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Effects of access to electricity interventions on socio-economic outcomes in low- and middle- income countries

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Systematic Review 45

Energy and extractives

International Initiative for Impact Evaluation

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About this review

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Howard White, chief executive officer of the Campbell Collaboration, provided guidance on the analysis.

Executive summary

The International Initiative for Impact Evaluation (3ie) was commissioned by the Asian Development Bank (ADB) in October 2019 to undertake a systematic review of electricity access interventions. The primary research question driving this review is 'What are the effects of electricity access interventions on social outcomes for households, firms and communities?'[1] The review was conducted using systematic methods and following internationally recognised methods as well as guidance from an Advisory Group comprised of researchers and policy specialists in the field of electricity access.

Background

Despite the benefits associated with electricity access, 800 million people worldwide still did not have access to electricity in 2017 (World Bank 2019). To help inform strategies to address this challenge, this systematic review synthesises existing high-quality evidence on the effects of a range of different supply- and demand-side electricity access interventions on social outcomes. We also aimed to address questions relating to contextual and implementation factors that may affect outcomes, as well as identify any evidence relating to costs.

Methods

We included studies in low and middle-income countries (LMICs) that evaluated the effect of an electricity access intervention on any intermediate or final education, health, welfare or environmental outcome as long as they were realised by individuals, households, businesses or communities. Studies had to adopt an experimental or quasi-experimental design to be included. To identify relevant studies, we searched 14 academic databases and specialist directories/websites in November 2019, contacted authors and implemented forwards and backwards citation tracking. For each included impact evaluation, we searched for complementary studies, such as process evaluations and qualitative studies. We screened studies at both title/abstract and full-text using a 'safety-first' approach (Shemilt 2016) and machine learning techniques to accelerate the screening process. Data extraction and risk of bias assessments were completed in duplicate. Finally, we synthesised the quantitative evidence using random effects meta-analysis with robust variance estimation and meta-regression and used thematic synthesis to analyse the qualitative and process evidence.

Search results and descriptive overview

We included 126 papers corresponding to 89 independent impact evaluations. Research spans much of the globe but is disproportionately conducted in South Asia and (31) Sub-Saharan Africa (28), with a focus on India (17), Bangladesh (8), Kenya (6) and Ghana (5). In many cases studies assessed the effects of levels of electricity availability, often rural grid connections, as opposed to a specific, discrete intervention. The studies assessed intervention effects on a variety of outcomes, with different – and often implicit – causal pathways. Over 90 percent of designs are quasi-experimental. Just over half (52%) of the studies received a rating of "medium to high" or "high" risk of bias in at least one critical appraisal category.

[1] Systematic Review Question 1 (SRQ1) is defined in Section 2 of this report.

Results

Review Question 1: What are the effects of electricity access interventions on socioeconomic development outcomes for private individuals, organisations and communities?

We first estimated average effects on five key outcome domain areas: intermediate outcomes related to uptake and use; education; socio-economic welfare; health; and the environment. The results suggest electricity access interventions produce positive, but small effects for treatment groups relative to the control groups on average across all outcome domains, including intermediate outcomes (g=0.17; 95% CI: [0.08, 0.26]); education; (g=0.05; 95% CI: [0.03, 0.07]); socioeconomic welfare (g=0.04; 95% CI: [0.03, 0.06]); health (g=0.11; 95% CI: [-0.01, 0.22]); and environment (g=0.07; 95% CI: [0.01, 0.14]).

Review Question 2: To what extent do effects vary by population group and location?

These effects were associated with considerable heterogeneity, which supported the decision for further moderator analysis. This additional analysis highlighted that interventions had an additional effect on increasing study time and decreasing the time allocated to non-paid work; that the combination of electricity access, system policy and management and affordability components was important for improving effectiveness; on average, education effects were realised more by children (aged 18 or less) and that socio-economic effects were realised more by women (although the additional effect on women was small (g=0.03). We also found mixed evidence on the extent to which assessed risk of bias, regional setting, and baseline electricity access affected estimated programme effectiveness.

Review question 3: What factors relating to program design, implementation, context are associated with better or worse outcomes along the causal chain?

We sought to understand and explain high levels of heterogeneity by reviewing all available qualitative and process evidence on barriers and enablers to programme effectiveness. We identified three types of factors that may have influenced intervention effects: structural and cultural factors; intervention design and implementation factors; and beneficiary-related characteristics:

- **Structural and cultural factors:** Authors of 33 studies highlighted or reported on the importance of pre-existing structural and cultural conditions in achieving improvement to social outcomes. Areas with limited political and economic unrest that are economically dense with base levels of infrastructure and access to established institutions are likely to be associated with larger changes in social outcomes than areas without these pre-existing conditions. Authors also suggest that public subsidies for substitute and complementary products will negatively and positively affect demand for electricity, respectively.
- **Intervention design and implementation factors:** Analysis of design and implementation characteristics across 60 studies highlighted several key barriers to programme effectiveness. Commercial connection fees and tariffs could not always be reconciled with the willingness and ability of target populations to pay for electricity services. These cost issues were made more acute given electrification priority areas were often in rural or complex geographies, which had knock-on effects for implementation delivery timescales and on-going

reliability. However, authors identified that the involvement of existing local networks to support delivery, the use of context-specific credit and payment tools, timely access to skills and expertise, and regular technical monitoring completed in conjunction with communities were key enablers to effectiveness.

- **Beneficiary-related conditions:** In total, 45 studies discussed factors related to the characteristics of the beneficiaries, specifically consumer knowledge; understanding and skills; attitudes, preferences, and belief; and beneficiary characteristics. Authors suggested that consumer demand for electricity was negatively affected when knowledge of potential benefits, costs and operational procedures was limited and when implementation suffered from delays. However, a subset of authors suggested that training community members in basic monitoring and maintenance may have enabled sustained use.

In particular, the results indicate that understanding and assessing the context-specific determinants of uptake and use of electricity infrastructure is key for yielding positive changes in social outcomes. Without appropriately considering these factors, beneficiaries may not take up electricity, use electricity at a much later date than anticipated, or consume low levels of electricity for basic energy services, for short periods of time. These barriers in the theory of change were expected to have constrained the realisation of social outcomes.

