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What stimulates the demand for grid-based electrification in low- and middle-income countries?

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About this working paper

This paper, *What stimulates the demand for grid-based electrification in low-and middle-income countries?* presents results from a rapid evidence assessment that synthesizes available, high-quality impact evaluations on interventions stimulating demand for electric grid connections in low- and middle-income countries. This paper has been copyedited and formatted for publication by 3ie.

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What stimulates the demand for grid-based electrification in low- and middle-income countries?

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Executive Summary

Electrification has a variety of known benefits, including reducing indoor air pollution, improving school enrolment, increasing income, and reducing crime or violence. Sustainable Development Goal 7 set a target of universal access to electricity by 2030. As a result, efforts to increase access to electricity are expanding across the globe which is to be commended. However, these efforts are not able to achieve the health, social and economic impacts because many households are choosing not to connect. This decision is often related to the poor quality of the utility, the cost of electrification and electricity, administrative burdens, and other physical or social constraints. There have been previous syntheses that focused on electrification but they did not exclusively focus on efforts to stimulate demand for connecting to the electric grid.

In this paper, we present results from a rapid evidence assessment in which we systematically reviewed and summarized the impact evaluations on interventions to increase electricity demand among those with access to the grid in low- and middle-income countries. We also examine the effects of electrification on well-being and identify barriers to adopting electrification.

We conducted a systematic search of academic bibliographic databases and library catalogues to identify qualifying studies. We conducted screening using the population, intervention, comparison, and outcome format. We included studies provided that they met the following inclusion criteria: 1) populations were based in a low- and middle-income country; 2) interventions were aimed to stimulate demand for connecting to the electric grid by improving affordability, decreasing burdens, and/or increasing awareness of electricity benefits; 3) studies used either an experimental and/or quasi-experimental design; and 4) study outcomes assessed a change in health, education, or welfare indicators.

We identified 51,320 articles from our search. After screening, we identified 7 articles on 4 unique studies that met the inclusion criteria. The studies took place in El Salvador, Ethiopia, Kenya, and Tanzania. Two studies used cluster randomization and the other two used individual-level randomization. All four studies considered direct costs to be the primary barriers to electrification and addressed the issue of affordability when designing the intervention. Two studies used vouchers to address affordability and two used subsidies to facilitate access to electrification.

All four studies found that interventions that addressed affordability of electrification were successful in improving electrification rates. However, no study was able to obtain a 100% connection rate, even when the connection was fully subsidized by the study. Three of the studies found that socioeconomic status was associated with grid connections. Wealthier households were more likely to connect, possibly because they were more likely to be able to pay for additional fees and the monthly bills or because they better understood the benefits of electrification.

We also found that households that connected to the grid tended to purchase electric appliances after connection and were also linked to income growth. Electrification was also found to be related to increased female participation in income-generating activities. The household income increase was likely because of the increased entry of women into the workforce. Electrification was also found to increase households' time allocation.

School-aged children living in households that connected to the grid were more likely to spend their time studying because they could study at night. In some of the studies, adults were able to spend less time collecting water and fuel and were able to use that time for socializing and resting.

Though this review identified studies that had a positive effect on electricity grid connection as well as downstream welfare benefits, it also highlighted that there is a lack of evidence regarding interventions to stimulate demand for the electricity grid. The studies included in this study primarily focused on affordability-related interventions which would not address the common social and human barriers to electrification, such as administrative, social or informational, and physical barriers. These barriers could prevent affordability-related interventions from reaching their full potential in stimulating demand for the grid and affecting human welfare, well-being, and health.

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1. Introduction

Sustainable Development Goal 7 set a target of universal access to electricity by 2030. Due to this goal and a large international effort from both the public and private sectors, electricity access is rapidly expanding (Roser and Ortiz-Ospina 2018). In 1996, 25% of the world's population did not have access to electricity; 20 years later, this value had fallen to 12% (Roser and Ortiz-Ospina 2018). The most common uses of electricity among newly electrified households are for lighting and television (Independent Evaluation Group World Bank 2008).

The effort to increase electrification is largely driven by its expected societal benefits. Electrification can reduce indoor air pollution and result in improved health outcomes (Independent Evaluation Group World Bank 2008). It may improve school enrollment, income, and employment (Bayer et al. 2020; Jiménez 2017). The whole community can benefit from electrification through increased security, improved care at clinics and the attraction of skilled workers (Independent Evaluation Group World Bank 2008). Electrification's benefits can even extend across the globe through decreased carbon emissions, although these effects are highly variable by location (Bayer et al. 2020; Independent Evaluation Group World Bank 2008; Jiménez 2017).

Although the national level of development and the location of households continue to affect electrification rates, many people live within connecting distance of electrical lines, i.e. they are "under the grid" and not connected (Blimpo and Postepska 2017; Bonan et al. 2017; Jimenez 2017; Lee et al. 2014). In urban areas of sub-Saharan Africa, 78% of the deficit in electricity access is demand-driven (Blimpo and Postepska 2017). The primary reason for low demand is often cost, but societal factors such as regulatory constraints, reliability of income and housing structure can also have effects (Blimpo and Postepska 2017; Bonan et al. 2017).

Because low demand is a growing challenge in efforts to achieve global electrification, there is interest in understanding the social systems affecting electric grid adoption. There have been multiple evidence syntheses about electrification, but these studies do not focus exclusively on stimulating demand for grid-based electricity (Adair-Rohani et al. 2013; Bensch 2019; Haby et al. 2016; Hamburger et al. 2019; International Initiative for Impact Evaluation (3ie) 2020; Irwin et al. 2020; Köhlin et al. 2011; Mathur et al. 2015; Policy and Operations Evaluation Department (IOB) of Dutch Ministry of Foreign Affairs 2013; Raitzer et al. 2019). To address the low demand for electrification, it is necessary to understand the motivations and implementation considerations that drive people to connect to the grid. Here, we present results from a rapid evidence assessment (REA) in which we systematically reviewed and summarized the available, high-quality impact evaluations on interventions to increase electricity demand among those with access to the grid in low- and middle-income countries (L&MICs) (Barends et al. 2017). We report on the effects of electrification on well-being, consider what factors prevent the adoption of electrification, and discuss who is excluded from the opportunity to adopt electrification. We comment on the social and human elements driving electricity demand and how people make the decision to connect to the electrical grid. We do not consider interventions for off-grid electrification because the associated technologies, barriers and behaviors are fundamentally different. We hope that policymakers and implementers will use this work in informing the design and implementation of their initiatives meant to generate demand for electric grid connection.

In the subsequent sections, we review the theory of change that demand-generating interventions assume in the adoption of electrification. We explain the methods used to produce this REA and present the results from the included studies. We then leverage the literature search conducted for this REA to comment on common challenges in the implementation, sustainability and evaluation of demand-generating interventions. Finally, we conclude by discussing the synthesized results, limitations and implications.

1.1 Interventions and theoretical model

We considered any intervention that had the goal of stimulating demand among those who live under the electrical grid. Such interventions would likely attempt to diminish the primary barriers to electrification, thus stimulating demand. Based on consultations with practitioners, our *a priori* hypothesis was that there would be three main types of interventions: (1) to reduce cost, (2) to decrease the administrative burden, and (3) to provide education about the benefits of electricity, new electrification programs or payment structures. All these interventions are theorized to work by making access to electricity less costly and/or more desirable. It is possible that interventions to stimulate demand could fall outside of these three categories. When we identified other demand-side interventions, we considered them for inclusion as well.

2. Materials and methods

The Millennium Challenge Corporation (MCC) commissioned this rapid evidence assessment to respond to immediate evidence needs and inform the development of an intervention to increase demand for access to the electrical grid in Burkina Faso. We only considered interventions to stimulate demand for connection to an electrical grid in Burkina Faso, in response to the planned intervention by MCC. We finalized the protocol adapted for this REA *a priori* to ensure no selection bias (Mathur et al. 2015). The following section outlines the search process and inclusion criteria for this review.

2.1 Search strategy

From November 11 to 18, 2019, we completed a systematic search of academic bibliographic databases and library catalogues to identify qualifying studies that are compliant with the guidelines specified by Kugley et al. (2017) (Appendix A).[1] Given the cross-sectoral nature of outcomes, where appropriate, the strategy considered sector-specific databases. Finally, where possible, the review team contacted key experts and organizations through our review advisory group to identify additional studies that met the inclusion criteria. We used a unified search to identify both supply- and demand-side interventions. An example of the search strings the strategy employed is presented in Appendix B. Where possible, we reviewed citations used by included studies and all studies that cited at least one study included in this review using *Web of Science*.

