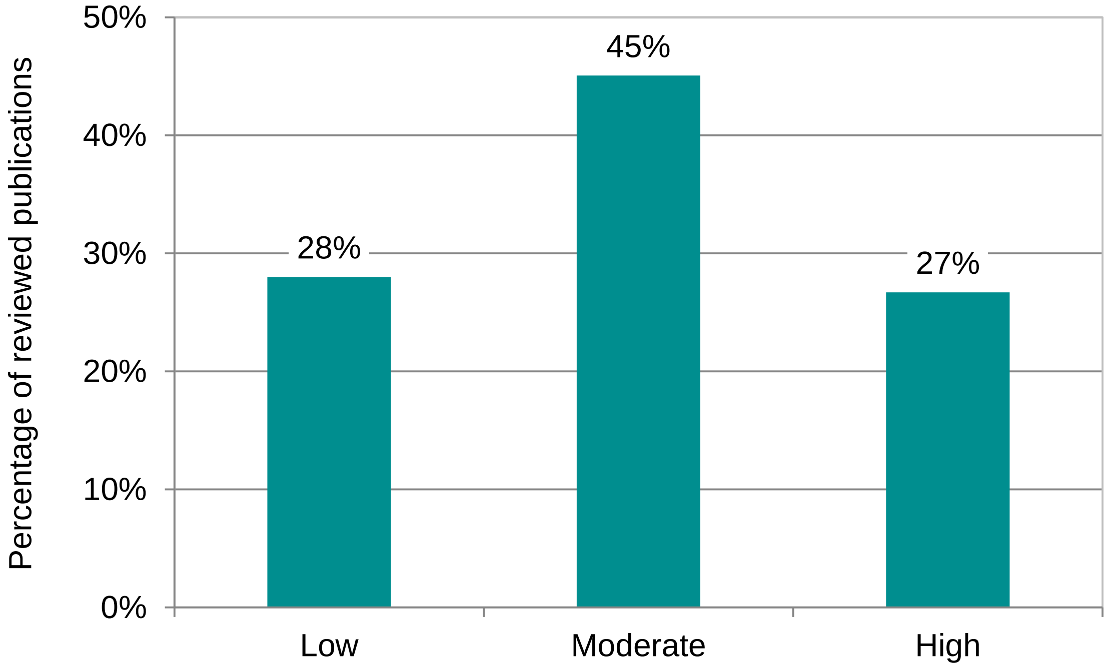
[6] Rarely, 'binary' papers will contain enough information to assume a tier level.

Figure 10: Tiers of electricity identified under each type of analysis



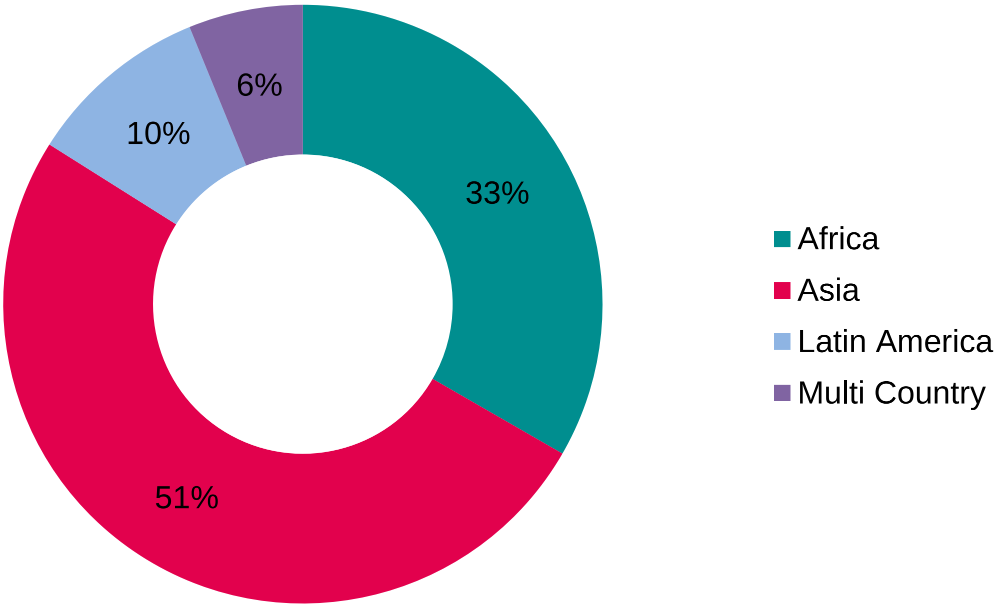
27 per cent of reviewed studies are considered high quality, 45 per cent are of moderate quality and 28 per cent are low-quality studies, according to the criteria described in the methodology section.

Figure 11: Studies per quality category



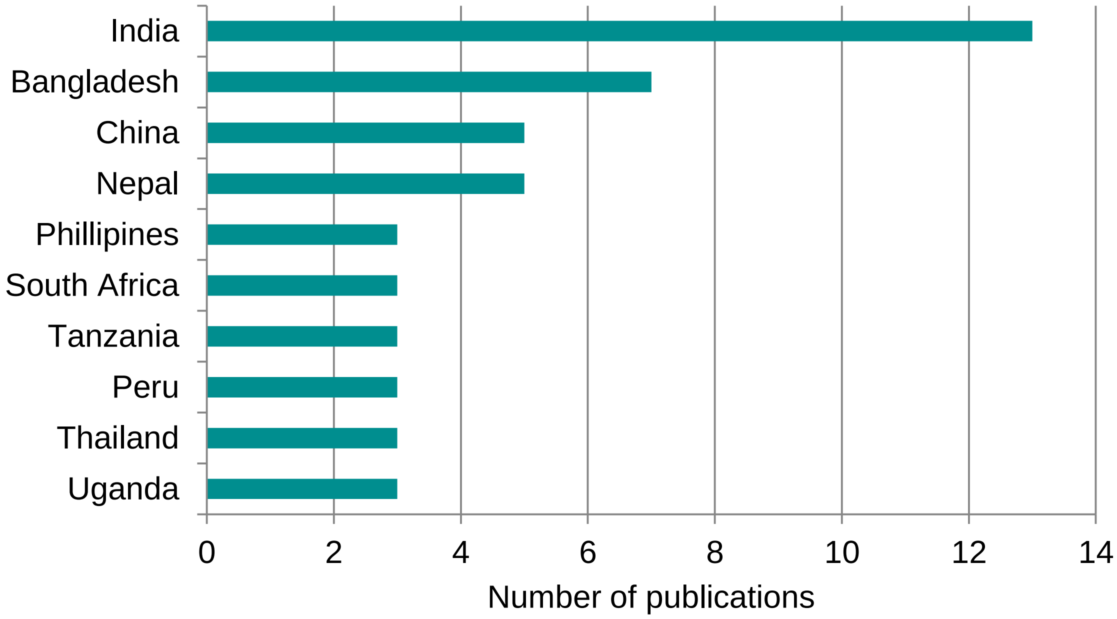
The majority of the studies cover primarily Asia (51 percent), followed by Africa (33 percent) and Latin America with a small share (10 percent). Others covered several countries from different geographies, limited to 6 percent of the total studies included in this review.

Figure 12: Percentage of studies covering geographic areas



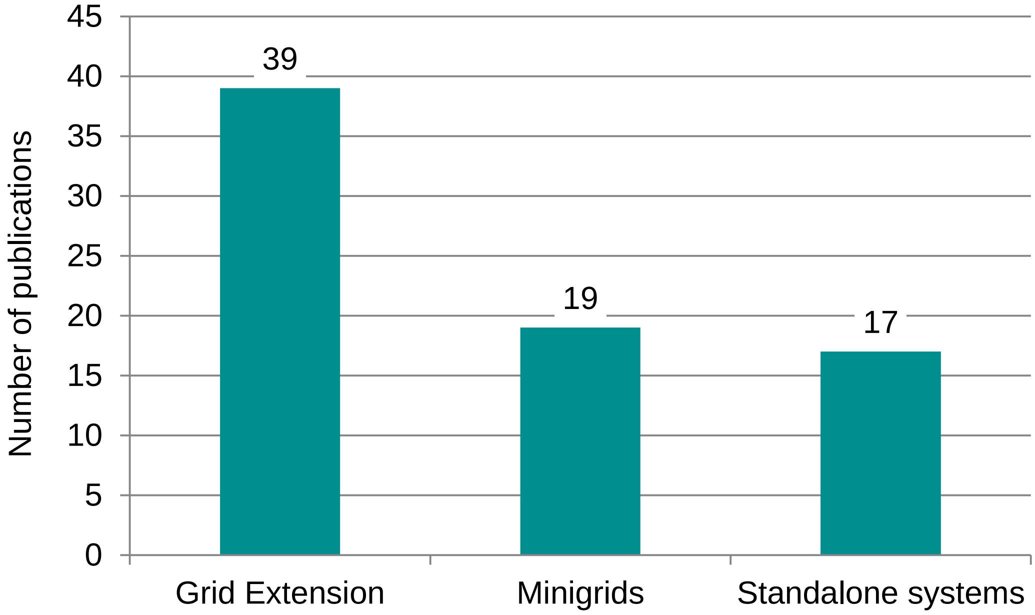
The most widely analysed country is India, followed by Bangladesh. This is understandable as India has by far the largest electricity access deficit in the world, exceeding 300 million people. Bangladesh is the third country with the largest access deficit, with 66.6 million without electricity, after Nigeria (SE4ALL, 2013).