Conclusion

Overall, we found that the effects of electricity access interventions on social outcomes were small on average but positive. The review suggests that small increases in intermediate outcomes may have limited the effect sizes for outcomes featuring later in the theory of change. This is validated by the results of the thematic analysis, which highlighted a range of factors that may have prevented uptake and use. As a result, we suggest the review has the following implications for policy and research:

- **Policy implications:** The findings suggest on average electrification interventions have positive and small effects on a range of education, socio-economic welfare, health, and environmental outcomes. Though only about two fifths of studies (35 of 89) assessed intermediate outcomes (e.g., electricity connectivity, reliability, lighting use, etc.), the generally small increases in these measures may help explain the small effects on the final outcomes considered. There is evidence to suggest that interventions targeting multiple constraints (e.g., electricity infrastructure and reliability, or reliability and affordability) yield better results than interventions only targeting one of these constraints. In addition to this consideration, policy makers should consider the contextual factors highlighted in this report, including potential barriers to uptake and use. Finally, commissioners of electricity access evaluations should specify the need to collect detailed information on design and context characteristics of interventions, as well as include funding for mixed-method studies that include an examination of how implementation and process performance affects the achievement of social outcomes.
- **Research implications:** The review highlighted two evidence gaps that it would be useful to consider filling. First, there is a particular need for additional evidence on the efficacy of demand-side interventions, including interventions beyond those providing financial support. Second, researchers should provide

detailed information on the design characteristics of interventions to enable more detailed examination of factors that may influence effectiveness. In collecting this information, it may be beneficial to rely on existing frameworks of energy access indicators, such as the ESMAP framework, that go beyond assessing connections to electricity sources, and consider additional attributes, such as reliability, power capacity and safety. Finally, given the results above, there is a need for clearly articulated theories of change. This would likely help sharpen study designs, including the specification of outcomes of interest, enhance consideration and analysis of rival explanations for results, and improve readers' ability to meaningfully interpret study findings.

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List of figures and tables

1. Introduction

The International Initiative for Impact Evaluation (3ie) was commissioned by the Asian Development Bank (ADB) in October 2019 to undertake a systematic review of electricity access interventions. The primary research question driving this review is 'What are the effects of electricity access interventions on social outcomes for households, firms and communities?'[2]

The review was conducted using systematic methods and following internationally recognised methods and drew upon guidance provided by an Advisory Group comprised of researchers and policy specialists in the field of electricity access.

1.1 Objectives

The objectives of this systematic review, as stated in the Terms of Reference, are to:

1. Map the existing evidence on the impacts of on- and off-grid access to electricity in low- and middle-income countries; and
2. Synthesise evidence on the impacts of the on- and off-grid access to electricity programs, given the existing literature.

As such, the study team has developed the review questions presented in Table 1.

Table 1: Systematic Review Questions

SRQ	Question	Focus
1	What are the effects of electricity access interventions on socioeconomic development outcomes for households (including women and children), firms and communities?	**Impact**
2	To what extent do effects vary by population group and location?	**Heterogeneity**
3	What factors relating to program design, implementation, context are associated with better or worse outcomes?	**Mechanism**
4	What is the cost-effectiveness of the interventions under review?	**Cost**

Source: 3ie (2019).

1.2 What is a systematic review and how to use it?

3ie systematic reviews appraise and synthesise the available high-quality evidence on the effectiveness of social and economic development interventions in low- and middle-income countries (Waddington et al., 2012). These reviews follow scientifically recognised review methods, and are peer-reviewed and quality assured according to internationally accepted standards. 3ie provides leadership in demonstrating rigorous and innovative review methodologies, such as using theory-based approaches suited to inform policy and programming in the dynamic contexts and challenges of low- and middle-income countries (Snilstveit 2012).

Findings from systematic reviews can be used to inform policy, practice, and future research. The structured approach to evidence gathering and synthesis mitigates the risks of making policy and practice decisions based on individual studies and can provide

[2] Systematic Review Question 1 (SRQ1) is defined in Section 2 of this report.

confidence to decision-makers that they have an unbiased summary of the evidence; the meta-analysis helps them understand both average effects and the variability of results across studies, thus informing their assumptions about the plausible magnitude of effect sizes for a given intervention as well as the extent to which it is context dependent (Pigott and Polanin 2020). From a research perspective, systematic reviews help contribute to the generalizability of findings from individual studies; highlight uncertainties, limitations, and evidence gaps where additional research is needed; inform priority-setting for research funding; and identify important topical focus areas for peer-reviewed publications (Moller 2018).

Systematic reviews occupy a specific place in the broad spectrum of activities - or evidence architecture - needed to effectively link data to decision-making (White 2019). As implied by the comments above, individual studies are essential building blocks for a systematic review; the fewer the number of studies addressing the same research question(s), the less potential value there is in reviewing them systematically. Similarly, systematic reviews comprise one building block in a range of evidence and considerations informing policy and programmatic decisions. In some cases, systematic reviews may be used by such decision-makers directly, particularly if the findings are strong, consistent, unambiguous, and sufficiently focused and nuanced to address current policy or programmatic questions. In other cases, and perhaps more commonly, systematic reviews serve as an input into a knowledge brokering process that distils academic research into pragmatic, tailored insights, whether in the form of policy briefs, guidelines, checklists or other knowledge products (White 2019). So, while reviews can be used as a data source to inform a direct policy decision, they can also be used as a source of ideas and information, while supports policy-making in a less direct way (Weiss 1977).

1.3 Remainder of this report

The remainder of this report is structured as follows:

- **Section 2** provides a background to the review.
- **Section 3** presents the review methodology employed.
- **Section 4** gives a descriptive overview of the search results and studies included.
- **Section 5** presents the key results of the review.
- **Section 6** sets out a discussion of the review results and some concluding remarks.
- **Section 7** presents acknowledgements and administrative information about the review.
- **Section 8** lists all references.

2. Background

This section presents a summary of key trends in electricity access, an overview of the rationale for intervention and the expected theories of change, and finally, an overview of why the review is important.

2.1 The problem, condition, or issue addressed by the review

While access to electricity was not a specific Millennium Development Goal, its universal provision was reported as a critical mechanism through which extreme poverty and hunger could be eradicated (United Nations 2015). In 2015, electricity provision was formalised as

an internationally recognised development objective through the creation of Sustainable Development Goal 7, which sought to 'Ensure access to affordable, reliable, sustainable and modern energy for all'. Achievement of this goal will be measured in part by: the proportion of country populations with access to electricity, and investment as a percentage of GDP into energy supply and efficiency projects (United Nations 2019).

2.1.1 Key trends in electricity access, reliability and use

This subsection provides an overview of key trends in the sector in terms of electricity access, reliability and use, drawing primarily on World Bank indicators.[3]

Access

Electricity access is defined here as the availability of an electricity connection at home or the use of electricity as the primary source of lighting (World Bank 2013). While this is a useful indicator to assess whether people are able to make effective use of electricity for energy services, we accept it is one of many attributes that should be considered when analysing electrification.