[1] The search strategy development for this review was supported by John Eyers, an information specialist contracted by 3ie.

2.2 Screening

We managed the selection of studies for inclusion using EPPI-Reviewer 4 software (hereinafter, EPPI) and completed by implementing the standard steps of de-duplication, title and abstract screening, and then full text screening (Appendix C).

2.2.1 Inclusion/exclusion criteria (PICO)

Screening was conducted using a protocol that followed the participants, intervention, comparison, outcome (PICO) format. However, exclusions were conducted in a hierarchical order: first excluding by year, then country, topic, empirical approach, beneficiary, whether it was an impact evaluation, and other study design characteristics.

Population (types of study participants)

The review includes populations residing in L&MICs as designated by the World Bank at the time the study was conducted. We collected data on differential effects and experiences for sub-populations available as far as it was possible and useful to do using Cochrane PROGRESS-Plus criteria (O'Neill et al. 2014).[2]

Interventions

The interventions considered here relate to the generation of demand for connection to the electrical grid. They include activities meant to improve the affordability of electrification, decrease administrative burdens and/or increase awareness of the benefits of electricity. Other interventions would be considered so long as they attempted to stimulate demand for electric grid connection and not other forms of electricity.

Comparison group and study design

We include evaluations that employ an experimental or quasi-experimental design and/or analysis method that seeks to robustly measure the net change in outcomes attributed to an intervention or policy compared to some appropriate counterfactual. We incorporated randomized and non-randomized studies that were sufficiently able to consider confounding and selection bias (Waddington et al. 2012). Feasibility studies, acceptability studies, literature reviews or systematic reviews were not accepted. Efficacy studies were only considered if they met the criteria in Appendix D. Process evaluations and qualitative studies were excluded from this analysis because they do not provide effect sizes to extract.

Outcomes

The review considered outcome(s) that assess(es) a change in indicators of health, education or welfare (Appendix E).

Date, language and form of publication

We included studies published in any language, although search terms were in English only. Studies were included if their publication date was 2000 or after. We considered all rigorous academic research, including peer-reviewed works, as well as working papers and other academic research not published in a peer-reviewed journal.

[2] *PROGRESS* stands for place of residence, race/ethnicity, occupation, gender/sex, religion, education, socioeconomic status, and social capital, and *Plus* refers to personal characteristics associated with discrimination, features of relationships and time-dependent relationships.

2.3 Data extraction

All articles included after full-text screening underwent the same data extraction process. Two reviewers read the manuscripts and recorded the information in a template similar to Supplemental Table 1. The extracted information from the two reviewers was then combined through a joint discussion and synthesis process. A single reviewer generated the results tables from the combined, extracted data. Narrative summaries of results were written by a single reviewer and reviewed by the other. Effect estimates are presented as beta coefficients directly extracted from texts, with no additional calculations conducted.

2.4 Reporting bias

Although there was no formal assessment of bias, we expect that there is considerable risk of publication bias. Organizations that conducted interventions that did not have positive impacts may choose not to publish their results. Furthermore, journals may not wish to publish articles on projects that had null impacts. Consequently, results should be interpreted cautiously. Even interventions with several studies indicating positive effects could be subject to this bias, because there could be many more unpublished interventions showing a null effect.

2.5 Inputs regarding implementation, sustainability and evaluation

In an effort to support the adoption of evidence-informed policy, we have provided additional inputs regarding the implementation, sustainability and evaluation of demand-generating interventions. We developed these comments alongside the REA. During the screening process for this REA, we flagged studies if they provided pertinent information regarding the implementation, maintenance or evaluation of the relevant interventions but, otherwise, did not meet the inclusion criteria for this assessment. For the most part, these studies had inappropriate comparators and/or insufficient evaluation design, but still provided relevant information. We extracted the actionable information for practitioners to use in implementing, maintaining and evaluating these interventions from these studies; it is presented after the main results.

3. Results

3.1 Search results

Through the search for supply- or demand-side interventions, we identified 69,330 papers, of which 51,320 remained after de-duplication (**Figure 1**). After title and abstract screening, we included 561 papers for full-text screening. Finally, we identified seven articles, which reflect four unique studies, for inclusion in this REA. Four linked articles reported on a study that delved into the use of vouchers to reduce the cost of a security inspection required for connection to the grid in El Salvador. The remaining studies occurred in Ethiopia, Kenya and Tanzania. Two studies used individual randomization and two cluster randomization. All studies were published after 2013.

Figure 1: PRISMA flow diagram

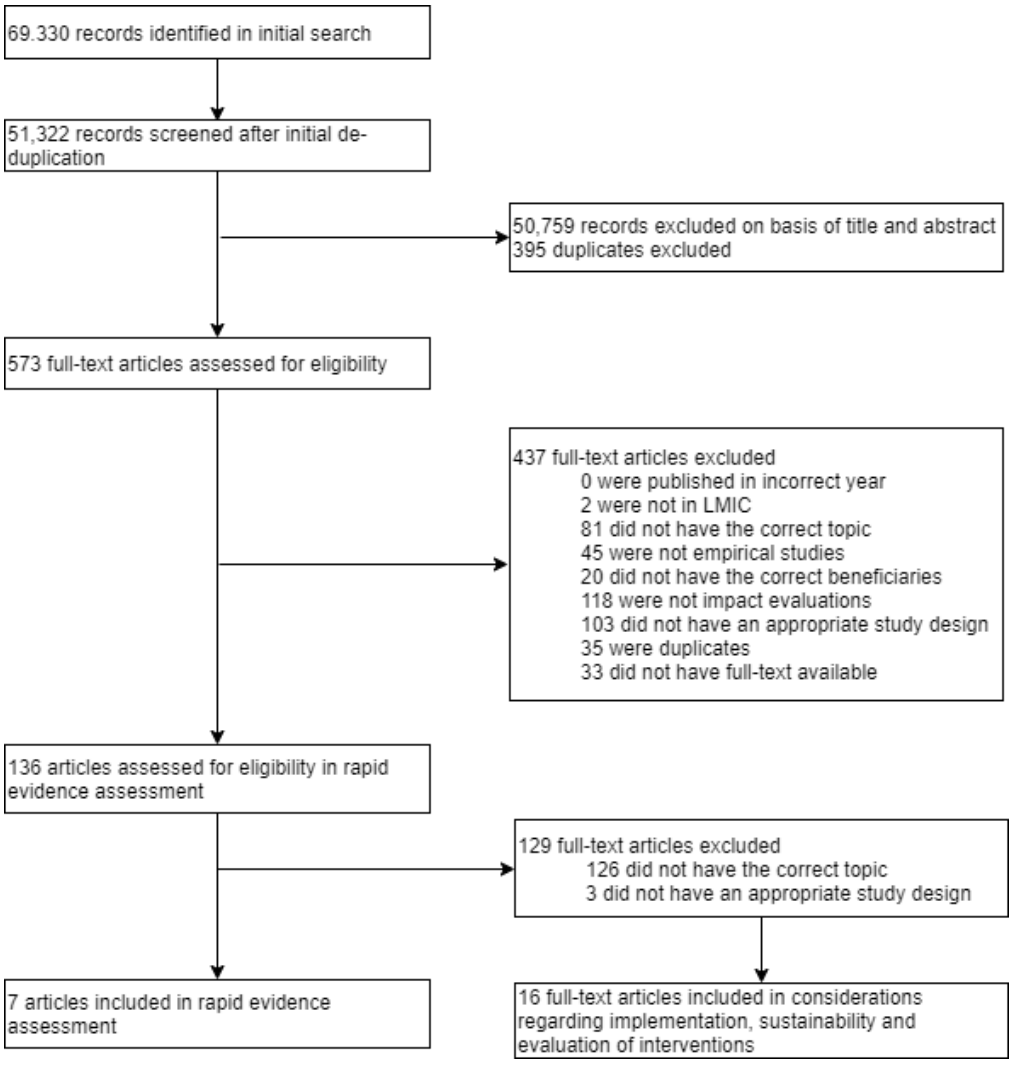

Table 1, Supplemental Table 1). Two used vouchers and two used subsidies to facilitate access to electricity. Only one article mentioned administrative burdens and physical/structural challenges as additional barriers to electrification (Lee, Miguel et al. 2016).