Figure 13: Number of studies per analysed country



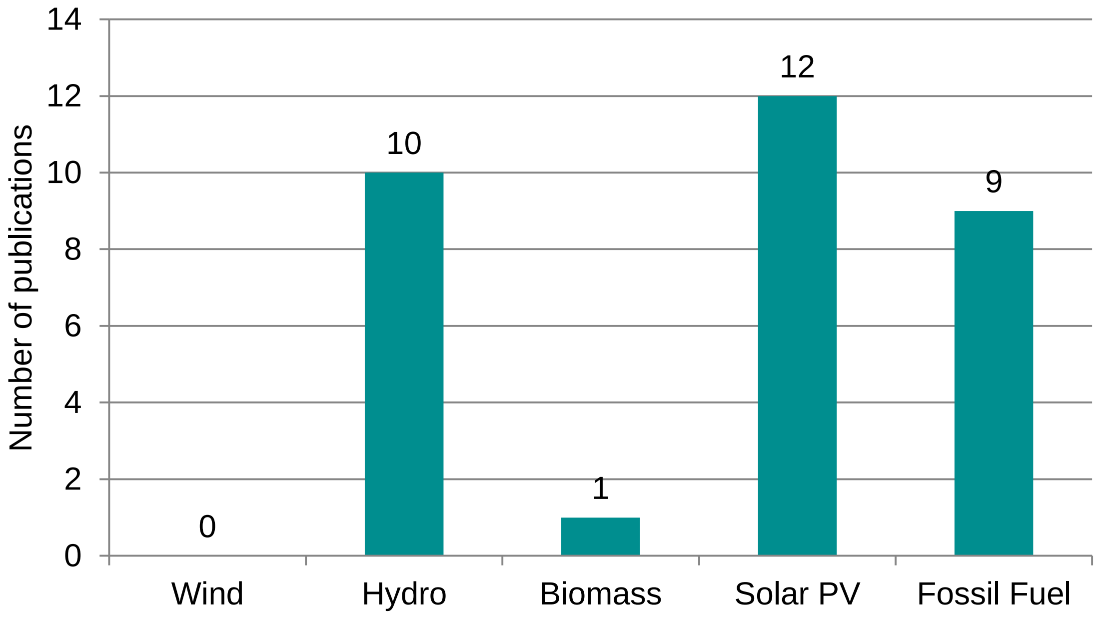
The majority of studies look at access to electricity provided through the grid, with a similar number of the rest of studies looking at mini-grids and stand-alone systems, mainly SHS.

Figure 14: Number of studies per electricity system



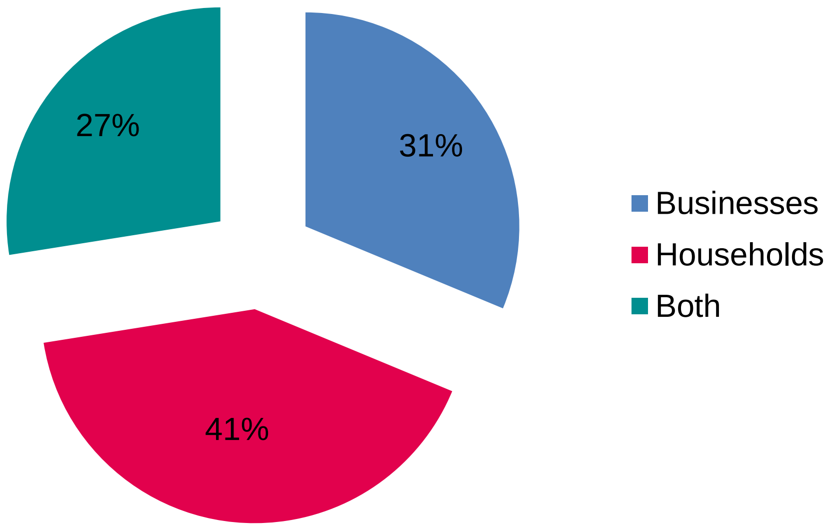
Those studies that provided information on the energy source for electricity generation show solar as the main source, followed by hydro and fossil fuels.

Figure 15: Number of studies covering specific generation technologies



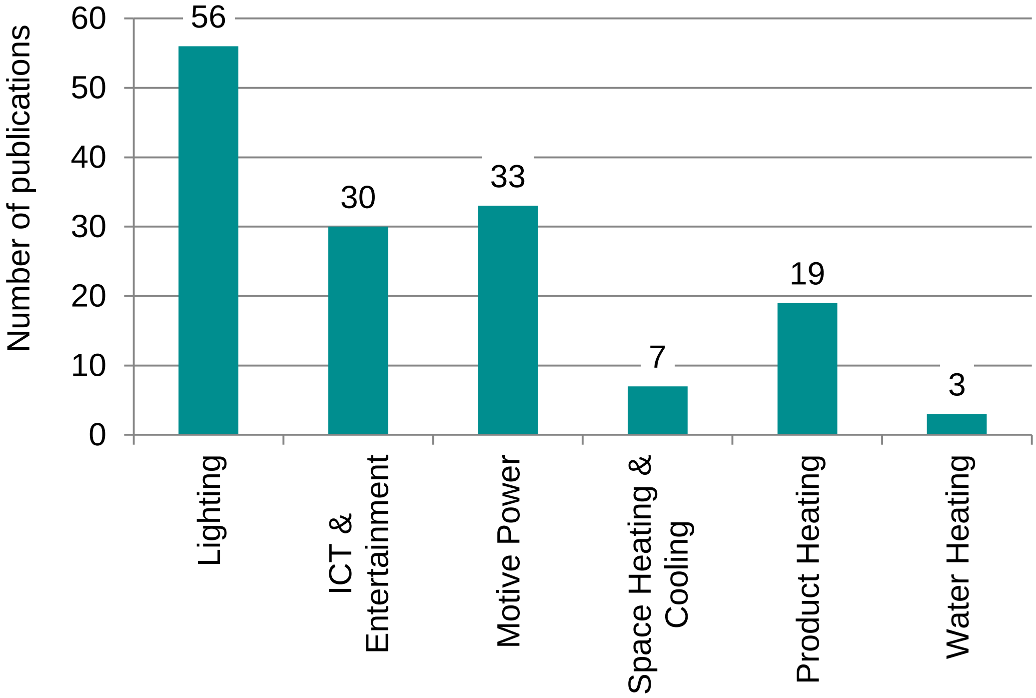
41 percent of the studies included in the review looked at impacts on households, 31 percent look at impacts on businesses and 27 percent cover both.

Figure 16: Breakdown of studies covering households, businesses or both



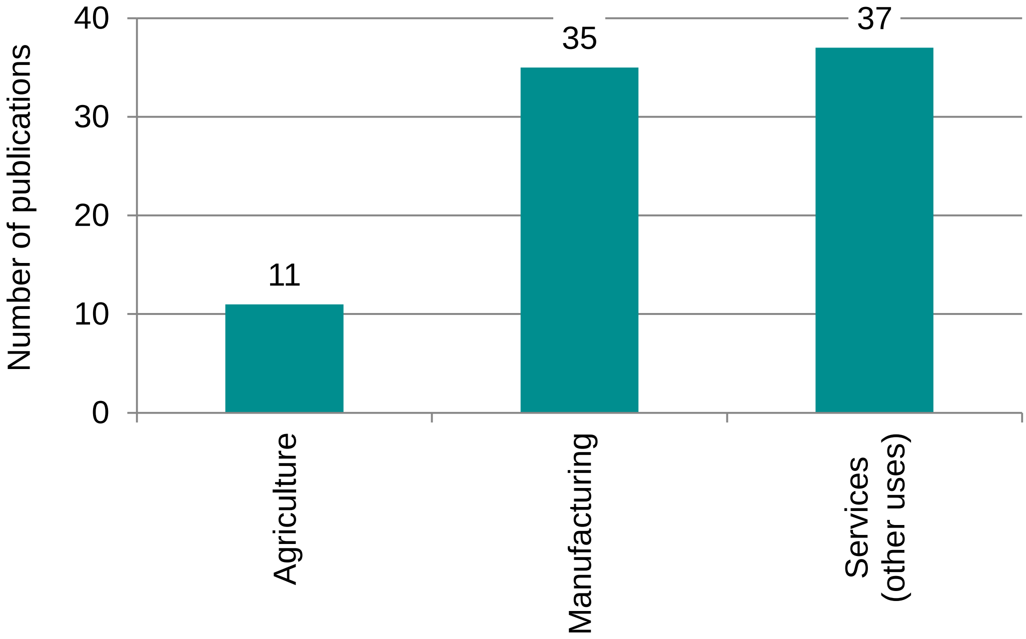
Lighting is by far the most widely reported application of electricity, followed by motive power for uses such as grain mills, irrigation or manufacture, and closely after by ICT and entertainment, such as music or TV.