Major advances have been made in increasing access to electricity. Between 2000 and 2017, with the proportion of the global population with electricity access increased from 78 to 89 percent. But 800 million people worldwide were estimated to not have any access to electricity in 2017 (World Bank 2019), with access issues shown to be more acute for low-income countries (especially Sub-Saharan Africa), rural communities and women and children:

- **Income status:** High-income country populations have had almost universal electricity access for the past few decades. Middle-income country populations were shown to have improved their access from 79 to 92 percent between 2000 and 2017 on average, although several LMICs have achieved 100 percent access in recent years, such as China and Brazil. Those living in low-income countries have relatively limited access, with electricity access for this group increasing from 15 to 41 percent in the same period on average. Again, there are outliers, such as Nepal, Afghanistan and Tajikistan, which all reported an access rate of at least 95 percent in 2017.
- **Region:** In terms of geographic regions, over 90 percent of Latin American and Caribbean and North African and Middle East country populations have had access to electricity between 2000 and 2017 on average. South Asian countries made drastic improvements in the same periods, with the population proportion with access increasing from 57 to 93 percent. But in the case of Sub-Saharan Africa, access improvements were more modest, increasing from 26 to 45 percent between in the same period.
- **Rural and urban communities:** Urban access to electricity increased from 93 to 97 percent between 2000 and 2017 in LMICs, and is considerably lower among rural communities is reported to be lower across the same period, with the rate of access increasing from 61 to 77 percent.
- **Women and children:** It is suggested that 3.5 million people die each year from harmful indoor air pollution caused by unsafe cooking practices, of which 54 percent were women and children (World Bank 2013). This is due to differing

[3] World Bank. World Development Indicators. Available at: https://bit.ly/2Z2clrT. Date accessed 30/03/2020.

energy needs and time allocation by sex and age (Clancy 2002; Kanagawa & Nakata 2008) – for example, women are more likely to be the main cooks in low income countries, and as such, are likely to suffer relatively more from health issues should electricity not be available (although we acknowledge that traditional fuels may still be used in connected households); respiratory issues in children are particularly acute in this regard.

Reliability

Having the physical infrastructure to access electricity is not sufficient to ensure reliable usage. Other factors may affect use, including those relating to electricity capacity, availability reliability, health and safety, and convenience among others. In the case of reliability, power outages in firms in a typical month can be used as an approximate measure of reliability[4], though it may also be useful to factor in the duration of outages, which are strongly correlated with outage frequency, and the potential differences in reliability issues across households and firms.[5] In any case, data from 2019 shows that power outages for firms were more commonplace in low-income countries (11.1 outages per month) compared to middle-income countries (6.7 outages per month). By region, power outages were most severe in South Asia (25.5 outages per month), although this is largely driven by Pakistan and Bangladesh. Other LMIC regions fare relatively better with Latin America and Caribbean countries observing 1.9 outages per month, while Sub-Saharan African countries observing 8.9 outages per month. Fragile and conflict afflicted states (FCAS) also suffered from comparably higher outage rates in 2019 (14.2 outages per month) which reflects the context-dependent nature of electricity reliability.

Consumption

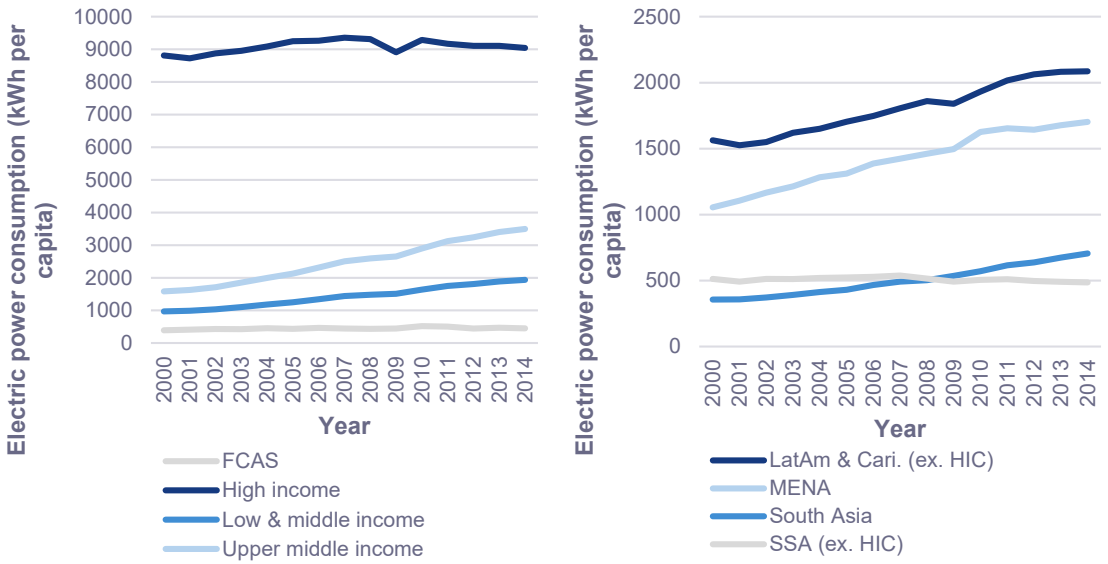
Providing access to a reliable source of electricity is not always sufficient to result in changes in electricity use. Figure 1 overleaf shows that, between 2000 and 2014, per capita electric power consumption increased globally on average, with high income countries consuming higher levels across the period. That said, growth in consumption across the period was greater for low and middle-income (100 percent) and upper-middle income countries (121 percent). By region, during the same period, consumption was highest in LMIC countries in Latin America and the Caribbean (LATAM and the Middle East and North Africa (MENA). Consumption growth was highest in South Asia (98 percent), followed by MENA (61 percent) and LATAM (33 percent). In fact, per capita consumption growth decreased for sub-Saharan African countries by 5 percent.[6]

[4] URL: https://data.worldbank.org/indicator/IC.ELC.OUTG?most_recent_value_desc=true. Date accessed: 25/03/2020; these results do not reflect the reliability of household electricity use.

[5] URL: https://trackingsdg7.esmap.org/data/files/download-documents/2019-Tracking%20SDG7-Full%20Report.pdf (p.31)

[6] The data shows how consumption relates to country populations. It does not provide an overview of total power consumption in a country.