Table 1: Summary of included studies in REA

First author	Year	Title	Country	Study design	Sample Size	Challenges to connection	Facilitators of connection	Intervention	Outcome
Barron*	2014	Electrification and time allocation	El Salvador	Individual randomized	500 households	Direct costs	Vouchers	Households were required to pay a $100 fee for security inspection in order to get electric connection	Both types of vouchers equally increased the probability of a formal connection by 11–19%. Two years after rollout, voucher group's connection rate was 19% higher than non-voucher households. In last two survey rounds, difference in connection between voucher and non-voucher groups was 11% in year 4 and 7% in year 5. Vouchers were significant in rounds 2 and 3, but not in later rounds when non-voucher household connections caught up.
Barron	2017	Household electrification and indoor air pollution							
Barron	2015	Fixed costs, spill-overs, and adoption of electric connections							
Torero	2016	Impact Evaluation of MCC Compact in El Salvador						The intervention randomly provided vouchers of 20% and 50% off of this inspection fee	

First author	Year	Title	Country	Study design	Sample Size	Challenges to connection	Facilitators of connection	Intervention	Outcome
Bernard	2015	Social interaction effects and connection to electricity	Ethiopia	Individual randomized	1,000 villages	Direct costs	Vouchers	At the time of installation of the electrical grid, non-transferable, discount vouchers of 10% and 20% off connection fees were offered to a random set of households	Receiving a 20% discount voucher increased connection probability by 14% points. 10% vouchers had no effect.
Chaplin	2017	Grid electricity expansion in Tanzania by MCC	Tanzania	Cluster randomized	178 villages	Direct costs	Subsidies	The intervention offered connections at an 80% discount rate in selected communities that were already receiving grid line extensions	The low-cost connections increased the rates of connection from 18% to 31%, but connection rates were still low.
							Education	Communications campaign informed households of the low-cost connection offers in treatment villages	

First author	Year	Title	Country	Study design	Sample Size	Challenges to connection	Facilitators of connection	Intervention	Outcome
Lee	2016	Experimental evidence on the demand for and costs of rural electrification	Kenya	Cluster randomized	2,289 households	Administra-tive	Subsidies	A random subset of clustered households received subsidized prices for connections to the grid; subsidies varied between 100% and 29% across communities	The full (100%) subsidy increased take-up likelihood by 95%, the 57% subsidy increased take-up by 23%, and the 29% subsidy increased take-up by 6%.
						Physical	Utility		
						Direct costs			

* These represent different publications that report on the same study and outcomes. Therefore, they are reported together.

3.2 Effects of demand-side interventions on connection to the grid

Two studies leveraged the expansion of the electrical grid to examine the effects of price reductions in areas that had previously not been electrified. Chaplin et al. (2017) offered 80% discounts on connections among a portion of the communities that were receiving grid extensions in Tanzania (**Table 2**, Supplemental Table 1). They also conducted a community-level communication campaign to inform community members of the opportunity. The intervention increased connection rates from 18% to 31%, but rates remained much lower than expected. In Ethiopia, Bernard and Torero (2015) examined how social interactions determined an individual household's decision to connect, even if they did not directly receive a discount voucher. They showed that households living within a 10-meter radius of a household that received a 20% discount voucher were 14% more likely to connect to the grid.

Table 2: Effect estimates from included studies in REA*

Study	Country	Intervention Type	Analysis method	Outcome	Effect estimate***	Interpreted effect estimate
Barron (2014)** Barron (2017)	El Salvador	Voucher	Random encouragement design/instrumental variables	Probability of adopting electricity connection	0.109 (0.058)	11% increase in adopting electricity connection
Barron (2015) Torero (2016)			Fixed effects with clustered standard errors			
Bernard (2015)	Ethiopia	Voucher	Instrumental variable	Probability of connecting for households within 10 meters of households receiving the 10% discount voucher	0.116 (0.093)	12% increase in grid connections for households within 10 meters of households that received the 10% discount voucher
			Regression with robust standard errors clustered at the village level	Probability of connecting for households within 10 meters of households receiving the 20% discount voucher	0.141 (0.074)	14% increase in grid connections for households within 10 meters of households that received the 20% discount voucher
Chaplin (2017)	Tanzania	Subsidy	Regression with clustered standard errors	Probability of households connecting to national grid	0.13 (0.02)	13% increase of grid connections

Study	Country	Intervention Type	Analysis method	Outcome	Effect estimate***	Interpreted effect estimate
Lee (2016)	Kenya	Subsidy	Random encouragement design/instrumental variables	Probability of connecting to the grid for households receiving low subsidy vouchers	5.94 (1.50)	6% increase in grid connections for households receiving low subsidy vouchers
				Probability of connecting to the grid for households receiving medium subsidy vouchers	22.88 (4.02)	23% increase in grid connections for households receiving medium subsidy vouchers
			Regression with clustered standard errors	Probability of connecting to the grid for households receiving high subsidy vouchers	94.97 (1.27)	95% increase in grid connections for households receiving high subsidy vouchers

* The effect estimates in this table cannot be directly compared to each other. For the reader, the authors have added a column to provide a short interpretation of the effect estimate.
** These represent different publications that report on the same study and are, therefore, reported together here.
***Effect estimates provided are beta coefficients with standard errors in brackets.

The two other studies examined the effect of price variation for those already living under the grid. Lee, Miguel and colleagues (2016) offered connection subsidies for a subset of households in Kenya. These subsidies ranged from fully (100%) to partially subsidized (29%). Although the full subsidy increased demand by 95%, this dropped dramatically as the subsidy diminished. Households receiving the 57% subsidy were only 23% more likely to connect than households that did not receive a subsidy. Also, the series of papers published on a single study in El Salvador show that vouchers for 50% or 20% off of an inspection fee initially stimulated demand by 11%–19%, but this effect decreased over time (Barron and Torero 2014, 2015, 2017; Torero and Barron 2016). While participants who received vouchers were 15% more likely to adopt in years 2 and 3, this decreased to 10% in years 4 and 5.

3.2.1 Social factors affecting adoption

Three of the studies found that increasing household wealth is positively associated with grid connections. Two studies established that wealth and income were positively related to a household's decision to connect (Barron and Torero 2015; Bernard and Torero 2015). Lee, Miguel and colleagues (2016) determined that connection rates in the low and medium subsidy arms were higher among more educated and wealthier households. However, Chaplin and colleagues (2017) did not find that household income had an impact on a household's decision to connect to the grid.

3.3 Downstream effects of demand generation on wellbeing within included studies

We also extracted information on the downstream effects of electricity grid demand generation from studies included within this review. However, given that this review was not meant to systematically identify these outcomes, the findings below are not representative of the evidence base for them. They represent the findings from the studies that met our inclusion criteria and are, therefore, only applicable within this context.

3.3.1 Effects on welfare

Two of the studies discussed how electricity access could improve household welfare. After connecting to the grid, households purchased appliances such as refrigerators, TVs and radios. In the El Salvador study, refrigerator ownership increased by 54.4% and TV ownership by 57.8% for households connected to the grid (Barron and Torero 2014). Chaplin and colleagues (2017) found that TV ownership was 56% higher among connected than non-connected households. Household grid connections were also linked to income growth (Barron and Torero 2014). In El Salvador, total household income was estimated to increase by $1,600 per year after electrification (Barron and Torero 2014). This effect was roughly equivalent to the average profits from non-farm businesses. Because electrification was related to increased female participation in income-generating activities, this income increase was likely the result of women entering the labor force. In Tanzania, households that connected to the grid had a 49% increase in annual household income compared to non-connected households (Chaplin et al. 2017). Although connecting to the grid did not increase the probability of households to engage in any income-generating activities, connection was related to increased probability of households that operated income-generating activities that used electricity. The revenue from income-generating activities increased after connecting to the grid.

3.3.2 Effects on time allocation

The included studies also found that electrification affects households' time allocation. In El Salvador, school-age children whose households were connected to the grid were more likely to participate in educational activities, such as studying, than children who did not have access to electricity (Barron and Torero 2014). Chaplin et al. (2017) found that connecting to the grid increased study time per day by 0.23 hours for children aged 5–14 because students were able to study more at night. For adults in El Salvador, connecting to the grid increased the likeliness of engaging in non-farm employment by 26% (Barron and Torero 2014). In Tanzania, adults spent less time collecting water and fuel, and more time socializing and resting (Chaplin et al. 2017).

3.3.3 Effects on health

In these studies, the effects of electrification on health were mixed. Barron and Torero (2017) found that $PM_{2.5}$ concentrations decreased by 66% more in intervention households than the control group. Chaplin et al. (2017) did not find any effects on pollution exposure, and found that children and youth living in households that had received the vouchers were more likely to report negative health outcomes, such as difficulty breathing, vision problems or wheezing than control communities. This may be due to increased time spent indoors, which increased exposure to indoor pollutants. However, Chaplin et al. (2017) did find that connected households were 10% more likely to receive health information from electronic media than non-connected households.