Figure 17: Number of studies referring to applications of electricity for productive uses



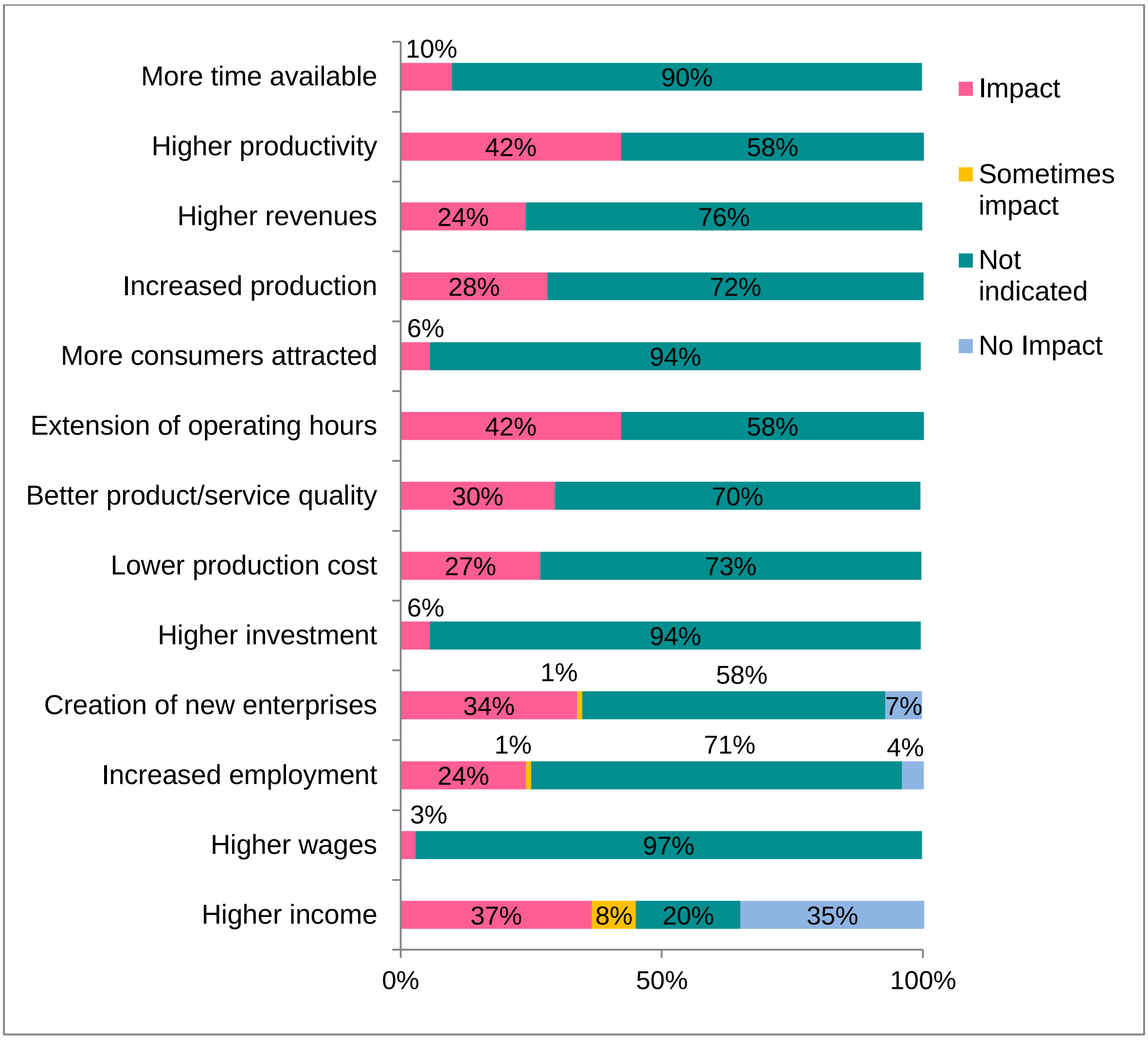
Most studies refer to electricity use for manufacturing or in the sevice sector (in almost equal numbers), while a smaller proportion refer to agricultural uses. It is worth noting that productive uses under the manufacturing sector category include a range of activities such as milling (Grain, Cassava, Oil, etc..), tailoring and food processing. The services sector includes mobile shops, barbers, electricians, and other services. Agriculture mainly refers to productive uses related to irrigation. It is also important to realise that some of the reviewed papers indicated productive uses in more than one sector, while others were mainly confined to one sector.

Figure 18: Number of studies referring to types of businesses per sector



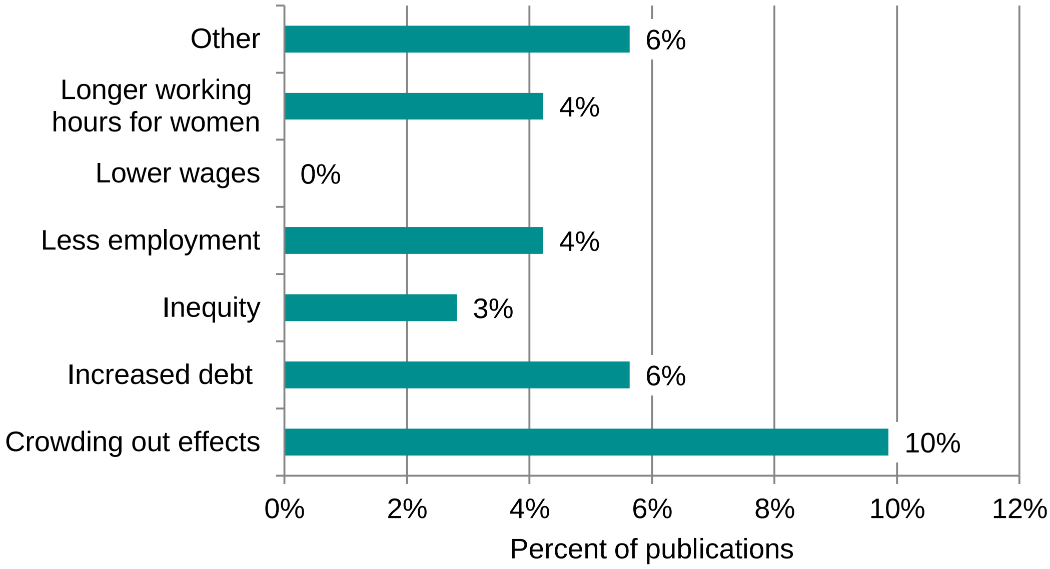
The figures below show, for each type of potential impact, what percentage of papers analysed it and found that there was a positive impact, what percentage analysed it and found no significant impact, what percentage found that the impact takes place in some circumstances, and what percentage did not analyse this issue. The most widely analysed impact of access to electricity is income generation, with 80% of the papers giving it consideration. However, only 37% of studies found a positive impact of electricity on income generation, and a similar percentage (35%) found that this impact was either minimal or non-existent. Therefore, and as will be further explained in the synthesis section, the literature is not conclusive on this topic. The creation of new enterprises is another issue widely studied in the literature, but in this case most studies analysing the topic agree on the positive impact of electrification. Increased productivity and extension of operating hours are also common topics where the literature agrees on the positive impact of electricity. Among all potential impacts, those that are indirect and depend not only on electricity, but on another set of enabling factors, are more contentious in the literature. This include impacts on income, employment, wages, creation of enterprises and investment.