Figure 1: Overview of electricity use by income status and region, electric power consumption - kWh per capita (2000-2014)



Source: IEA Statistics - OECD/IEA (2014). *3ie analysis of World Bank Data Bank indicators.*

2.1.2 Strategic rationale for intervention

The strategic rationale for increasing access to electricity is underpinned by the realisation of the following social benefits for individuals, organisations and communities:

- **Energy and fuel use:** New and/or improved electricity access may result in beneficiaries increasing their energy consumption, either through increased lighting or appliance ownership (World Bank 2008). Changes to access may also result in substituting consumption of other energy sources like biofuels or kerosene with electricity (Heltberg 2003).
- **Education**: Electricity access is expected to provide a range of benefits for the education sector (Kanagawa & Nakata 2008). There are a number of mechanisms through which benefits could be produced – for example, better access is likely to increase the effective school day, provide access to information and communication technology (ICT) learning resources, support schools in attracting and retaining high quality teachers, and enable increased home studying. All of these are expected to improve the efficiency and quality of the education process, i.e., the creation of human capital.
- **Health**: Previous synthesis suggested that new and/or improved electricity access may be linked with positive health outcomes relating to reduced mortality, lower incidence of diseases (Irwin et al. 2020), especially in the case of respiratory disease as a result of poor air quality due to the use of traditional fuels. This may be a result of increasing the effective access to better physical and/or digital facilities, for example through the ability to refrigerate vaccines and the use of electronic health technologies. Poor reliability of electricity sources was shown to have the opposite effect (Spalding-Fecher 2005; Bruce & Ding 2014).
- **Time allocation:** Electrification may cause individuals to reallocate their time to either work or leisure, depending on the specific context of interest. For example, the provision of lighting in the evening may result in workers increasing the time

they allocate to securing paid income as they are able to work productively for longer (Grimm 2013). However, household or business production may become more efficient and facilitate increased leisure time, as assessed for example by Grogan (2018) or Khandker (2014).

- **Economic development**: Economic growth is expected as a result of new and/or improved electricity access through improvements in productivity in formal, informal, and household sectors (Kanagawa & Nakata 2008). First, electrification is expected to directly produce a more productive labour force for a range of reasons, including increased levels of education, access to better commercial facilities, better working conditions, and longer effective working days. Second, access may also result in productivity improvements by increasing the effective economic density of workers, such that they are aware of, and have access to, a greater number of employment and/or commercial opportunities relative to those without electricity access. This is especially true for non-farm income generating opportunities associated with value added processing and industrialisation (Davis 2003). However, where electricity access expands the output of businesses without any productivity improvements, this may result in the displacement of other business activity in local areas.
- **Social capital and cohesion**: Access to electricity is expected to increase levels of social capital and cohesion, as it provides an increased number of opportunities for individuals to develop relationships and interact with one another. This could be through increased access to information and entertainment services, public or community spaces, and/or services or personal security, for example through improved lighting of public spaces.
- **Leisure and information base**: Electricity can provide improved access to media and sources of leisure, namely through television and radio services. These goods are considered to increase the quality of leisure time of users and provide more meaningful access to a range of news sources, both resulting in improvements to welfare.
- **Environment**: Changes to electricity access may affect the environment positively, by decreasing the use of firewood (potentially leading to decreased deforestation) and other ‘traditional’ polluting energy sources, increasing the use of more energy efficient appliances or the increased implementation and use of renewable energy sources (Kanagawa & Nakata 2008; Chaplin 2017). These changes may result in decreased costs for individual households and/or produce positive externalities such as improved air quality and biodiversity. It should be noted, however, that as with the implementation and operation of any large infrastructure project, negative externalities may arise, such as pollution or effects on biodiversity - for example, as areas are cleared to make way for the development of grid lines or increased levels of non-renewable-based power generation.
- **Mobility**: Expanding electricity access to certain areas may also influence individual or household labour decisions (for example see ADB 2010). The provision of electricity may increase the economic density of an area, whereby more labour or income-generating opportunities become available as electricity access is provided. Firms may be attracted to set up in areas with new access, or local residents may be able to access employment digitally through their improved access to media. Increased access may also attract households to the area as

they update their beliefs about the potential gains to their wellbeing, beyond the economic sense – for example through improved health services or greater sense of safety and security.

2.1.3 Challenges for expanding electricity access

Despite the benefits cited above and notable improvements in access, many challenges exist that prevent their realisation. These challenges feature at the political economy, supplier, and consumer levels:

- **High costs of investment and operation of electricity networks:** The expansion and operation of national or localised electricity networks requires significant investment – for example, into the construction, connection, and maintenance of power generators, transmission networks and local distribution networks. These investment costs are only justified if a sufficient level of revenue can be recouped from consumers over the expected duration of operation for the network in question (Cook 2011). These costs are particularly high for remote and rural areas and some urban settlements in LMICs, given the low population density, and often low levels of connection materials (for example see Miller 2015). This can also create challenges for suppliers seeking right level of finance when required to support such investments. Finally, expansion projects may result in issues of community severance or displacement and/or result in negative environmental impacts such as deforestation to accommodate a prospective power plant site, although current evidence relating to the net effect from electricity access projects is mixed (Azuela & Herrera-Martin 2009; Tanner & Johnston 2017).
- **Reliability**: As highlighted above, the benefits of electricity can only be achieved if consumers can access electricity when they need it. Where maintenance of electricity infrastructure is not adequate, power outages and potentially damages to infrastructure can occur (IEA 2018). Reliability issues typically relate to in-country capabilities in installing and operating electricity networks (and other solutions) efficiently and effectively while protecting electricity infrastructure from external pressures. Key technical factors that could result in reliability issues include underestimating demand and/or not accounting for induced demand when expanding electricity infrastructure, insufficient safety and security procedures to deal with peak time demand, especially in the case of off-grid systems that are not able to draw on national infrastructure, and natural or human sabotage of power sources.
- **Limited capacity in markets to extend utilities:** In some cases, a constraint on access is limited local technical capacity to provide and maintain access interventions, either through limited human capital or access to required materials and supplies (Crousillat, et al. 2010).
- **Planning and coordination challenges:** Infrastructure projects require the coordination of multiple stakeholders, including private suppliers, target communities, local and national governments, and donors. The need to engage with multiple parties (or not consider all relevant parties) can result in ineffective planning, implementation delays, and poor delivery.
- **Weak institutions and regulators**: The effectiveness of governments and other related institutions has been shown to be a key factor in facilitating the expansion and maintenance of electricity infrastructure (Best 2017). Effective governments can support electricity access interventions through the creation and enforcement of consumer and supplier regulation and being responsive to challenges in terms of

economic and political instability. In fact, the performance of reforms to improve the governance of electricity infrastructure are often constrained by challenging political and economic context of interventions (Smith, 2004).