3.4 Study quality and risk of bias

Studies were generally of high quality, although we did not perform a formal risk of bias assessment. The four individual studies used randomization to improve the comparability of intervention and control sites. Randomization occurred at the individual or cluster level. However, in two cases, randomization did not function as expected. Chaplin et al. (2017) indicated that firms installing electrical lines in intervention villages may have had better access to land because local residents were expected to benefit from the intervention. Bernard and Torero (2015) had to drop some households from their intervention sample because they were determined to be too far from the electrical line. These alterations in study design could decrease the generalizability of results.

4. Considerations for implementation, sustainability and evaluation of interventions to increase the demand for grid electrification

4.1 Considerations for implementation and sustainability

To stimulate demand, interventions must adequately address the barriers to electrification. These barriers fall into five, overlapping categories: (1) electric utility quality, (2) economic, (3) administrative, (4) physical and (5) social or informational. All these barriers affect a household's decision to connect to the grid. They were identified through the intensive literature search and screening process that accompanied the REA. Many of these barriers were identified through descriptive studies that did not meet the inclusion criteria for study design, but still provided important insights into the implementation of demand-side electrification interventions. Successful interventions will address some or all of these challenges.

4.1.1 Electric utility quality

The electric utility must be of a suitable quality for households to view it as worth the investment (Kennedy et al. 2019). Aside from the connection cost, households also take into account the potential benefits from connecting to the grid and the reliability of the electricity service. If electricity supply is unreliable, households are discouraged from connecting to the grid (Khandker et al. 2012; Thomas and Urpelainen 2018). In India, households' willingness to pay increased as the service quality of the electric utility improved and power was available for a longer duration (Kennedy et al. 2019). This is logical because the size of the benefits from electrification is reduced if electricity supply is unreliable (Dang and La 2019; Poczter 2017; Samad and Zhang 2017). The structure of the utility may be important in determining the quality of the utility because private electric companies in Peru provided higher quality services than public companies (Alcazar et al. 2007). The utility must also be capable of sustaining itself. In Bihar, strengthening the electric utility's capacity to collect on electricity bills from consumers increased the utility's viability because they were able to recoup costs without having to increase prices for paying customers (Rains and Abraham 2018).

4.1.2 Economic

Electricity consumption has inherent costs that must be passed onto the consumer to allow the utility to be sustainable. There are two types of costs for the consumer: the initial cost and then regular payments for electricity consumption. The latter cost can take the form of prepayment, fixed fee or metered monthly payments. However, even if subsidies are offered to cover the consumption costs, low-income households may not be able to pay the remaining upfront costs associated with grid connections (Bonan et al. 2017). Households with irregular income may choose not to connect even if they have enough resources to pay the upfront fees because they cannot guarantee they would be able to pay future utility bills (Blimpo and Postepska 2017). Economic constraints may also be less obvious. As mentioned in the results section, households in El Salvador had to show a land ownership certificate in order to be connected (Barron and Torero 2015). This was not always possible for the poorest households.

When designing interventions, it is important to consider responsible and fair means for counteracting the economic cost to connect (Bonan et al. 2017). Subsidies, vouchers and tariffs should account for the number of people who could connect to a given line, their geographic distribution, and the sustainability of the project. There may be a difference in economic benefits gained from electrification based on the subsidy level. In Kenya, households that were willing to pay for grid connections experienced more economic gains than those only connected when the connection was, basically, free (Lee et al. 2020). However, households that were able to pay first tended to be wealthier and more educated. Regions with higher income and/or those most likely to benefit economically from electrification could experience higher connection rates in response to voucher and subsidy schemes (Blimpo and Postepska 2017).

4.1.3 Administrative

In some settings, the process for getting access to the electrical grid can be so long and burdensome that households may choose not to connect. Lee and colleagues (2016) concluded that excessive bureaucracy may have reduced demand. In Kenya, households would have to wait on average 188 days after submitting their application to receive electricity (Lee et al. 2019). In Ethiopia, some households obtained indirect

connections to the electricity grid to avoid the bureaucratic process and the upfront connection cost (Barnes et al. 2016). Systems must be put in place that allow for connections to be obtained in a timely and uncomplicated manner.

4.1.4 Physical

Highly remote areas may have increased costs associated with electrification due to the need to install long line extensions. Lower costs can be achieved by connecting more people to these extensions (Chaplin et al. 2017). Group-based subsidies could decrease the cost of connecting each individual household to the line and, therefore, stimulate demand in a cyclical fashion (Lee et al. 2014; Lee, Miguel, et al. 2016).

Electrification is not always possible due to physical limitations of the house. The construction materials of a household's dwelling affect whether or not the house can be electrified (Blimpo and Postepska 2017). If the walls of the house are made of wood, grass, mud or metal sheets, it may not be eligible for connection (Barnes et al. 2016; Barron and Torero 2015). Interventions might be able to increase demand by finding ways to connect these ineligible houses either by providing improved materials or by developing safe connection mechanisms.

4.1.5 Social and informational

Individuals may choose not to connect because of limited knowledge of the payment system or the advantages of electrification (Bonan et al. 2017; Peters et al. 2009). Cultural norms might prevent people from fully switching to electrical energy sources even once they are electrified (Blimpo and Postepska 2017; Peters et al. 2009). Households may view electricity as a luxury (Bonan et al. 2017). Therefore, education campaigns could be used to show the cost and health benefits of relying mainly on electricity (Peters et al. 2009). Training can be provided to entrepreneurs who would benefit from the adoption of electricity based tools (Peters et al. 2009).

4.2 Considerations for design of an impact evaluation

All the general guidelines and standards in designing rigorous impact evaluations are applicable when evaluating demand-side electrification interventions (White 2009). In particular, a methodology for constructing a counterfactual should be integrated into project design from the inception phase. The development of a counterfactual for demand-side interventions to support electrification is challenging because these interventions often cannot be randomized. The installation of an electrical grid is a large public works project often driven by practical and political considerations rather than evaluability criteria. However, if evaluations are planned from the outset, grid connections can be phased over time in a randomized manner to allow for rigorous evaluation. Nonetheless, there is considerable endogeneity involved in the decision to connect to the electric grid (van de Walle et al. 2017). Propensity score matching and instrumental variable approaches could be appropriate in the context of non-randomized trials (van de Walle et al. 2017). Eligibility criteria for specific government programs may be used to induce quasi-experimental variation and could be leveraged to allow for model identification through regression discontinuity (Burlig and Preonas 2016).

As part of the design phase, it is important to carefully assess barriers to electrification in the target population. These may be different across groups and the differences could

affect the ultimate effectiveness of the intervention. A pre-assessment or feasibility study should be conducted to identify these barriers and specific contextual factors from the intervention setting that should be incorporated into the final design. A monitoring process should also be incorporated into the intervention to track progress and improve implementation as needed.

A pre-analysis plan should be written before the beginning of data collection. Such a plan can be registered at the *Registry for International Development Impact Evaluations* or one of the journals supported by the Center for Open Science. The benefit of such an approach is that it ensures the necessary data are collected to allow for a successful evaluation after the study is completed.

If a voucher-based intervention is used, the chosen discount level ought to be appropriate and feasible. It should ensure that those who benefit from the intervention are unique from those who would have connected in the absence of the intervention (Bernard and Torero 2011). The chosen discount level should not be so low that only wealthy households that would have connected either way choose to take advantage of the intervention. However, the discount level should also not be so large as to prevent the sustainable scaling of the discount—it ought to be designed within the potential range for future pricing policies the utility might implement (Bernard and Torero 2011). This will ensure the impact is to be estimated on a population that is representative of the people who would be potential discount beneficiaries in the future.

In addition to year and district, the variables in **Table 3** were considered as covariates in the four included studies as potential correlates of electrification. Authors of future studies may wish to consider these for inclusion in their own models.

Table 3: List of variables authors considered as covariates in the four included studies

Household head characteristics	Household-level variables	Village-level characteristics	Intervention-specific variables
Age	Number of individuals in the household	Number of female-owned income-generating activities	Formal connections within 100 meters (n and %)
Gender	Construction materials	Number of income-generating activities using non-electric energy	Total number of eligible neighbors
Education	Wealth/Income	Population density	Proportion of neighbors who received vouchers
Marital status	Use of wood for cooking		Average fee for neighbors
	Daily consumption (USD) Household energy use Number of chickens Use of a bank account Occupation Distance to nearest pole Households connected within X meters		

5. Discussion

The results indicate that interventions to reduce the direct cost of connections can be successful in increasing demand for electrification. However, no qualifying impact evaluations of interventions to diminish other barriers to electrification were identified.