Figure 19: Impact of electricity (direct and indirect)



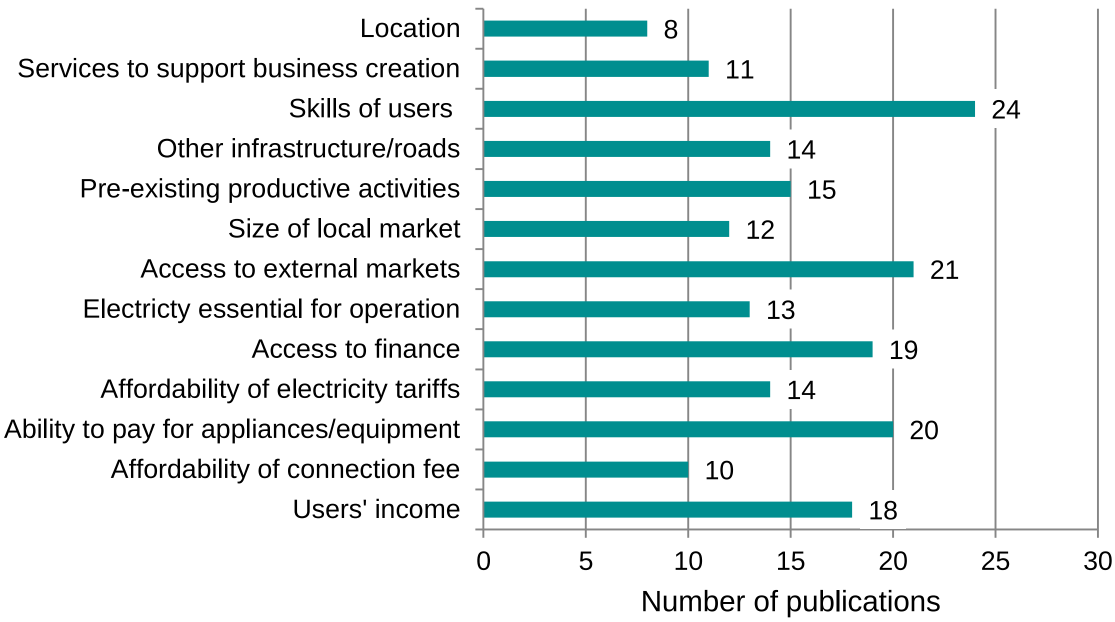
Some studies also point to potential negative impacts of electrification. The most widely reported relate to crowding out effects, which happen when demand is constrained and electrified businesses displace their unelectrified counterparts, leading to further inequality in the communities. Some studies also refer to financial stress for businesses which invest in electrification but cannot generate enough revenue to cover this investment.

Figure 20: Number of publications referring to negative impacts of electricity



The figure below shows the number of publications indicating the enabling factors that allow benefits from access to electricity for productive uses to be felt. These publications highlight that access to electricty needs to be accompanied by adequate users' skills, the ability to pay for appliances and equipment to be used for productive use, sufficient users' income, access to finance and access to markets (amongst other factors) to enable users to benefit from that access.

Figure 21: Enabling/constraining factors of electricity impacts



5. Synthesis

5.1. Literature treating access to electricity as a binary variable

These studies analyse the impact of access to electricity on a number of income and poverty related indicators. Electricity is considered as a binary variable, meaning that the explanatory variable is having some sort of electricity supply, regardless of its quality and final use. These studies usually have large samples which mix population with different levels of access to electricity and therefore it is not possible to ascertain or assume a specific level of access to electricity behind the identified impacts on different measures of poverty and income.

A total of 27 papers fell within this category. 31% were considered as high quality, 50% as moderate quality and 19% as low quality. Most papers use quantitative techniques to analyse the impacts of electricity on several poverty and income related indicators.

None of the reviewed studies on poverty impacts of electricity use experimental approaches, due to the difficulty of randomly allocating electricity to specific households or businesses. Therefore the highest standard of quality is provided by studies using quasi-experimental approaches with non-random treatment assignment that have a proper argumentation about how selection bias is controlled for. These include: instrumental variable estimation to correct the placement bias by using well justified instruments for electricity access (such as land gradient in Dinkelman 2011 and Sadanand, 2013 with the later author also using the 1971 population density in the municipality as an instrument; the proportion of households in a community with electricity in Khandker et al, 2012); the definition of plausible control groups through propensity score matching techniques (Bensch et al, 2010); Difference-in-differences combined with PSM (Khandker et al, 2009a); panel analysis (Barnes and Binswanger, 1986; van de Walle, 2013). Other high quality studies disentangle the relationship between electricity and poverty reduction using qualitative methodologies (UNDP and World Bank, 2012; Kooijman-van Kijk, 2012).

The literature reviewed analysed the impact of electricity on a number of poverty and income generation related indicators such as:

- Agricultural productivity or agricultural output (Barnes and Binswanger, 1986; Cecelsky and Glatt, 1982; Barnes et al, 2002; UNDP and World Bank, 2002)
- Household total, farm or non-farm income (Bensch et al, 2010; Clancy and Dutta, 2005; Khandker et al, 2009[7]; Khandker et al, 2012; Khandker et al, 2009[8]; Obermaier, 2012; van de Walle et al, 2013; IDS, 2003)

[7] Bangladesh

[8] Vietnam

- Household expenditures (Khandker et al, 2009[9]; Groh, 2011; Khandker et al, 2012; Khandker et al, 2009; van de Walle et al, 2013)
- Business income and revenues (Groh, 2011; Khandker et al, 2009[10]; Kooijman van Dijk and Clancy, 2010; Kooijman-van Dijk, 2012; Maleko, 2005; Meier et al, 2010; Mulder and Tembe, 2008; Grimm et al, 2013; UNDP and World Bank, 2002)
- Production, productivity or value added of microenterprises (Grimm et al 2013; Kooijman van Dijk and Clancy, 2010)
- Number of hours that business stay open (World Bank, 2008)
- Number of enterprises or propensity to run a home business (Khandker et al, 2009[11]; UNDP and World Bank, 2002; World Bank, 2008)
- Poverty rate (Khandker et al, 2012)
- Total or gender differentiated paid and unpaid work- measured working hours or days, as % of employed people or as number of people involved in microenterprises (Chowdhury, 2010; Costa et al, 2009; Dinkelman, 2008; Grogan and Sadanand, 2011; Khandker et al, 2012; Kooijman van Dijk, 2010; Maleko, 2005; Sadanand, 2013; UNDP and ESMAP, 2004; UNDP and World Bank, 2002; van de Walle et al, 2013; World Bank, 2008; IDS, 2003)
- Wages (van de Walle et al, 2013; Dinkelman, 2008; Grogan and Sadanand, 2011)

A **shift in time use** (for women in particular) is the most strongly reported impact of access to electricity with a potential impact on poverty reduction. Electricity increases the productivity of unpaid household work and enables longer working hours in paid work, increasing (mostly female) labour supply and leading to more **employment**. Some of the estimates provided by the literature include increases in female employment by 9 to 9.5 percentage points within 5 years (Dinkelman, 2008); increase in employment hours by more than 15% for women and 1.5% for men (Khandker et al, 2012); reduction of the amount of time spent on non-market home production activities by 1.09 hours per day (UNDP and World Bank, 2002); increases in regular wage work for men by 16.6 days per year, but reduction of male casual work by 10.4 days, while casual work for women increases by 6 days per year (van de Walle, 2013); increase in the propensity of rural Nicaraguan women to work outside the home by 23% (Sadanand, 2013). Several publications report no impacts on male employment (Dinkelman, 2008; Sadanand, 2013). Other studies report no significant impacts on employment, for example evidence provided by Costa et al (2009) shows that access to electricity does not have an impact on the hours worked by women in domestic activities but does increase work opportunities for men but not for women. Barnes et al (2002) find that the time electrified households save in

[9] Bangladesh
[10] Vietnam
[11] Vietnam

household activities appears to be used to increase leisure time and social activities, not for productive activities. A similar conclusion is reached by (IDS, 2003) as electrified villages in China indicate that the major benefits are related to quality of life: lighting, television and reduced labour on domestic tasks, but the possibilities to increase income are very limited.

On the other hand, other authors point to the fact that women don't tend to use electricity productively. Lighting is the main use of electricity in rural areas and is mostly used for doing household chores rather than for income generating activities (Kooijman van Dijk, 2010; Clancy et al, 2005). The jobs that are created are generally unskilled, obtained through self-employment, not formal employment, of a precarious nature and with limited potential to generate income for the community as a whole (Chowdhury, 2010; Kooijman van Dijk, 2010; Dinkelman, 2008; Oakley et al, 2007).

The literature that looks at impacts of electricity on **wages** finds that women wages decrease with electricity, while male wages increase (Dinkelman, 2008; Grogan and Sadanand, 2011) also report an increase in male wages.

Increases in **agricultural productivity** are inconsistently reported. Barnes and Biswanger (1986) find that electrification had an impact in agricultural productivity in India when it induced investments in pumpsets but it did not generate the explosive growth anticipated by many early planners. In another publication, Barnes et al, 2002 indicate instead that (highly subsidised) electrification of pumpsets has been highly effective in India contributing to a spectacular increase in agricultural productivity and living standards. However, these results are not based on a detailed analysis taking into account other confounding variables. UNDP and World Bank (2002) find that electricity has no effect on agricultural output or income. Cecelsky and Glatt (1982) instead explain that when electricity is used for irrigation the value of output often increases several-fold in a short period, but because irrigation can also be done with diesel or mechanically powered (e.g. wind) pumpsets, most of the benefits cannot be solely attributed to electricity.