- **Costs of connection:** A key access challenge cited in the literature is affordability. Use of electricity is associated with several costs, depending on the nature of electricity access intervention and energy source. In the case of on-grid electricity, the building of interest must be wired safely, and connected to the grid, which involves administrative costs in terms of applying and coordinating with local electricity suppliers. In some cases, the materials used to construct buildings do not facilitate a grid connection, which adds additional costs (for example, see Ahlborg and Hammar 2014). These connection costs result in lower or delayed connection to higher tier energy sources and are made more acute if households or communities depend on seasonal income (Chaplin 2017).
- **Limited demand**: Limited demand for electricity affects supplier investment decisions relating to access expansion projects, and the ability for beneficiaries to fully realise the benefits of improved access. Low demand is cited as a key barrier to investment in LMIC electricity access projects (Scott & Seth 2013). This is true for some communities that are in proximate locations to on-grid infrastructure (Lee et al. 2014). Several studies find that willingness to pay for electricity is low in LMICs, with low consumer surplus, weak institutions, and poor community engagement exacerbating the issue (Blankenship 2019; Lee 2020). In some cases, household incomes are not always sufficient to cover the costs of gaining access to or consuming electricity. However, while costs are seen as a major determinant of demand, other factors include electricity reliability, consumer preferences, and social acceptance (García, & Bartolomé 2010).
- **Information failures:** Information failures related to the administrative and physical requirements of connecting to and paying for access and use of electricity, as well as the set of benefits associated with its use, may result in households, firms and public services consuming suboptimal levels of electricity – for example by only making use of electricity for subsistence lighting (for example see Bahaj et al. 2019 source), or delaying connecting to an electricity source at all.[7]

2.2 How the interventions might work

This subsection presents an overview of how electricity access interventions are defined and are expected to deliver social outcomes for target populations. First, we summarise the set of interventions considered in the review and then present a working theory of change that illustrates the set of expected causal pathways that result in improvements to outcomes of interest.

2.2.1 Description of the interventions

Understanding the design space for electricity access interventions is complex, and a number of frameworks exist that attempt to map interventions in terms of their characteristics. One example of this is the ESMAP Multi-Tier Framework developed by Bhatia & Angelou (2015) which characterises interventions across a number of dimensions

[7] In other words, a delay in the transition between Level 5 and Level 6 of the Simplified Energy Results Change Table of the ESMAP Energy Results Chain (Bhatia & Angelou 2015).

including capacity, duration reliability and quality. For the purpose of this review, electricity access interventions can be broadly defined across three key dimensions: physical access, system management and policy, and incentives and consumer access (Mathur et al. 2015), as shown in Table 2 overleaf. The dimensions relating physical access and system policy and management refer to supply-side interventions, whereas the incentives and consumer access dimension interventions are expected to influence electricity demand. The rationale for selectin this framework was primarily to ensure consistency between synthesis updates but we discuss the potential benefits of increasingly drawing on the ESMAP framework introduced above in Section 7.

Table 2: Overview of electricity access interventions by dimension

Dim.	Intervention group	Intervention sub-group
1) Physical access	a) Expanding coverage of the (on-grid) national (or regional) power transmission system to new areas and communities	i) Construction of new transmission lines.
		ii) Network densification measures.
	b) Expansion of off-grid, decentralized power provision to new areas and communities, in the form of central grid, mini-grid, and stand-alone solutions	i) Financial incentives (for private enterprises).
		ii) Donation of equipment
		iii) Construction of off-grid systems
2) System management and policy	a) Technical support	i) Supply-side management of on-grid system efficiency (for example, use of energy efficient equipment to increase generation and improve efficiency, and measures to reduce transmission and distribution losses at the point before the consumer meter).
		ii) Supply-side advance notification about on-grid service interruptions and service restoration times.
		iii) Supply-side post-installation maintenance and services (both on-grid and off-grid systems).
		iv) Supply-side improvement to quality of systems, installation and after-sales services (off-grid systems).
	b) Legal and regulatory frameworks and policies	i) Standards reform (for example, relating to design of micro-grid systems).
		ii) Improved standards for off-grid components and system designs (for example, subject to their being eligible for inclusion in subsidised programmes).
3) Incentives and consumer access	a) Financial resources that improve affordability	i) Tariff rationalisation (for example, introduction of staged or time-use tariffs);
		ii) Introduction/expansion of consumer credit schemes/loans/subsidies.
		iii) Rental (fee-for-service) schemes.
	b) Technical resources aimed at training and supporting consumers to maintain/repair and manage/construct off-grid systems	-
	c) Awareness raising campaigns and products that advertise and promote the (sustained) use of new energy sources.	-

Source: Adapted from Mathur et al. (2015) and Raitzer et al. (2019).

2.3 Theories of change

Figure 2 overleaf integrates multiple programme theories of change related to improving access to electricity. This particular simple visual representation is adapted from two recent synthesis projects with a similar focus and scope.[8] A more detailed model of the anticipated causal pathways is provided in Appendix A.

This model is loosely structured around the three intervention types mentioned in Table 2. Arrows point from theorised causes to effects, collectively depicting a combination of theorised and empirical pathways through which interventions in these three areas may contribute to three main types of impacts: socioeconomic; health, safety and wellbeing; and environmental impacts.