5.1 Social and human elements driving electricity demand

The mode these studies used to increase demand was primarily by reducing financial constraints. In El Salvador, those who received vouchers for low-cost connections were initially more likely to connect; however, over time the electrification rate of the control group approached that of the intervention group (Barron and Torero 2014). This indicates that both groups wanted electrification, but household-level budget constraints initially prevented the control group from connecting. Lee, Miguel and colleagues (2016) argue reducing inflated construction costs due to corruption and administrative burdens could be effective in lowering connection fees, thus alleviating budget constraints.

In addition to the primary mechanism of action, there were also significant spillover effects in El Salvador and Ethiopia. Households whose neighbors received vouchers were more likely to become electrified, whether or not they received the voucher (Bernard and Torero 2015). The effect was likely a result of being surrounded by

households that were more likely to adopt electrification (Bernard and Torero 2015). This could be due to changing social norms or a reduction in the cost of connection, because other houses had already been connected. In the agriculture sector, there is evidence that wealthier households first adopt new technologies, which increases knowledge and reduces barriers in poorer households, and spurs technology adoption (Foster and Rosenzweig 1995). Chaplin and colleagues (2017) found that the cost of connecting a household could be reduced by decreasing connection fees to such an extent that more households connect to each extended line. In El Salvador, it was calculated that the electric utility might actually increase revenue by sharing 20% of the connection fee with households in the first few years after electrifying an area (Barron and Torero 2015).

5.2 Limitations in available studies

Through this REA, only four unique studies that considered the impact of demand-side interventions on electricity access were found. Although 51,320 papers were initially identified after de-duplication, 50,759 articles were excluded during title and abstract screening. An additional 538 articles were eliminated during full-text screening for the broader systematic review and another 143 articles during the eligibility assessment for this REA. A common reason for exclusion was that the study was not about grid electricity access or use. For example, studies were eliminated because the intervention had not been to promote access to the electricity grid; instead, it motivated families to save electricity or use renewable energy, such as solar lamps. Many studies described reasons individuals may choose not to connect, without considering an intervention. Other excluded studies only provided the baseline results from an impact evaluation.

The four studies included only tested the effects of affordability interventions and not interventions related to administrative barriers, information campaigns or other demand-side interventions. While administrative burdens, lack of information and understanding of billing schemes, reliability of the utility, and physical constraints are established barriers to connection, there do not seem to be impact evaluations that consider efforts to address these barriers (Blimpo and Postepska 2017; Bonan et al. 2017; Lee, Miguel et al. 2016). In addition to broadening the base of knowledge related to affordability interventions, future work should consider the possible impacts of other interventions. Affordability alone might not be sufficient to reach full electrification. Only 5% of rural households in Kenya that were eligible to connect to a low-voltage line at relatively low cost chose to connect after five years (Lee et al. 2014). Half of the unconnected households were within 200 meters of a line. Even when connection fees were fully subsidized, the connection rate did not reach 100% (Lee, Miguel et al. 2016).

5.3 Strengths, limitations and future directions

The primary strength of this work is that it is a result of a rigorous and systematic search of the available peer-reviewed and grey literature. We are confident that we have identified all published works related to the generation of demand for electrification in L&MICs. However, the number of impact evaluations we identified was low and only addressed one of several barriers, which suggests that there is a major gap in the evidence on demand generation for electrification. There is considerable scope for publication bias in these results. One possible explanation for the dearth of evidence is that there could have been other evaluations of intervention found to be unsuccessful

and, therefore, not published. Another possible explanation is that there simply is not sufficient research in this field. More impact evaluations on a broader range of interventions are needed to truly understand what works in the field of demand generation for electrification. Future work should be grounded in and extend upon the large body of literature that considers barriers to and facilitators of electrification.

6. Conclusion

The available published evidence indicates that interventions to increase the affordability of connecting to the grid can be successful in doing so. However, such interventions may disproportionately benefit the wealthy because these are the individuals who are the most likely to be able to afford any remaining costs, regular payments and housing suitable for electrification. Financial constraints exclude less wealthy households from the opportunity to adopt electrification. Costs could be reduced through novel extension and funding schemes that support more households connecting to each extension line. However, even with supportive funding measures, electrification rates were found to remain low. Therefore, other barriers to electrification, including the social and informational, administrative and physical barriers must also be addressed. Robust methodological approaches that are planned before intervention implementation will be needed to quantify its impacts. We hope that practitioners use this work to consider the design of their own interventions.

7. Acknowledgements

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Appendix A: Databases and catalogues searched

Electronic searches of bibliographic databases and library catalogues

- Cochrane Library
- EBSCO Discovery: IDEAS RePeC and World Bank e-library
- EBSCO: Agricola, Gender Studies, Greenfila, Africa-wide, CAB Abstract, ERIC
- IBSS (Proquest)
- Ovid: CAB Global Health, Econlit, Medline, PsycInfo
- Scopus
- Web of Science

Other specialist databases

The following set of additional specialist databases were searched as part of this review and are also presented in Mathur et al. (2014)

- 3ie RIEPS (Repository of Impact Evaluation Published Studies)
- Abdul Latif Jameel Poverty Action Lab (J-PAL)
- British Library for Development Studies (BLDS)
- The Campbell Collaboration Library
- Danida Research Portal (Ministry of Foreign Affairs of Denmark)
- Department for International Development (DFID) Research for Development (R4D) database
- Eldis
- International Labour Organization (ILO) Library
- JOLIS library catalogue – International Monetary Fund, World Bank and International Finance Corporation
- OpenGrey
- Organisation for Economic Co-operation and Development (OECD) iLibrary
- Social Science Research Network (SSRN) eLibrary Database
- World Bank Independent Evaluation Group (IEG)
- World Bank Development Impact Evaluation (DIME) Initiative

Relevant websites

Supplemental Table 1 presents a set of organization websites that were searched as part of the review. From experience, these websites offer less sophisticated search functionality. Consequently, reduced searches were implemented using the search strings developed for the review to the extent possible.

Table A1: Extended summary of included studies in REA

First author	Year	Title	Topic	Country	Collaborating organization	Intervention	Study design	Sampling approach	Statistical approach	Relevant covariates considered
Barron*	2014	Electrification and time allocation	Affor-dabili-ty	El Salvador	IFPRI	Government already covered installation of the meter; however, households were required to pay a $100 fee for security inspection to get electric connection	Individual randomized	Random	Random encourage-ment design/ins-trumental variables	Formal connections within 100 meters (n and %); total number of eligible neighbors; proportion of neighbors who received vouchers; average fee for neighbors; household size; wall and floor material; wealth; age, sex and literacy of household head; year; sub-district; use of wood for cooking
Barron	2017	Household electrification and indoor air pollution			Salvadorian Bureau of Statistics					
Barron	2015	Fixed costs, spillovers and adoption of electric connections			UC Santa Cruz				Fixed effects with clustered standard errors	
Torero	2016	Impact Evaluation of MCC Compact in El Salvador			Universidad del Pacifico, Peru	The intervention randomly provided vouchers of 20% and 50% off this inspection fee				
					World Bank					

First author	Year	Title	Topic	Country	Collaborating organization	Intervention	Study design	Sampling approach	Statistical approach	Relevant covariates considered
Bernard	2015	Social interaction effects and connection to electricity	Affor-dabili-ty	Ethiopia	Ethiopian electric power corporation Ethiopian economic association IFPRI	At baseline, electricity was unavailable and electrical lines were installed shortly after At the time of installation, non-transferable, discount vouchers of 10% and 20% off connection fees were offered to a random set of households	Individual randomized	Random	Instrumen-tal variable Regression with robust standard errors clustered at the village level	Population density; distance to the nearest pole; wealth; age and sex of head of household; household size; connected households within radius (30 or 100 meters); daily consumption
Chaplin	2017	Grid electricity expansion in Tanzania by MCC	Affor-dabili-ty	Tanzania	MCC DH Infrastructure	The intervention offered connections at an 80% discount in selected communities that were already receiving grid line extensions	Cluster randomized	Random	Regression with clustered standard errors	Gender, age, education level and marital status of the household head; number of household members; household income per capita per day; amount of water household pumps;

First author	Year	Title	Topic	Country	Collaborating organization	Intervention	Study design	Sampling approach	Statistical approach	Relevant covariates considered
					EDI Mathematica MCC Tanzania electric supply company NRECA	Customers still paid for application fee and to wire homes Communications campaign informed households of the low-cost connection offers				whether any male adult household member (15 and older) missed work in the last 30 days due to illness; time adult females spend sleeping at night; time adult females spend socializing; number of female-owned income-generating activities; number of income-generating activities using non-electric energy
Lee	2016	Experimental evidence on the demand for and costs of rural electrification	Affor-dabili-ty	Kenya	Berkeley Energy and Climate Institute Blum Center for Developing Economies Center for Effective Global Action	A random subset of clustered households received subsidized prices for connection to the grid; subsidies varied between 100% and 29% across	Cluster randomized	Random	Random encourage-ment design/in-strumental variables	Community characteristics were used in stratification process

First author	Year	Title	Topic	Country	Collaborating organization	Intervention	Study design	Sampling approach	Statistical approach	Relevant covariates considered
					Development Impact Lab Kenya Power Kenya's Rural Electrification Authority National Bureau of Economic Research	communities			Regression with clustered standard errors	Household size; number of chickens; respondent age, education, use of a bank account and occupation; high-quality walls
					UC Center for Energy and Environmental Economics Weiss Family Program Fund for Research in Development Economics World Bank	Treatment households were given a ready to use board				Included interactions between household economic status and treatment

* These represent different publications that report on the same study and are, therefore, reported together here.