Most of the literature analysing **household income or expenditure** reports positive impacts as a result of electrification. Khandker et al, 2009 find that electrification can increase per capita expenditure by 9% and overall total income can go up by 12% in Bangladesh. In India, household income per capita can increase by nearly 38.6% with electrification, mostly due to increases in non-farm income, while total expenditure increases by 18%, with non-food expenditure increasing in a much higher percentage (Khandker et al, 2012). Electrification increases household's cash farm income in Vietnam by 30% with no effect on non-farm income. The total income increases by 25%. Per capita expenditure increases by 10% due to electricity adoption. Van de Walle et al, 2013 find a much lower impact of electricity on income and expenditures in India than the one reported by Khandker et al (2012). The consumption gain with electrification is 7%. This could be due to the omission of the external effect of electricity in Khandker et al, 2012, by which non-electrified households in an electrified community also benefit from it. They find that village electrification adds 1% to the annual consumption growth rate for HH without electricity. Bensch et al (2010) find that there is a significant increase in total HH income in Rwanda but results should be interpreted with caution due to a potential selection bias. In fact, in the populations studied, connected HH were not using electricity to operate appliances linked to income generation activities and therefore the higher income may have been due to pre-existing advantages in connected HH. IDS (2013) instead show limited potential for income generation of the provision of electricity to Chinese rural areas, with diesel as the primary fuel associated with production activities.

Literature dealing with impacts on **businesses' income and revenues** show inconclusive results. Most studies suggest that electrification is a necessary but not a sufficient condition of enterprise success. Kooijman van Dijk and Clancy (2010) find very small changes in incomes to entrepreneurs and reduced profits per enterprise due to market saturation. These results are backed by a later study by the same author showing that impacts of rural electricity supply on poverty reduction in terms of income generation in India are small for the typical rural entrepreneur who owns a small scale enterprise targeting the local market (Koojman van Dijk, 2012). Grimm The differences in enterprise income of electrified and non-electrified communities reported by other studies (Meier et al, 2010; Mulder and Tembe, 2008) is likely due to the fact that electrification reaches first those communities with road access and in market hubs, therefore more likely to have healthier revenues but this selection bias is not taken into account in their methodologies. Other studies link electrification to longer hours operating businesses but cannot link this to increased revenues (World Bank, 2008; UNDP and World Bank, 2002).

The impact of electricity on **enterprise creation** is inconsistently reported. No evidence of additional rural industries as a result of rural electrification is found in Vietnam (Khandker, 2012), but the propensity to run a home business increases by 10.7% in electrified households in the Philippines (UNDP and World Bank, 2002).

Only one reviewed paper looks at the **impact on poverty rates** and finds that the poverty rate in India declines by 13.3% as a result of access to electrification (Khandker et al, 2012).

A handful of studies in this category recognise that the **quality of the electricity supply** can play a major role in increasing consumption levels and achieving poverty reduction outcomes (Khandker et al, 2012; Kooijman van Dijk and Clancy, 2010; Kooijman van Dijk, 2012; Maleko, 2005). This is because reliability and predictability are crucial for impact on income. Blackouts or fluctuating voltage cause damage to appliances and products and can force enterprises to stop operation. The studies that talk about the importance of reliability and predictability do so in general terms, without showing robust evidence or quantifying actual impacts, except for Khandker et al (2012), who estimates that increasing the average availability of electricity at the village level by one hour increases the rate of household adoption by 2.7 percent and electricity consumption by 14.4 percent.

The literature shows how difficult it is to identify and measure specific causal linkages between changes in energy services and economic poverty reduction impacts in what is inevitably a multi-factorial system with energy only one of a linked set of variables. The most frequently reported **causal chains** linking electricity to poverty impacts are the improved productivity or output of enterprises using electricity for their activities (Barnes and Binswanger, 1986; Cecelski and Glatt, 1982; Grimm et al, 2013; Khandker et al, 2012; Khandker, 2009- Vietnam; Kooijman-van Dijk and Clancy, 2010; Kooijman-van Dijk, 2012; Maleko, 2005; Meier et al, 2010; Mulder and Tembe, 2008; World Bank, 2008); and the freeing up of time for paid work, which would increase labour supply (Chowdhury, 2010; Dinkelman, 2008; Grimm et al, 2013; Khandker et al, 2012; Kooijman-van Dijk and Clancy, 2010; Sadanand, 2013; UNDP and ESMAP, 2004; UNDP and World Bank, 2002; Van de Walle et al, 2013).

The first causal chain describes the following process:

1. Access to electricity is provided
2. There is a demand for products or services that require electricity for their provision or whose production processes could be upgraded with electricity to increase output or productivity. In the farm sector, some of the reported activities that could be upgraded with electricity include heating and lighting for hatcheries and poultry farms, milking machines and cooling for dairy farms, agro-processing equipment such as threshers, hullers, millers and crushers and pumpsets for irrigation. Non-farm activities that may benefit from electrification include tailoring, wood working, welding, hairdressing, beer brewing, retail sales and flour milling.
3. There are means to invest in electricity using devices.
4. Enterprises connect to and use electricity
5. Income and revenues of enterprises increase as a result, with the potential to generate employment and provide an income for poor people.

The second causal chain describes the following process:

1. Electricity is provided
2. Households connect to and use electricity
3. Electricity extends evening working hours and reduces household drudgery
4. More time is available to carry paid work activities
5. There are employment opportunities to absorb this additional labour supply as new enterprises are created or existing ones operate for longer hours or can produce thanks to electrification
6. Labour income increases, with the potential to reduce poverty.

The **constraining** (when absent) **or enabling** (when present) **factors** of poverty impacts of electricity are the weakest links of the causal chains presented above. The following constraints or enabling factors are consistently described by the literature assessed:

- Demand for the products and services provided with electricity. The demand in rural areas is often constrained and cannot absorb additional production. The size of the local market and the proximity to markets for enterprise products determine the size of the demand, and the availability of transport and communications infrastructures facilitate access to external markets. In some cases proximity to transportation can lead to decline in local services such as grain mills that can be provided by more specialised markets.

- Ability to pay for electricity-using devices. The income level of the population and a critical size of the enterprise determine the ability to pay for appliances. Access to credit can ease income constraints as shown by evidence that bank proximity leads to more investment in motorised pumps and grain mills (Barnes and Binswanger, 1986).
- Employment opportunities. Developing countries often have a large labour surplus and therefore an increase in labour supply as detailed in the second causal chain would not directly increase employment. However, evidence reviewed seems to indicate that whereas formal employment does not usually increase, casual and self-employment does, as it is not subject to the same constraints as formal employment (van de Walle et al, 2013). In any case new microenterprises benefitting from electricity tend to focus on the local demand and have a small income generating potential. Training programs or support for business development can ease this constraint, improving the employability of the labour surplus enabled by electrification.

5.2. Literature about the impact of electricity in specific communities

Literature synthesised under this section corresponds to the review of studies referring to the impacts on poverty levels, income generation or related variables of specific electricity supply projects or for specific communities. Often the tier of electricity supply can be estimated from the information provided in the paper because all the members of the community have a similar quality of supply, as opposed to more general household surveys that mix communities with different levels of access.

The review included 32 papers which address the impact of electricity in specific communities/from specific projects. Out of the 33 reviewed papers under this category, 8 papers were of high quality representing 25% of the total, 11 papers were of moderate quality and 13 papers were of low quality. Overall, the synthesis and conclusions provided in this section will be mostly based on high quality papers, while complementing these findings with those of moderate and low quality papers, detailing when they contradict or support what is said by high quality papers, or when they are able to provide valuable insights that the most robust papers have not identified.

In terms of research design, 12 out of the 33 papers (36%) in this category used an “observational analytical” approach while the remaining 21 papers (64%) used an “observational descriptive” research design.

High quality papers use the following methodologies to account for selection bias and confounding variables: regression based single difference comparisons with PSM or other matching techniques, sometimes complemented with qualitative observations (ADB, 2010; Banerjee et al, 2011; Bensch and Peters, 2010; Harsdorff and Bamanyaki, 2009; Herrin, 1983; Peters et al, 2011) and descriptive case study approaches with a clear description of causal chains (Kirubi et al, 2009; UNDP, 2012)

A common challenge in some of the papers is the fact that access to electricity only took place 2 or 3 years before the analysis which did not allow enough time for impacts on income and poverty to take place.