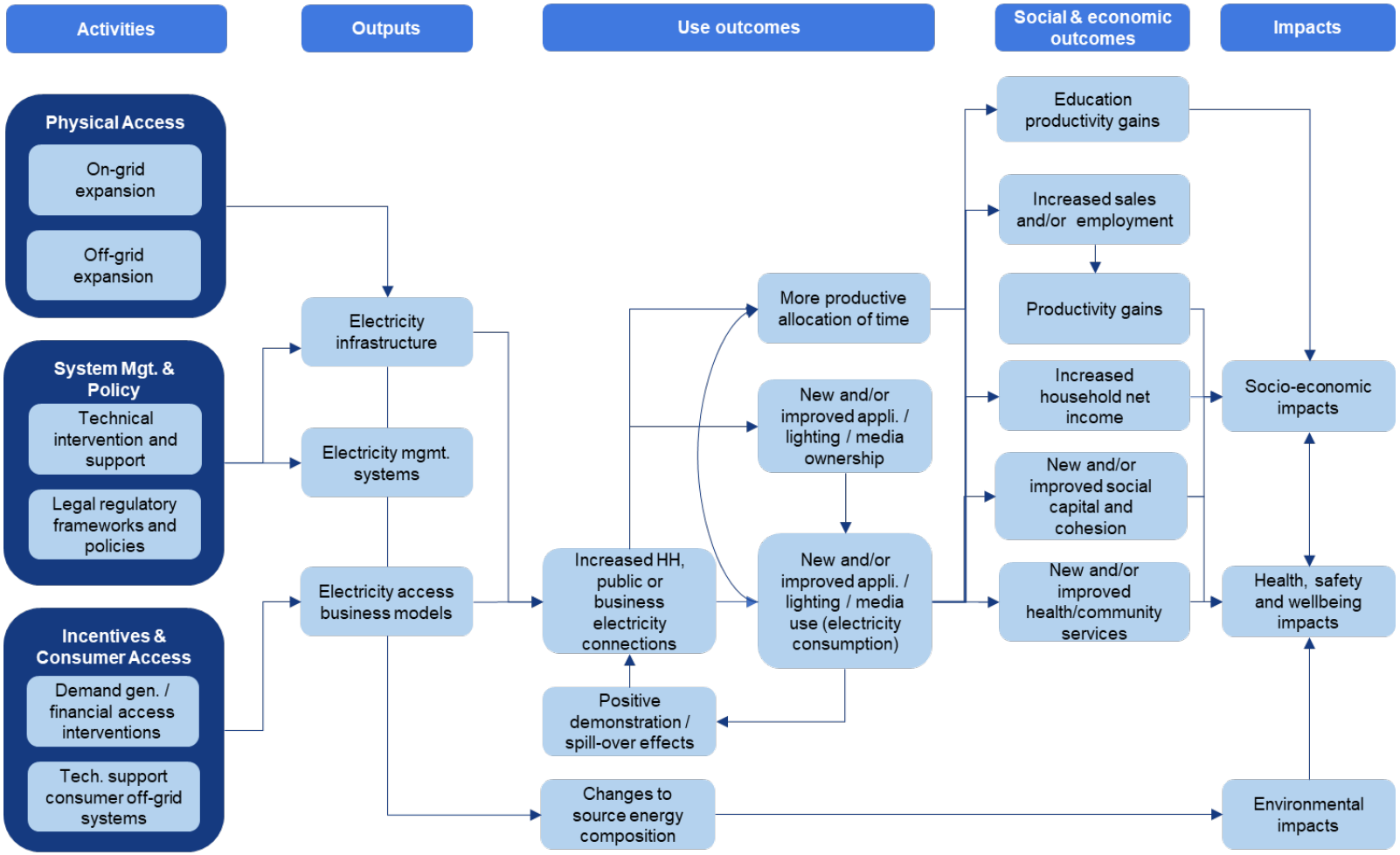
The provision of new and/or improved electricity access interventions is assumed to enhance underlying electricity infrastructure. Technical, regulatory, and policy interventions are assumed to improve electricity system management and/or infrastructure. Interventions targeting consumer incentives and financial access may result in the introduction of new, or modification of existing, electricity products, services, processes or business models. These changes, either independently or jointly, are expected to provide new and/or improved opportunities for targeted populations to access electricity for desired energy services when they are needed. It is assumed that these interventions have been designed and implemented effectively and provide a well-maintained supply of electricity at an appropriate power capacity, that is affordable, and priced such that it is cheaper than existing traditional energy sources.

As a result, it is expected targeted populations will either connect to, and make use of an increasingly socially optimal level of electricity infrastructure for a range of key activities, including lighting, electrical appliance ownership and use (e.g. to access information and communication resources, provide temperature control) and household or firm production. Increased use may also produce demonstration and/or spill-over effects, where peers of electricity users are able to experience the potential benefits of electricity and then go on to invest in electricity infrastructure as a result. Adoption and use of electricity here assumes that uptake is widespread and does not suffer from time lags.

This increased use is expected to result in the set of impacts listed in the subsection 2.1.2 above, the realisation of which underpins the strategic rationale for providing new and/or improved electricity access. These changes are thought to arise through multiple assumed causal pathways, including the more productive allocation of labour and capital inputs present in households, firms and community and public services or producing intangibles changes related to a sense of safety, community, and wider well-being, and transitioning consumers towards cleaner energy sources, resulting in environmental benefits.

[8] This model has largely been adapted from Mathur, K., Oliver, S. and Tripney, J., 2015. Access to Electricity for Improving Health, Education and Welfare in Low-and Middle-Income Countries: A Systematic Review [Protocol]. Campbell Systematic Reviews, 11(1), pp.1-55; Raitzer, D.A., 2019. Impact evaluation of energy interventions.

Figure 2: Electricity access programme theory of change



Source: Adapted from Mathur et al. (2014) and Raitzer et al. (2019).

2.4 Why is it important to do this review?

The rationale for this review is twofold: First, to provide a comprehensive and up-to-date understanding of electricity access interventions, given the increasing importance of energy access in alleviating poverty. Second, to directly support the ADB in assessing the relative effectiveness of its own activities in the sector and provide insight on the Bank's sector strategy from 2020 onwards. The remainder of this subsection discusses these two points.

2.4.1 Updating our understanding

Access to energy, and in particular electricity, has become increasingly important as an expected mechanism for poverty reduction in LMICs (United Nations 2015). Thus, to address the global gap in access to electricity donors, national governments and the private sector have stepped up their investments in the sector. For example, investments in high-impact countries[9] increased by USD 10.8 billion in 2015-2016 over 2013-2014 levels to an average of USD 30.2 billion per year (Sustainable Energy for All 2018). Aid to the energy sector among The Organisation for Economic Co-operation and Development (OECD) donors also increased over this period, reaching an average of USD 29.8 billion between 2014-16, with the ADB being the 6th largest donor to the sector (OECD 2019).

To illustrate the scale of investment, and the need for evidence synthesis, an overview of key programming is provided in Table 3 overleaf.

2.4.2 Addressing evidence needs for the ADB

The ADB Independent Evaluation Department intends to make direct use of this review to inform the bank's wider sector investment from 2020 onwards. In particular, this systematic review forms part of the IED's Sector-wide Evaluation on the Asian Development Bank (ADB) Support for the Energy Sector Policy and Program, which evaluates ADB's 2009 energy policy and energy-related activities approved from 2009 to 2018. Currently, 43 percent of the bank's energy operations are focused on expanding access to electricity, mainly through power transmission and distribution projects, and off-grid electricity projects. The results of this review will be used in conjunction with other evidence to allocate resources to electricity access programmes by the ADB.

[9] A classification developed by the World Bank and International Energy Agency to denote countries with "the most potential to make rapid progress towards the goal of universal electricity access".