Table A1: (cont'd): Extended summary of included studies in REA

First author	Year	Challenges to connection	Facilitators of connection	Problems with implementation	Outcome	Other results	Problems with study design, limitations, and biases	Conclusions	Additional interpretations
Barron*	2014	Direct costs	Vouchers	--	Both types of vouchers equally increased the probability of a formal connection by 11 to 19%. Two years after rollout, voucher group's connection rate was 19% higher than non-voucher households. In the last two survey rounds, difference in connection between	An additional connection within 100 meters increased the probability that a house connected almost the same amount as receiving the voucher (10% points). A 10% point increase in the share of neighbors that connected related to 2% point increase	There was a small number of compliers (16%) that may make the use of an instrumental variable approach inappropriate	Vouchers decreased cost and, thereby, facilitated early connection; yet, over time, people in the control group started increasing their adoption. The lower fee increased adoption in the earlier rounds, but not later in the process. Voucher recipients adopted connections 1 to 2 years	The electric utility could increase customer base and revenue by sharing 20% of the connection fee in the early years of an electrification project
Barron	2017								
Barron	2015								

First author	Year	Challenges to connection	Facilitators of connection	Problems with implementation	Outcome	Other results	Problems with study design, limitations, and biases	Conclusions	Additional interpretations
					voucher group and non-voucher group is 11% in year 4 and 7% in year 5. Vouchers are significant in rounds 2 and 3, but not in later rounds when non-voucher household connections caught up.			before the controls.	
Torero	2016					The vouchers did not crowd out demand for formal connections Households with informal electricity at baseline were 18% more likely to take up voucher.		There were likely spillover effects. Households with informal connections were more responsive at baseline to vouchers and spillover effects.	
Bernard	2015	Direct costs	Vouchers	After households were identified, some were determined to be too far from the grid to connect and had to be	Receiving a 20%-discount voucher increases one's connection probability by	Each additional household that receives a voucher within a 30-meter radius	Much of the study centers on the effects of neighbors adopting electricity without	The social driver may function through a preference to have similar amenities to one's peers	--

First author	Year	Challenges to connection	Facilitators of connection	Problems with implementation	Outcome	Other results	Problems with study design, limitations, and biases	Conclusions	Additional interpretations
				dropped	14% points; 10% vouchers had no effect	increased the probability that a non-voucher household connected to the grid by about 2% points, depending on exact model specification	focusing on the effects of the vouchers The order for assigning vouchers and choosing study participants is unclear	This could be related to social status	
						This was reduced to a 0.3% point increase for each connected neighbor within 100 meters and the effect is non-significant after this.	Small sample population		

First author	Year	Challenges to connection	Facilitators of connection	Problems with implementation	Outcome	Other results	Problems with study design, limitations, and biases	Conclusions	Additional interpretations
Chaplin	2017	Direct costs	Subsidies Education	Much lower connection rates than expected	The low-cost connections increased the rates of connection from 18% to 31%, but connection rates were still low	The increase in connection rates associated with the low-cost connection was greater than the increase in connection rates associated with line extensions	Firms building lines may have found it easier to get access to land in intervention than control sites because these firms know the intervention would occur	Reducing connection fees may also reduce the total cost of connecting each household after accounting for the cost of line extension by connecting more households to a given line	--
Lee	2016	Administrative Direct costs	Subsidies Utility	There was a lengthy and bureaucratic process to	The full (100%) subsidy increased take-up likelihood	Willingness to pay was higher when households	--	Low demand may be due to cost inflation during	--

First author	Year	Challenges to connection	Facilitators of connection	Problems with implementation	Outcome	Other results	Problems with study design, limitations, and biases	Conclusions	Additional interpretations
		Physical		obtain connection Long-term blackouts were a deterrent for connection	by 95%; the 57% subsidy increased take-up by 23%; the 29% subsidy increased take-up by 6%	were given more time to obtain credit		construction, excessive administrative burden, low reliability and credit constraints	

* These represent different publications that report on the same study and are, therefore, reported together here.

Table A2: List of websites searched as a part of this review

Websites	Links
African Development Bank	http://www.afdb.org/en/
Asian Development Bank	http://www.adb.org/
African Population and Health Research Centre (APHRC)	http://www.aphrc.org/
Agence Française de Développement (AFD)	http://www.afd.fr/lang/en/home
Australian Agency for International Development (AusAID)	http://www.ausaid.gov.au/Pages/Publications-and-Research.aspx
Canadian International Development Agency (CIDA)	http://search-recherche.gc.ca/rGs/s_r?st=s&num=10&st1rt=0&langs=eng&cdn=cida
Caribbean Development Bank (CDB)	http://www.caribank.org/publications-and-resources
Centre for Energy Policy and Technology (ICEPT)	http://www3.imperial.ac.uk/icept
Economic Commission for Latin America and the Caribbean (ECLAC/CEPAL)	http://www.cepal.org/default.asp?idioma=IN
Eldis	http://www.eldis.org/
Energy for Development Network	http://www.energyfordevelopment.net/
Energy Governance Initiative	http://www.wri.org/our-work/project/electricity-governance-initiative
Energy Sector Management Assistance Program (ESMAP)	https://www.esmap.org/node/25
Institute of Development Studies (IDS)	http://www.ids.ac.uk
Inter-American Development Bank	http://www.iadb.org
Inter-American Development Bank Office of Evaluation and Oversight	http://www.iadb.org/en/office-of-evaluation-and-oversight/
International Energy Agency (IEA)	http://www.iea.org/topics/energypoverty/
International Renewable Energy Agency (IRENA)	http://www.irena.org/menu/index.aspx?mnu=Subcat&PriMenuID=36&CatID=141&SubcatID=339

Websites	Links
Japan International Cooperation Agency (JICA)	http://www.jica.go.jp/english/
National Bureau of Economic Research	http://www.nber.org/
Norwegian Agency for Development Cooperation (NORAD)	http://www.norad.no/en/tools-and-publications
Overseas Development Institute (ODI)	http://www.odi.org.uk/
PEMBINA Institute	http://www.pembina.org/re/work/developing-countries
Science and Development Network (SciDev Net)	www.scidev.net/en/
STEPS Centre	http://steps-centre.org/project/low_carbon_development/
Swedish International Development Cooperation Agency (SIDA)	http://www.sida.se/english/
Swiss Agency for Development and Cooperation (SDC)	http://www.sdc.admin.ch/en/Home/Documentation
United Nations Development Programme (UNDP)	http://www.undp.org/undp/en/home.html
United States Agency for International Development (USAID)	http://www.usaid.gov/
UN Energy Knowledge Network	http://www.un-energy.org/members/wbg

Appendix B: Example search strings for CAB Abstracts (EBSCO)

S19 S4 AND S14 AND S18 **Limiters - Publication Year: 2000–2020**

18,389

S18 S15 OR S16 OR S17

1,783,114

S17 DE "economic analysis" OR DE "cost analysis" OR DE "cost benefit analysis" OR DE "cost effectiveness analysis" OR DE "consumption functions" OR DE "demand functions" OR DE "supply functions" OR DE "utility functions"

53,548

S16 TI ((economic* or cost* or budget* or financ*) N3 (effect* or benefit* or efficien* or utilit*)) OR AB ((economic* or cost* or budget* or financ*) N3 (effect* or benefit* or efficien* or utilit*)) OR DU ((economic* or cost* or budget* or financ*) N3 (effect* or benefit* or efficien* or utilit*))