The literature reviewed analysed the impact of electricity on a number of poverty and income generation related indicators such as:

- Poverty (ADB, 2005; Bose et al, 2013; Etcheverry, 2002; Palit et al, 2013)
- Household income (Anderson et al, 2005; ADB. 2010; Banerjee et al, 2011; Brossman, 2013; Calderon 2005; Green, 2004; Harsdorff and Bamanyaki, 2009; Herrin, 1983; Legros et al, 2011; Sharif et al, 2013; World Bank, 2008; Yadoo and Cruickshank, 2012)
- Business profits or income (Banerjee, et al. 2011; Bose et al, 2013; Herrin, 1983; Kirubi et al, 2009; Peters et al, 2013; Peters et al, 2011; Harsdorff and Bamanyaki, 2009; Matinga, 2013; Neelsen and Peters, 2011; Oakley et al, 2007; Obeng and Evers, 2010)
- Production and productivity of enterprises and agricultural activities (Bose et al, 2013; Bensch and Peters, 2010; Kirubi et al, 2009; UNDP, 2012)
- Creation of new enterprises, direct and indirect employment effects (Scott et al, 2013; Bastakoti, 2003; ADB, 2010; Bensch and Peters, 2010; Oakley et al, 2007; Peters et al, 2011; UNDP, 2012; Yadoo and Cruickshank, 2012)
- Total or gender differentiated paid and unpaid work- measured working hours or days, as % of employed people or as number of people involved in microenterprises (Anderson, and Berg, et al. 2005; Bose et al, 2013; Chakrabarti, 2002; Oakley et al, 2007; Obeng and Evers, 2010)

Identifying tiers of access to electricity under this category of reviewed papers was a challenging task. The papers often provided insufficient information to assist in determining the tier, which had to be inferred from the limited details provided. The majority of papers suggested a tier 2 access (see Figure 10 in Chapter 4). The remainder of papers were split between tiers 1 (3 papers), tier 3 (6 papers), tier 4 (6 papers), and tier 5 (1 paper). Factors that helped in identifying the tiers of electricity included the capacity of the system, hours of daily use, legal/illegal connections, reliability of access including voltage fluctuations and the number of outages, type of appliances and equipment used in households and businesses for productive uses. It is worth noting that in some cases we were not able to assume a tier of electricity access as the literature would not provide enough information to do so.

The literature is inconsistent as regards the **household income generation and poverty reduction potential** of electricity. Seven papers refer to positive income generation and poverty impacts of access to electricity for households (Anderson et al, 2005; Calderon, 2005; Sharif et al, 2013; Legros, 2011; Yadoo, 2012; Bose, 2013; Echeverry, 2002). However ten papers conclude that impacts were minimal or non-existent (AfDB, 2011; ADB, 2005; ADB, 2010; Banerjee, 2011; Brossman, 2013;

Green, 2004; Harsdorff and Bamanyaki, 2009; Herrin, 1983; World Bank, 2008; Palit et al, 2013). Studies reporting positive impacts tend to be of lower quality. They do not take into account confounding variables, are based on the author's perceptions or lack robust statistical analysis. Papers that report no impacts on poverty or income generation are generally of higher quality, but tend to refer to low levels of access to electricity. When a specific tier can be assumed, it is mainly tier 2, followed by tier 1, with only one study referring to a higher level of access equivalent to tiers 3 or 4. Lack of impact is attributed to low consumption levels, equipment malfunction and lack of productive uses. When income generation happens, it is mostly in non-farm enterprises that represent a small percentage of total household incomes.

Literature analysing impact on **business income and profits** is also inconclusive. However, 8 out of 11 papers analysing impacts of access to electricity on business income and profits conclude that by itself, electricity achieves minimal or no impact (Banerjee et al, 2011; Herrin, 1983; Peters et al, 2013; Peters et al, 2011; Harsdorff and Bamanyaki, 2009; Neelsen and Peters, 2011; Oakley et al, 2007; Obeng and Evers, 2010). Many of the papers reporting lack of impacts analyse a level of access equivalent to Tier 2, some others do not provide enough information to be able to assume a level of access and one refers to a level of access similar to tier 3 or 4. The reasons why business income does not improve with electricity provision are mainly: low usage beyond lighting, low quality of supply and a lack of sufficient production scale that makes investments in electricity worthwhile. Some interesting insights are provided in (Peters et al, 2011), who shows a differentiated impact for enterprises created before and after electrification. There are no positive impacts of electrification for firms created before grid access. Profits from (pre-existing) connected firms in the access region are actually lower than their matched counterparts in the non-access region, even though the difference is not significantly different from zero. However, electricity-reliant firms created after electrification perform much better than pre-electrification firms**.** They include welders, saw mills and printing shops, which did not exist before. These firms use more electric appliances and have better market access because they offer new products to final consumers and intermediate products to other enterprises. They also find some crowding out effects among competing traditional manufacturers, with job losses and decreased profits. Also, drain on business as local consumer's purchasing power is diverted to the new electricity-reliant manufacturers. Obeng and Evers, 2010 also show inconclusive results, depending on the types of electricity using activities. Shops and drinking bars experience an increase in income as a result of electrification with solar PV, but there is not more income in the rest of electrified businesses as compared to non-electrified ones. In fact, electrified tailors and chemical shops had lower income than non-electrified ones. Three papers report positive impacts for business income and profits (Bose et al, 2013; Kirubi et al, 2009; Mating, 2013). Kirubi et al (2009) report significant impacts as electricity improved the productivity of artisans and enabled higher sales of 20-80% for carpentry businesses and 20-70-% for tailoring businesses in Kenya. The other two papers provide anecdotal evidence.

The literature is more consistent about the **improvements in productivity** as a result of electrification. The four papers that deal with this issue report positive impacts (Bose, 2013; Bensch and Peters, 2010; Kirubi et al, 2009; UNDP, 2012). Kirubi et al (2009) quantify these impacts for artisans in Kenya, finding increases in the productivity per artisan in the order of 100-200% for carpentry businesses and 50-170% for tailoring businesses. Impacts in the productivity of the agricultural sector are not high, as the main energy used is diesel for tractors, not electricity.

Several authors refer to the **creation of new enterprises** as a result of electrification (Bastakoti, 2003; Bensch and Peters, 2010; Oakley et al, 2007; Peters et al, 2011; Yadoo and Cruickshank, 2012). Many of them rely on electricity for their activities and therefore would not have been possible without it, such as welding, printing shops, iron fabrication, battery charging, ice production, food drying, poultry or soap making. The presence of electricity is associated with a higher diversity in the activities of microenterprises. These new activities tend to perform better than pre-electrification enterprises (Peters et al, 2011). Oakley et al (2007) conclude that the introduction of electricity into two poor South African communities (urban and rural) had a significant impact on the number, type and collective volume of micro-enterprise activity, but overall it had a limited livelihood impact due to minimal employment creation and limited increases in turnover. Other authors point at a negligible contribution to local employment (ADB, 2010; UNDP, 2012).

Positive impacts on the **number of working hours** are consistently reported, but links to income generation are not explicitly drawn (Anderson, and Berg, et al. 2005; Bose et al, 2013; Chakrabarti, 2002; Obeng and Evers, 2010).

The review has not proved a clear relationship between the tier of access of electricity and reported poverty related impacts beyond the normative relationship between the amount of electricity provided or consumed and the applications it enables:

- Papers referring to access to electricity at tier 1 are consistent in reporting weak impacts on income generation and productive limited to lighting.
- Papers referring to access at tier 2 in some cases show the use of a variety of electric equipment and tools that can boost the productivity and revenues of SME. Direct impacts reported at tier 2 are typically extension of working hours, lower cost of production, better product/service quality. In terms of indirect impacts, a few cases reported increase in employment and the creation of new enterprises although limited compared with tiers 3 and 4.
- Papers indicating a tier of access between 3 and 4 report a higher level of productive uses and hence on increased production and improved income. Direct and indirect impacts at tier 3 or 4 access include longer working hours, higher revenues, better product/service quality, increased production and higher productivity.
- One paper indicating tier 5 level of access indicated a specific high-energy consuming manufacturing activity and positive impacts on income.

Nevertheless, in order for impact of access to electricity to take place, enabling factors play a very important role, especially as they relate to access to capital and supporting business development services in order to be able to profit from the connectivity. In all cases, electricity is only a complementary factor to achieve increased income generation and a number of enabling factors must be in place to realize this potential.

The literature provides the following explanations of how improved access levels with a reliable supply can improve income generation:

- Reduced frequency of equipment breakdowns and fewer interruptions to business.
- Unlike grid electrification which provides AC power, there are limitations associated with DC electricity and appliances that can run off it, and they do not allow for a wide range of income generating activities.
- Losses in production as a result of blackouts.
- A reliable and affordable grid supply would dramatically reduce costs for electricity-reliant industries such as the semiconductor or tea processing industries.