Table 3: Illustrative overview of existing programmes of electrificiation in LMICs

Programme	Funder	Aims and activities	Expected completion	Geog.	Planned Inv. $bn
Power Africa	MCC	MCC is assisting governments in planning potential projects and establishing regulatory and institutional structures needed to promote private investment. To increase investment in African energy projects that improves energy security, generates economic growth, and fights poverty	2018	Tanzania, Senegal, Liberia, Sierra Leone, Ghana, Benin and Malawi.	1.5
UN SEForALL	UN	As a global platform, Sustainable Energy for All (SEforALL) seeks to empower leaders to broker partnerships and unlock finance to achieve universal access to sustainable energy. Members have funded clean energy initiatives in South-East Asia (SHIFT SEA) and began research into green transport consultancy in select countries.	2030	Vietnam, Philippines and Indonesia.	0.12
Rural Electrification Dev.Project	DFID (UK Gov)	To increase access to affordable, sustainable electricity services in rural and peri-urban areas., through the provision of 700,000 new electricity connections countrywide, including over 23,000 commercial and irrigation connections.	2010	Bangladesh	0.48
Transforming Energy Access	DFID (UK Gov)	To accelerate access to affordable, clean energy services for poor households and enterprises through forming investment partnerships with global innovators supporting early stage testing and scale-up of technologies and business models.	2024	African developing countries	0.92
Power Africa	US Gov	To bring together the collective resources of U.S. Government and their public and private partners, to strengthen the African energy-sector, and create connections to turn more Lights On. Working with public and private partners to facilitate project deals across Africa to provide new and improved electricity to those without. Turning lights on.	2030	29 Countries in Africa	12.2 by 2018
Access to Energy Fund	Netherlands Development	The AEF seeks to provide 3.2 million people in developing countries with access to energy services to boost economic development and	2018	SSA and South Asian countries	0.11

Programme	Funder	Aims and activities	Expected completion	Geog.	Planned Inv. $bn
(AEF)	Finance	alleviate poverty. The fund supports energy generation, transmission and distribution projects in developing countries and focuses on sustainable energy.			
The NDC Partnership	Dutch Gov	To provide 50 million people with access to renewable energy by 2030. As agreed in the Paris Climate Agreement, the Netherlands will support developing countries in: combating climate change and increasing their resilience to the effects of climate change. This is done through improving access to renewable energy, management of river basins, agricultural advice and sustainable management of forests.	2030	20 Developing countries worldwide	0.63
EnDev	Dutch Gov / German Gov	Provision of long lasting, affordable energy services to poor groups. Supporting access to improved cooking systems, off-grid solar technologies (solar home systems and pico-PV), mini-grids (solar/hybrid or hydropower), grid extension and biogas.	2019	25 Developing countries worldwide	0.37
Energy for All	ADB	The partnership aims to provide access to safe, clean, affordable modern energy. Investments in electricity and other renewable energy sources are a cornerstone of the ADB's Energy for All Initiative. The initiative develops and mainstreams approaches for scaling up access to affordable, modern and clean energy among the region's poor, including household access to electricity from renewable energy technologies such as micro-hydro, solar, biomass, and small wind power, as well as access to clean cooking fuel, such as LPG or biogas from livestock manure.	2020	ADB Member countries	33.6
Scaling Up Renewable Energy	Climate Investment Fund	The SREP helps low income countries move toward low carbon development. Encouraging low income countries to adopt renewable energy technologies, scaling-up deployment of solutions such as solar, geothermal, and biomass to increase energy access.	Unspecified	27 countries worldwide	0.49 by 2019

Source: Various.

2.4.3 Previous synthesis in the area

Several previous efforts sought to synthesise the evidence on the effects of electricity access interventions on social outcomes. We summarise these efforts in Table 4 overleaf, where each row represents a synthesis output and each column represents a specific characteristic of the work, relating to its scope and the methods employed. The shaded boxes in the table indicate the characteristics of each study.

These studies have a clear focus on examining electricity access interventions in LMICs, included a range of study designs, and considered a variety of broad outcome groups. The more recent reviews produced the following results:

- Hamburger et al. (2019) reviewed 31 impact evaluations as part of a systematic review with a focus on geographic bias. The authors assessed the household electricity access interventions on energy expenditure, household income, household savings, business creation, and education in developing countries. The review found that the geographical distribution of studies was narrow and found studies set in South Asia produced the highest number of positive impacts, followed by Latin America and the Caribbean and sub-Saharan Africa.
- In a systematic review, Mathur et al. (2015) found positive impacts on measures of educational inputs, including school enrolment, study time, and years of schooling, and measures of household income. The review found mixed effects on business income, health, and time allocation, but found that hours worked for women increased when for men it did not. Finally, the review reported few studies evaluated outcomes related to health and women's empowerment.
- Irwin et al. (2019) systematically reviewed studies that evaluated the health effects of electricity access interventions, and found mixed results with respect to changes in health status among adults and children. The authors suggested that reliability issues were a key barrier to programme effectiveness.
- Raitzer et al. (2019) plotted the increased use of impact evaluation to understand the range of potential effects produced by the power sector, including electricity access interventions. The review does not attempt to synthesise results but maps the characteristics of studies and identifies key evidence gaps -improved electricity capacity and reliability, clean energy incentives, smart grids, renewable energy, energy efficiency and fuel substitution – and highlights promising methods for future impact evaluations.

This review attempts to build on these efforts by including more current research, build on our understanding of how effects might vary by outcome, intervention and study characteristics, and complement these results through an assessment of the available qualitative evidence and experience-based evidence provided by study authors.

Table 4: Illustrative overview of relevant previous synthesis projects

Author (Year)	Type	Topical focus	Designs included			Papers		Outcomes					Units of analysis						Region	
			Experimental	Quasi-experimental	Other (e.g., descriptive)	Individual studies	Systematic reviews	Health	Income/employment	Education	Gender	Other	Individual	Household	Group/Community	Firm	Country	Regional/Global	Low-middle income	High-income
3ie (2020)	Systematic review	Social impacts of electricity access	■	■	■	■		■	■	■	■	■		■	■	■			■	
Hamburger (2019)	Systematic review	Geographic bias of IEs on electricity access	■	■	■	■		■	■	■				■					■	
Irwin (2019)	Systematic review	Social and health impacts of electricity access	■	■	■	■		■					■	■	■				■	
Raitzer (2019)	Review	Social impacts of electricity access	■	■		■		■	■	■	■	■	■	■	■	■			■	
Bensch (2016)	Systematic review	Impact of market-based reform on electricity access		■		■			■			■		■	■	■	■		■	
Haby Michelle (2016)	Systematic review of reviews	Social and health impacts of electricity access	■	■	■		■	■					■	■	■	■	■	■	■	■
Mathur (2015)	Systematic review	Social impacts of electricity access	■	■		■		■	■	■	■		■	■	■	■			■	

Author (Year)	Type	Topical focus	Designs included			Papers		Outcomes					Units of analysis						Region	
			Experimental	Quasi-experimental	Other (e.g., descriptive)	Individual studies	Systematic reviews	Health	Income/employment	Education	Gender	Other	Individual	Household	Group/Community	Firm	Country	Regional/Global	Low-middle income	High-income
Adair-Rohani (2013)	Systematic review	Social and health impacts of electricity access																		
IOB (2013)	Systematic review	Social impacts of electricity access																		
Kohlin et al. (2012)	Review	Social impacts of electricity access																		

Source: Various.