129,894

S15 TI (("random* control* trial*" OR "random* trial*" OR RCT OR "cluster random* trial" OR "propensity score matching" OR PSM Or "regression discontinuity design" OR RDD OR "difference in difference*" OR DID OR "systematic* review*" OR meta-analy* OR "meta analy*" OR SR OR "control* random* trial*" OR "case control" OR matching OR "interrupted time series" OR "random* allocation*" OR (random* N3 (allocat*)) OR "instrumental variable*" OR IV OR "research synthesis" OR "scoping review" OR "rapid evidence assessment" OR "systematic literature review" OR evaluation OR assessment OR ((quantitative OR "comparison group" OR counterfactual OR "counter factual" OR counter-factual OR experiment*) N3 (design OR study OR analysis)) OR QED)) OR AB (("random* control* trial*" OR "random* trial*" OR RCT OR "cluster random* trial" OR "propensity score matching" OR PSM Or "regression discontinuity design" OR RDD OR "difference in difference*" OR DID OR "systematic* review*" OR meta-analy* OR "meta analy*" OR SR OR "control* random* trial*" OR "case control" OR matching OR "interrupted time series" OR "random* allocation*" OR (random* N3 (allocat*)) OR "instrumental variable*" OR IV OR "research synthesis" OR "scoping review" OR "rapid evidence assessment" OR "systematic literature review" OR evaluation OR assessment OR ((quantitative OR "comparison group" OR counterfactual OR "counter factual" OR counter-factual OR experiment*) N3 (design OR study OR analysis)) OR QED)) OR DU (("random* control* trial*" OR "random* trial*" OR RCT OR "cluster random* trial" OR "propensity score matching" OR PSM Or "regression discontinuity design" OR RDD OR "difference in difference*" OR DID OR "systematic* review*" OR meta-analy* OR "meta analy*" OR SR OR "control* random* trial*" OR "case control" OR matching OR "interrupted time series" OR "random* allocation*" OR (random* N3 (allocat*)) OR "instrumental variable*" OR IV OR "research synthesis" OR "scoping review" OR "rapid evidence assessment" OR "systematic literature review" OR evaluation OR assessment OR ((quantitative OR "comparison group" OR counterfactual OR "counter factual" OR counter-factual OR experiment*) N3 (design OR study OR analysis)) OR QED))

1,671,883

S14 S5 OR S6 OR S7 OR S8 OR S9 OR S10 OR S11 OR S12 OR S13

4,909,767

S13 (DE "Africa" OR DE "Francophone Africa" OR DE "Africa South of Sahara" OR DE "North Africa" OR DE "Portuguese Speaking Africa" OR DE "Anglophone Africa" OR DE "South America" OR DE "Argentina" OR DE "Bolivia" OR DE "Brazil" OR DE "Chile" OR DE "Colombia" OR DE "Ecuador" OR DE "Falkland Islands" OR DE "French Guiana" OR DE "Guyana" OR DE "Paraguay" OR DE "Peru" OR DE "Amazonia" OR DE "Suriname" OR DE "Uruguay" OR DE "Venezuela" OR DE "Latin America" OR DE "Central America" OR DE "Belize" OR DE "Costa Rica" OR DE "El Salvador" OR DE "Guatemala" OR DE "Honduras" OR DE "Nicaragua" OR DE "Panama" OR DE "Mexico" OR DE "Asia" OR DE "Central Asia" OR DE "East Asia" OR DE "South Asia" OR DE "South East Asia" OR DE "West Asia" OR DE "Middle East" OR DE "Egypt" OR DE "Iran" OR DE "Iraq" OR DE "Israel" OR DE "Jordan" OR DE "Lebanon" OR DE "Oman" OR DE "Palestine" OR DE "Persian Gulf States" OR DE "Saudi Arabia" OR DE "Syria" OR DE "Yemen" OR DE "Arab Countries" OR DE "Caribbean" OR DE "Bahamas" OR DE "Turks and Caicos Islands" OR DE "Antilles" OR DE "Pacific Islands" OR DE "Macquarie Island" OR DE "Melanesia" OR DE "Micronesia" OR DE "Norfolk Island" OR DE "Polynesia" OR DE "Wake Island"

2,234,878

S12 TI (("transitional countr*" OR "emerging econom*" or "global south")) OR AB (("transitional countr*" OR "emerging econom*" or "global south")) OR SU (("transitional countr*" OR "emerging econom*" or "global south"))

1,494

S11 TI ((lmic or lmics or "third world" or "lami countr*")) OR AB ((lmic or lmics or "third world" or "lami countr*")) OR SU ((lmic or lmics or "third world" or "lami countr*"))

41,311

S10 TI (low N3 middle N3 countr*) OR AB (low N3 middle N3 countr*) OR SU (low N3 middle N3 countr*)

ent 7,989

S9 TI ((low* N1 (gdp or gnp or "gross domestic" or "gross national" or GNI))) OR AB ((low* N1 (gdp or gnp or "gross domestic" or "gross national" or GNI))) OR SU ((low* N1 (gdp or gnp or "gross domestic" or "gross national" or GNI)))

149

S8 TI (((developing or "less* developed" or "under developed" or underdeveloped or "middle income" or "low* income") N1 (economy or economies))) OR AB (((developing or "less* developed" or "under developed" or underdeveloped or "middle income" or "low* income") N1 (economy or economies))) OR SU (((developing or "less* developed" or "under developed" or underdeveloped or "middle income" or "low* income") N1

(economy or economies)))

2,146

S7 TI (((developing or "less* developed" or "least developed" or "under developed" or underdeveloped or "middle income" or "low* income" or underserved or "under served" or deprived or poor* or "resource limited" or "resource constrained") N1 (countr* or nation? or population? or world or state*))) OR AB (((developing or "less* developed" or "least developed" or "under developed" or underdeveloped or "middle income" or "low* income" or underserved or "under served" or deprived or poor* or "resource limited" or "resource constrained") N1 (countr* or nation? or population? or world or state*))) OR SU (((developing or "less* developed" or "least developed" or "under developed" or underdeveloped or "middle income" or "low* income" or underserved or "under served" or deprived or poor* or "resource limited" or "resource constrained") N1 (countr* or nation? or population? or world or state*)))

3,960,438

S6 TI (Africa or Asia or Caribbean or "West Indies" or "South America" or "Latin America" or "Central America") OR AB (Africa or Asia or Caribbean or "West Indies" or "South America" or "Latin America" or "Central America") OR GL (Africa or Asia or Caribbean or "West Indies" or "South America" or "Latin America" or "Central America") OR SU (Africa or Asia or Caribbean or "West Indies" or "South America" or "Latin America" or "Central America")

2,248,613

S5 TI ((Afghanistan or Albania or Algeria or Angola or Antigua or Barbuda or Argentina or Armenia or Armenian or Aruba or Azerbaijan or Bangladesh or Benin or Byelarus or Byelorussian or Belarus or Belorussian or Belorussia or Belize or Bhutan or Bolivia or Bosnia or Herzegovina or Hercegovina or Botswana or Brazil or Bulgaria or "Burkina Faso" or "Burkina Fasso" or "Upper Volta" or Burundi or Urundi or Cambodia or "Khmer Republic" or Kampuchea or Cameroon or Cameroons or Cameron or Camerons or "Cape Verde" or "Central African Republic" or Chad or Chile or China or Colombia or Comoros or "Comoro Islands" or Comores or Mayotte or Congo or Zaire or "Costa Rica" or "Cote d'Ivoire" or "Ivory Coast" or Croatia or Cuba or Djibouti or "French Somaliland" or Dominica or "Dominican Republic" or "East Timor" or "East Timur" or "Timor Leste" or Ecuador or Egypt or "United Arab Republic" or "El Salvador" or Eritrea or Ethiopia or Fiji or Gabon or "Gabonese Republic" or Gambia or Gaza or "Georgia Republic" or "Georgian Republic" or Ghana or "Gold Coast" or Grenada or Guatemala or Guinea or Guam or Guiana or Guyana or Haiti or Honduras or India or Maldives or Indonesia or Iran or Iraq or Jamaica or Jordan or Kazakhstan or Kazakh or Kenya or Kiribati or Korea or Kosovo or Kyrgyzstan or Kirghizia or "Kyrgyz Republic" or Kirghiz or Kirgizstan or "Lao PDR" or Laos or Latvia or Lebanon or Lesotho or Basutoland or Liberia or Libya or Lithuania or Macedonia or Madagascar or "Malagasy Republic" or Malaysia or Malaya or Malay or Sabah or Sarawak or Malawi or Mali or "Marshall Islands" or Mauritania or Mauritius or "Agalega Islands" or Mexico or Micronesia or "Middle East" or Moldova or Moldovia or Moldovian or Mongolia or Montenegro or Morocco or Ifni or Mozambique or Myanmar or Myanma or Burma or Namibia or Nepal or "Netherlands Antilles" or "New