The most widely reported channels through which electricity can lead to income generation and poverty reduction are:

- Electricity enables new or improved non-farm activities to be undertaken, such as the provision of cold drinks and entertainment in hospitality and retail businesses, weaving, carpentry, tailoring, carving, sculpting, mobile phone charging, or social TV halls. When new products that could not exist before electrification fill a new niche, the income generation potential is higher.
- Electricity reduces production costs, improves the competitiveness of local industries and increases sector viability. It can also reduce barriers to entry for new domestic entrants.
- Electricity enables an increase in agricultural (through irrigation) and non-agricultural output.
- Electricity enables better access to market information and weather forecasts and increases the life of perishable goods, allowing more optimal pricing decisions for activities such as fishing or agriculture.
- Electricity can strengthen the value chain for some agricultural activities. Many fruits and vegetables rot before they reach a market. Local processing and storage could reduce the amount of agricultural wastage, improving the market for small-holder farmers, reduce food imports and increase domestic food supply, thereby reducing hunger. Without affordable, dependable power along the chain that is dispersed in rural areas, though, this is not a possibility (UNDP, 2012).
- Electric light extends the working day and can lead to increased production or sales.
- Electrification has an expansive effect on local demand, partly due to people moving from outside areas to the community.

On the other hand, the most widely reported constraints to realize the poverty reduction and income generation potential to electricity are:

- Lack of a market that can absorb additional production, including a reduced local market and limited external market access. An interesting insight provided by Peters et al (2011) is that investments in electricity and electricity using equipment often require a sufficient scale of production to make financial sense. If there is not a sufficient demand and production cannot be increased beyond an optimal point, the firm may incur losses as production costs would be higher than revenues. In this case the firm could be worse off than before electrification.
- Weak transport and telecommunication infrastructures.
- Lack of capital or access to finance to invest in new appliances: if people cannot afford appliances linked with productive uses energy access will not make a difference.
- Lack of knowledge/skills relevant to new business opportunities created. People may be unable to recognise or practice a new energy-based income-generating activity. Electrification projects should be accompanied by technical and financial assistance to assess productive use potentials, so that businesses are aware of cost structures and potential market opportunities.
- Wider business environment barriers to enterprise development, such as policies entrepreneurialism, corruption, lack of resources, etc.
- Inability to reduce labour following the acquisition of electricity, due to contractual or familial commitments.
- Weak productive take up of electricity; many firms connect just for light and radio but they don’t use modern machinery.
- Base of the pyramid population with low incomes and lack of knowledge and capacity concerning energy services.

Table 1 summarises the impacts and constraints reported by the different studies according to the assumed tier of electricity access that they refer to.

Table 3: Impacts and constraints reported in the literature per tier of electricity access

Tier	Literature	Impacts	Constraints
0	0 papers		
1	3 papers	Applications mostly limited to lighting and limited productive uses.	• Users' skills • Not enough capital to purchase appliances • Lack of distribution channels to sell the produced goods outside the own village
2	12 papers	More diverse applications. Most reported impacts include: Extension of working hours, lower cost of production, better product/service quality. A few cases reported increase in employment, and the creation of new enterprises although limited compared with tiers 3 and 4.	• Users' skills • Size of the local market • Access to external markets • Business support services • Access to finance
3	6 papers	Not all connected enterprises use access for productive uses; sometimes applications are limited to lighting. Most widely reported impacts include: extension of working hours, higher revenues, better product/service quality, creation of new enterprises, increased production, higher productivity, more available time for paid work, energy cost savings.	• No pre-existing productive activities that could be upgraded through electricity. • Recent introduction of electricity • Lack of complementary infrastructures • Business support services • Access to finance
4	6 papers		
5	1 paper	A level 5 tier of access allows the use of electricity for manufacturing processes that require a continuous and reliable supply, such as tea processing or the tea industry. Reported impacts include lower operating costs of electricity-reliant industries, which contribute to global competitiveness.	Income increases through businesses favour rich and middle income households.

The poverty reduction potential of electrification programmes can be maximized through integrated rural-development programs.

5.3. Literature acknowledging different impacts conveyed by different levels of access to electricity

This literature acknowledges that electricity access is not binary (yes or not) but that there are different qualities or levels of access which could have different levels of impact on poverty or income generation.

Eleven papers were included in this group, only a minority of the total literature reviewed. Two of the papers in this group were considered as high quality, eight as moderate and two as low quality. Most studies are analytical. The methodologies include cross-sectional regression models, sometimes with IV estimation and PSM, time series analysis and panel analysis with different endogenous variables related to income generation, such as profitability of enterprises (Akpan et al, 2013) income of enterprises (Gibson and Olivia, 2010; Rao, 2013; Eifert et al, 2008); total factor productivity (Arnold et al, 2006), value added (Eifert et al, 2008), poverty measured as absolute and relative income, expenditure, poverty perceptions or population below the poverty line (Cook et al, 2005; Yang, 2005); employment (Gibson and Olivia, 2010; IFC, 2012); firm growth (Goedhuys and Sleuwaegen, 2010). Some papers use descriptive approaches to show the effects of different levels of access to electricity (IDS, 2003; Kittleson, 1998). The level of access to electricity or the quality of electricity provision are measured in different ways: the number of days with power outages; the average daily availability of grid-electricity, the possession of a generating set or the cost of running it for a microenterprise (which involves more reliability but less affordability); the increase in load capacity; affordability; and the investments in electricity infrastructure.

Some of the papers look at both the impact of access to electricity as a binary variable and of the quality of this access. When this is the case, they present inconsistent results. Two authors find that a connection to electricity per se is not found to have a significant impact on the profitability of microenterprises or on poverty indicators (Akpan et al 2013; Cook et al, 2005). The latter authors indicate that access to electricity increased spending in their China and Thailand case studies but did not increase income, particularly of poor people. Two other authors find positive effects of the presence of electricity for likelihood of participating in non-farm enterprises for rural households (Gibson and Olivia, 2010) or the likely earnings of a household non-farm enterprise (NFE) (Rao, 2013). According to the first author, the participation rate in NFEs goes up by 13.3 percentage points and the expected number of NFEs operated by each household raises by 1.5 times when the household utilizes electricity.

Existing literature usually concludes that better levels of access to electricity lead to improved poverty and income generation outcomes, however the methods used to assert this are not always robust, or estimators obtained cannot attribute a significant relationship between levels of access and outcomes.

Running a generating set has been found to make enterprises more productive and profitable. Power outages lead to losses in sales from 3% to 7% in poor African countries (Eifert et al, 2008) and are often rated by African and Indian enterprises as the highest constraint on enterprise growth (Goedhuys and Sleuwaegen, 2010; IFC, 2012). Generating sets can support enterprises to cope with unreliability. Some estimates show that for every unit increase in the expenditure of running a generating set the profitability of microenterprises can increase by 13.1% (Akpan et al, 2013) and that electricity access supplemented with the possession of a generator increases the average enterprises growth by 2% (Goedhuys and Sleuwaegen, 2010) and their productivity (Arnold et al, 2006). However, the high estimates of the first study could be due to self-selection bias not dealt with, as the most profitable companies are also those that can afford to purchase and operate a generating set. Own generation comes at a high price. The total expenditure on generating sets by some enterprises in Nigeria is up to three times the tariff for grid electricity (Akpan et al, 2013), up to ten times the price of grid electricity in some African low income countries (Eifert et al, 2008) and a very high cost for Indian industrialists (IFC, 2012).

Service reliability encourages households to consume more electricity and to engage in non-farm enterprises (NFE). Increasing the average availability of electricity at the village level by one hour increases the rate of household adoption by 2.7 percent and electricity consumption by 14.4 percent (Khander et al, 2012). Households in villages which never suffer blackouts have an average of 1.3 more NFEs even when controlling for presence of electricity and the share of rural income from NFE is 27 percentage points higher for households in villages that never suffer blackouts (Gibson and Olivia, 2008). Having electricity opens up a wider range of productive activities but to the extent that electricity supply is unreliable a rural household may suffer from damaged appliances and be less willing to engage in an electricity dependent enterprise. Another study focusing on NFE suggests that better supply is associated with higher incomes of household non-farm enterprises, with the gains happening predominantly up to 16 hours of supply per day and to a lesser extent for higher availability (Rao, 2013).

Quality of electricity supply measured as increasing load capacity or investments in infrastructure are found to have a positive relationship with poverty reduction (Cook and Duncan, 2005; Yang, 2004).

IFC (2012) estimates that if there had been no power outages at all in 2005, 5.2 million additional jobs could have been created in the manufacturing sector in India. This amounts to about 1.2% of the total labour force. The total amount of jobs that could be created per formal firm in India by having one less hour of power outage is 0.056 and a one percent growth in electricity consumption in India will result in a 0.53% growth in employment (IFC, 2012). However, these estimates are made under the assumption that each firm would decide to hire as many employees as required to produce the amount of sales that would not be lost if they did not have to face power outages, which is not completely realistic. Better supply can also enable industrial development, as shown by a hydropower project thanks to which Bhutan was able to allot additional industrial licenses for power intensive industries like steel.

The literature refers to two causal chains linking better access to electricity to improved poverty impacts and income generation. First, improved supply allows adoption of a greater number of appliances and higher consumption, therefore improving the potential number of non-farm productive activities that a household can engage in and increasing the potential poverty impacts of energy services. Secondly, improving the quality of electricity supply can increase the output and productivity of agricultural land or of enterprises that suffer from interruptions to their production processes, damaged appliances and high costs of own generation. This can lead to employment generation.

The most widely reported constraints to achieving poverty impacts through an improved electricity supply are a low level of economic development in the region, and therefore the lack of agricultural or industrial enterprises that can benefit from this improved supply; a lack of investment capacity in electricity using equipment; and poor transport infrastructures limiting access to markets.

6. Discussion and Conclusions

The literature that links different levels of access to electricity to different poverty impacts is very limited. Traditionally electricity access has been defined as a binary variable, involving the availability or not of a connection. High quality literature on the issue is rarer still.

A coherent relationship between different levels of access to electricity and poverty reduction, defined in income terms, could not be proved by this literature review. One important shortcoming is that very few papers were found to analyse the impact of high quality levels of access to electricity, equivalent to Tier 5.

There is a clear normative relationship between the amount of electricity supply and the uses it enables. Whether or not these uses actually take place and whether or not they generate enough revenue to enable poverty reduction depend on a number of other factors. It is also a fact that unscheduled outages lead to production losses, which have been quantified by some papers as reaching between 3 and 7% of total sales in African countries. Whether or not improving reliability and quality would lead to poverty reduction depends on whether or not there is an industry that can benefit from it, or favourable conditions for the creation of new industries.

Evidence shows that service reliability encourages households to consume more electricity and to engage in non-farm enterprises (NFE). Studies looking only at the impacts of having electricity, regardless of its quantity or quality, also report positive impacts on the number and diversity of NFE, productivity, number of business operating hours and amount of hours spent on paid work by household members. However, results are not conclusive as regards income generation. New businesses created are often small and unprofitable, lacking a sufficient scale and asset base to generate enough income to enable poverty escape.

Poor people often long for formal jobs that provide stability and can have a transformational effect (Banerjee and Duflo, 2011). Evidence of the ability of electricity to create these types of jobs is thin. One relevant paper discusses the role of several attributes, among which access to electricity for promoting high growth entrepreneurial firms in Africa (Goedhuys and Sleuwaegen, 2010). A thriving class of high growth entrepreneurial firms are believed to have a higher potential of employment and wealth creation, than marginal/informal trade and service microenterprises. There are some firm specific factors such as size, age, innovation, entrepreneur characteristics and resources. Small firms face a scale disadvantage and are less likely to grow. They result from a particular business environment characterised by characterized by "small market sizes, low levels of human capital, lack of access to inputs, and poor infrastructure such as roads, ports, communication facilities and provision of energy". Electricity supply interruptions are considered as the major constraint to the growth of businesses by most of the high growth industries in 6 out of 11 countries included in Goedhuys and Sleuwaegen (2010) study. Firms' growth increases considerably when they invest in their own generating sets even though the cost of own generation can be up to ten times higher than the grid. This provides a rationale for investments in distribution and transmission systems and increases in load capacity, which would come at a lower cost than generating sets for electricity-reliant industries.

The difficulty in showing a clear link between specific levels of access to electricity and income generation points at the importance of a number of other factors related to market creation and the development of skills that increase the employability of the additional labour supply.

Studies that look at the impact of integrated development programs involving access to electricity, market creation and development of skills are very rare. One example refers to a community-based micro-grid in Kenya which in spite of its high unreliability delivered significant positive impacts on income levels of the community (Kirubi, 2009). This was possible in combination with the facilitation of access to markets and to other infrastructures. The rural electrification project was part of an integrated infrastructure package including all-weather roads, schools, markets and business services. Business support services involved the formation of a self-help group for local SMEs to provide financial and technical support including setting up a credit fund for artisans, providing training on product design and marketing, book keeping and self-organising. A local branch of the Kenya Commercial bank was opened, which facilitated access to finance. The market was also expanded as the donor bought local products for its diverse portfolio of development activities. Another significant aspect of this case study was that there was a latent demand of electricity by local businesses previous to the project implementation and the local community contributed to a significant share of the initial capital cost.

The integration of energy access and market creation policies should also take place at the national level. As an example, programs to provide electricity to rural communities dependent on agriculture should be compatible with industrial policies that strengthen the value chain of agricultural products and trade policies that facilitate access to external markets and prevent flooding of the local markets with subsidised imported crops.

Good guidance for energy practitioners to improve the productive use of electricity is provided by the PRODUSE Manual (Bruderle et al, 2011). It provides a step-by-step guidance for designing and implementing activities that complement electrification projects and promote their productive uses, from initial planning to implementation and evaluation of projects.

As regards recommendations to improve the quality of research on the topic of the level of access that enables and sustains poverty reduction, the key failing to avoid is selection bias, by which communities or enterprises with higher income generation potential can afford higher levels of electricity access and hence deliver better income generation outcomes, even though these could not be attributed to electricity. Appropriate controls, good matching techniques, the use of panel data or instrumental variables could solve this problem. Surveys before and after electrification, instead of single cross-sectional analysis will also deliver more robust results. The selection of several communities with similar characteristics in all observable variables except for their level of access to electricity would provide a good basis for the analysis of the different impacts of different levels of supply. However, it would be challenging to find such comparable communities. Another common flaw of existing research is the short period of time between the pre-electrification baseline and the post-electrification endline, which would not allow for significant impacts to take place. Finally, more studies are needed that look at the joint impact of integrated development programs including not only access to electricity but also market creation, access to finance and development of skills.

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

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Appendix A. Literature Review Search Terms

Table 4: Literature Review 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 Illuminat*	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*
Standalone	Communication OR radio OR television OR TV 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 B. Additional Literature Reviewed

Two publications were identified after our literature review was first completed, which were deemed relevant for our study. The two papers (Chakravorty et al, 2014; Alcott et al, 2014) are based in India and were published in 2014. Both of them fall under the category of papers that acknowledge that different levels of access to electricity can achieve different poverty impacts and describe or quantify these. This was the smallest group of literature identified in our literature review, with most of the papers reviewed considering electricity as a binary variable. The two new papers use an analytical approach to explain the different effect that different levels of access to electricity can have on income related indicators. Both are considered as high quality papers as they fulfil DfID's principles of high quality studies and successfully tackle the issue of endogeneity of the quality of electricity supplied, in both cases through the use of instrumental variables that account for non-random assignment of high quality electricity supply.

While these papers support the contention that higher levels of electricity access have the potential to provide greater support to productive activities and hence greater effect on poverty, their inclusion in the review would not change the overall conclusion that a coherent relationship between different levels of access to electricity and poverty reduction, defined in income terms, could not be proved.

Chakravorty et al (2014) estimate the returns to household income due to improved access to electricity in rural India. The quality of access to electricity is measured in two different ways for the two periods of time of their panel. In 1994 it is measured as a dummy variable with three potential values: low quality when outages are prevalent, medium quality when outages average one or two per week and high value when a continuous power supply is received. In 2005 the three potential values are determined on the basis of number of hours of electricity per day that the household receives on average. The threshold for high quality is 18 hours per day. The paper finds that a grid connection increases non-agricultural incomes of rural households by about 9% during the study period (1994–2005). However, a grid connection and a higher quality of electricity (in terms of fewer outages and more hours per day) increases non-agricultural incomes by about 28.6% in the same period. Therefore, the effect of quality is much higher than the effect of a simple connection. The paper cannot disentangle the various channels through which quality of electricity supply operates to improve HH incomes.

Alcott et al (2014) look at the impact of poor quality of supply on revenues and productivity of Indian manufacturers. Their study combines a case study of 22 large textile manufacturers that have generators to face shortages, with a larger scale analysis of panel data from the Annual Survey of Industries. Their results show that electricity shortages affect productivity much less than revenue because most of the inputs can be flexibly adjusted during power shortages (especially if these are scheduled). The case study shows that energy costs rise by 0.24% of revenues during weekly power holidays, physical output drops by 1.1% and productivity decreases only by 0.05%. The instrumental variable estimates for the Annual Survey of Industries show that for plants that own generators a 1% point increase in shortages increases the share of self-generated electricity by 0.57% points, which raises total input costs by 0.02 to 0.07% of revenues. Across all plants a 1% point increase in shortages decreases revenues by 0.68%. The loss of revenue productivity is much smaller: the effect is not statistically different than zero, and the confidence interval bounds it at no more than 0.29%. A nationwide average shortage of 7.1 percent as it happened in 2005 would translate into an input cost increase of 0.13 to 0.5 percent of revenues and a revenue loss of 4.8 percent. Effects of shortages are different between plants that self generate and those that do not. Only plants with generators experience an increase in total energy costs, while non-generators experience much larger revenue losses. Firms in industries with higher electric intensity are more exposed to shortages, experiencing a larger increase in energy revenue share and a larger decrease in output. Also, small plants are more affected because they are less likely to own a generator due to the economies of scale of owning and operating generators. As a result, unreliable electricity supply could distort the firm size distribution in developing economies.

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