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3,092,406

S4 S1 OR S2 OR S3

133,602

S3 DE "renewable energy" OR DE "energy consumption" OR DE "energy policy" OR DE "solar energy"

61,761

S2 DE "electrification" OR DE "electric power" OR DE "electricity" OR DE "electricity supplies"

8,051

S1 (TI ((((electric* OR electrific* OR energy) N3 (access* OR adequa* OR affordab* OR alternative* OR availab* OR connect* OR consumer* OR consump* OR coverage OR delivery OR demand* OR development* OR distribution OR efficien* OR end-user* OR expansion OR generat* OR grid OR hydro OR market* OR micro OR network* OR outage* OR performance OR planning OR policies OR policy OR power OR production OR program* OR project* OR provision* OR quality OR reliability OR renewable OR resource* OR rural OR sector* OR service* OR solar OR source* OR standard* OR subsid* OR supply* OR supplies OR supplier* OR sustainab* OR tariff* OR technolog* OR transmission OR usage OR "use")))) OR AB ((((electric* OR electrific* OR energy) N3 (access* OR adequa* OR affordab* OR alternative* OR availab* OR connect* OR consumer* OR consump* OR coverage OR delivery OR demand* OR development* OR distribution OR efficien* OR end-user* OR expansion OR generat* OR grid OR hydro OR market* OR micro OR network* OR outage* OR performance OR planning OR policies OR policy OR power OR production OR program* OR project* OR provision* OR quality OR reliability OR renewable OR resource* OR rural OR sector* OR service* OR solar

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129,964

Appendix C: Steps for study screening

1. **Import study records:** All output files of the implemented search strategy were imported into EPPI.
2. **Removal of duplicate studies:** An automated process within EPPI was used to remove known duplicate files.
3. **Development of study classifiers:** A study classifier was developed using input data from an initial round of title and abstract screening that identifies a probability a study would be included in the review, using machine-learning techniques.
4. **Title and abstract screening:** The title and abstract (T&A) of all imported and de-duplicated studies were screened by two reviewers using the criteria set out in the protocol. Each reviewer indicated whether they believed the study met the inclusion criteria. In practice, this means assigning a *yes*, *no* or *unsure* outcome to each T&A screened. The review team held weekly meetings to reconcile any differences in screening outcomes and make refinements to the screening approach adopted. The output of this process was a set of screened studies that were put forward for full text screening.
5. **Full-text screening:** A full text for each study that met all inclusion criteria defined in the T&A screening was retrieved. Two reviewers examined each full text in detail against the protocol again, and assigned a *yes* or *no* outcome only. The output of this stage was a set of studies deemed suitable to include in the review.

Appendix D: Criteria for efficacy studies

1. The intervention being evaluated promotes a social, economic or behavioral change either as one of the final measured outcomes or as a mechanism within the theory of change (beyond the self-technical performance of an energy system).
2. The study measures any other outcomes in addition to or beyond purely indicators of technical performance of energy systems (e.g. returns to education, economic productivity, quality of life, disability adjusted life years [DALYs] and spillover effects).
3. The study records any additional formative information that could guide the design or execution of future studies.
4. The program or outcomes measured answer, or attempt to answer, a question relevant to the rollout of international development policies or interventions.

Appendix E: Illustration of outcomes considered

Health outcomes			
Mortality/ longevity	F1	Were any of the following outcomes assessed (multi code okay)?	1 = Average age at death 2 = Infant/child mortality rate 3 = Maternal mortality rate 4 = Overall mortality rate 5 = Risk of premature death 6 = % still born births 7 = Other (specify)
Morbidity	F2	Were any of the following outcomes assessed (multi code okay)?	1 = Incidence/prevalence of physical disease or ill-health 2 = Incidence/prevalence of mental illness 3 = Average birth weight 4 = Accident/injury rate 5 = Height for age score (nutrition measure) 6 = Weight for age score (nutrition measure) 7 = Other nutrition measure (specify) 8 = Knowledge of healthy behaviors (e.g. demerits of smoking) 9 = Other
Reproductive health	F3	Were any of the following outcomes assessed (multi code okay)?	-
Health knowledge	F4	Were any of the following outcomes assessed (multi code okay)?	1 = Knowledge of family planning 2 = Fertility level 3 = Use of modern contraceptives 4 = Childbirth with attendant 5 = Other (specify)
Access to quality services/ products	F5	Were any of the following outcomes assessed (multi code okay)?	F.5.1 Use of services (e.g. visits to clinics) F.5.2 Health facility opening hours F.5.3 Staffing levels F.5.4 Staff absenteeism rate F.5.5 Immunization/vaccination rate F.5.6 Access to medicines F.5.7 Refrigerated storage of medicines F.5. 8 Other (specify)

Environmen-tal health	F6	Were any of the following outcomes assessed (multi code okay)?	F.6.1 Household air pollution levels F.6.2 Rates of exposure to hazardous pollutants F.6.3 Access to clean/safe water supplies F.6.4 Use of water pumps/filtration F.6.5 Use of firewood F.6.6 Use of energy efficient appliances F.6.7 Temperature control (ambient/refrigeration) F.6.8 Access to market (ICT/refrigeration for fresh produce) F.6.9 Food safety F.6.10 Other (specify)
Education outcomes			
Schooling	G1	Were any of the following outcomes assessed (multi code okay)?	1 = Enrolment rates 2 = Attendance rates 3 = Years of schooling completed 4 = School completion rates 5 = Length of the school day 6 = Other (specify)
Quality of school	G2	Were any of the following outcomes assessed (multi code okay)?	1 = Availability of ICT (for example, computers, TV) 2 = Connection to internet 3 = Other (specify)
Quality and quantity of teachers	G3	Were any of the following outcomes assessed (multi code okay)?	1 = Number of qualified teachers 2 = Staff absenteeism rate 3 = Other (specify)
Access to information (out of school)	G4	Were any of the following outcomes assessed (multi code okay)?	1 = Computer use 2 = Internet use 3 = Mobile phone use 4 = TV/radio use 5 = Use of another, related ICT 6 = Other (specify)
Educational achievement	G5	Were any of the following outcomes assessed (multi code okay)?	1 = Test/exam scores 2 = Graduation rates 3 = Adult literacy rates 4 = Other (specify)
Study at home	G6	Were any of the following outcomes assessed (multi code okay)?	-

Welfare/Economic outcomes			
Energy Poverty	H1	Were any of the following outcomes assessed (multi code okay)?	1 = Household energy expenditure (total) 2 = Household electricity consumption 3 = Lighting usage – household (e.g. number of hours) 4 = Lighting usage – community spaces 5 = Price of operating lighting
Livelihood	H2	Were any of the following outcomes assessed (multi code okay)?	1 = Paid employment rate 2 = Self-employment rate 3 = Business start-up rate (i.e. new businesses created) 4 = Number of weekly hours worked (in paid/self-employment) 5 = Number of weekly hours worked (in agricultural work) 6 = Number of weekly hours worked (total; may include chores) 7 = Weekly wages (proxy for employee productivity) 8 = Monthly earnings 9 = Self-employment income/profits 10 = Household income 11 = Use of mechanized industrial/ agricultural equipment 12 = Job creation 13 = Agricultural productivity (e.g. yields) 14 = Firm-level productivity 15 = Extended opening hours for businesses 16 = Worker absenteeism rate 17 = Average number of lost work days per year 18 = Other (specify)
Community engagement/ cohesion	H3	Were any of the following outcomes assessed (multi code okay)?	1 = Volunteering levels 2 = Attendance at community events 3 = Use of services (other than health/e.g. library, sport centers) 4 = Other (specify)

Time-use	H4	Were any of the following outcomes assessed (multi code okay)?	1 = Number of weekly hours spent on housework 2 = Weekly hours spent on leisure activities (including TV) 3 = Number of household labor saving devices 4 = Hours spent collecting fuel (e.g. firewood) 5 = Hours spent collecting water 6 = Children's study time at home 7 = Other (specify)
Security	H5	Were any of the following outcomes assessed (multi code okay)?	1 = Official crime rates 2 = Fear of crime rates 3 = Expression of feeling safe 4 = Other (specify)
Human rights	H6	Were any of the following outcomes assessed (multi code okay)?	1 = Individual, civil and political rights (e.g. voting turnout rates) 2 = Economic, social and cultural rights (e.g. land ownership rates) 3 = Collective rights to self-determination, heritage and equity (e.g. unionization rates) 4 = Other (specify)
Women's empowerment	H7	Were any of the following outcomes assessed (multi code okay)?	-

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