3. Methodology

This section presents a summary of the methodology employed by the review, covering an overview of the approach, and a specification of our selection criteria, search strategy, data extraction, critical appraisal, and synthesis methods. A more detailed description of the methodology is provided in Appendix A.

3.1 Overview of method

This review complies with internationally recognised best practice in relation to the development of systematic reviews and evidence synthesis (The Steering Group of the Campbell Collaboration, 2016; Kugley et al. 2017; Higgins & Green, 2011; Shadish & Myers, 2004). It sets out to synthesise quantitative causal impact evaluations and analyse effect size data (statistical meta-analysis), to provide estimates of the central tendency and heterogeneity of reported changes in outcomes of interest. To capture evidence on the context, implementation, and underlying mechanisms of electricity access interventions, the review implemented a thematic analysis to understand the type of barriers and enablers that could influence programme effectiveness.

3.2 Study inclusion and exclusion criteria (PICOS)

The study inclusion and exclusion criteria are summarised using a population, interventions, comparators, outcomes and study designs (PICOS) framework shown in Table 5. In addition to the criteria presented below, studies in any language were included in the search if their publication date was 2000 or after, although search terms were in English only. Studies were not excluded based on publication type (e.g., peer-reviewed articles, study reports in the grey literature or doctoral theses).

Table 5: PICOS summary of review criteria for inclusion and exclusion of studies

Criteria	Inclusion and exclusion definitions
Population	• Programme participants in low- and middle-income are included, as defined using the Atlas method.[10]
	• Programme participants in high-income countries are excluded.
Intervention	• Any intervention that seeks to provide new and/or improved electricity access to for either residential units (households, villages, municipalities), community-based organisations (schools, health clinics, community centres) or commercial enterprises (except those that build their own power transmission systems to access electricity for their own use alone), as summarised in Table 2.
	• Interventions that seek to increase demand for electricity among any population group (demand-side).
Comparisons	• Populations that receive 'business as usual' access, an intervention with a different type of access, or no intervention are included.
	• Studies with no comparison are excluded.
Outcomes	• The review will not exclude studies on the basis of recorded outcomes as long as they are realised by individuals, households, businesses or communities.
Study design	• Randomised and non-randomised counterfactual studies.

Source: 3ie (2019).

[10] More information on this approach is available here: https://bit.ly/3eBAWKJ. Date accessed: 26/06/2020.

For all included studies, the review team also completed a targeted search for associated qualitative studies, process and economic evaluations. These studies were included if they assessed some aspect of the implementation, uptake or use of named interventions that were the focus of included studies.

3.2.1 Excluded studies

The following interventions related to electricity access were outside the scope of the review:

- **Energy efficient consumption:** Interventions that seek to improve the energy efficiency or consumption of end users could arguably be included as an intervention that improves electricity access. Making existing electricity consumers more efficient may affect the ability of an electricity system to provide energy to others. However, for the purposes of this review, we have excluded interventions of this type, as the main focus is on providing new and/or improved access directly.
- **Specific-use solar-power technologies:** Other interventions seek to provide solar-powered technologies with end uses ranging from lighting, basic appliance charging, and agriculture. These technologies are solar powered, the focus of these interventions is on enabling the end technology use, rather than providing unconstrained energy access. As a result, and because of the focus of the ADB portfolio on higher-tiered electrification projects, these interventions have been excluded from this review. However, we do acknowledge that lighting and charging enabled by low-tiered electricity solutions are an important subcomponent of electricity access.

3.3 Search strategy

A systematic search of academic bibliographic databases and library catalogues was completed between 16-19 November 2019 to identify qualifying studies. If we identified any further studies before January 2020 we also included these in the review. This strategy addressed potential publication bias issues by comprehensively searching unpublished literature and implementing additional searches for grey literature in specialist organisational websites, websites of bilateral and multilateral agencies, and repositories of impact evaluations in international development.[11] A full specification of the search strategy can be found in Appendix A.

The strategy also considered the following data sources:

- **Other specialist databases:** Given the range of outcomes considered, a set of specified sector specific databases were reviewed as appropriate.
- **Relevant websites:** A set of specified organisation websites were searched, although these websites offer less sophisticated search functionality. As such reduced searches were implemented using the search strings developed for the review as far as it was possible to do so.
- **Backward and forward citation tracking:** Once screening was completed, all citations by included studies and all studies that cited at least one included study in the review were reviewed for inclusion using Web of Science where it was possible to do so.

[11] Grey literature refers to documents produced and published outside of typically commercial and academic publication channels – for example, government department reports. A full list of databases and online sources searched can be found in Appendix A.

- **Communication with researchers:** The review team engaged with the research community to request information about potential eligible studies up to the end of January 2020. This occurred through two main channels: (1) contacting researchers and experts recommended by the review's Advisory Group, and (2) publishing a call for information via a related blog post on the 3ie website and promoting it using social media.
- **Complementary wider research:** This review drew on qualitative research and the wider evidence base, including informally reported experience-based evidence to understand factors relating to intervention design, implementation, and context that may plausibly affect the effectiveness of programmes. We carried out a targeted search and contacted authors to collate the available evidence.

3.4 Screening, extraction and data analysis

This subsection provides an overview of the steps taken to identify relevant studies and collect and analyse data.

3.4.1 Screening

The selection of studies for data extraction as part of the review was managed using EPPI-Reviewer 4 software (EPPI)[12] (Thomas et al. 2010) and was completed by implementing the following steps:

- **Prepare study records:** All output files of the implemented search strategy were imported into EPPI. Studies that were identified through the additional means specified were added to EPPI manually. An automated process within EPPI was used to remove known duplicate files.
- **Title and abstract screening:** The title and abstracts (T&As) of all imported and de-duplicated studies were single screened with safety-first. In practice, one study was reviewed by one person. This person assigned one code which indicated that either the study should be included for full-text screening, or that the study should be excluded, or that they were unsure; several exclude codes were created to provide more insight into the rationale for exclusion in each relevant case. We held periodic meetings to discuss studies that screeners had marked with 'unsure'.
- **Machine learning aides:** The screening process was supported by a machine learning tool provided in EPPI. Input data from a completed review with broadly the same scope was used to predict how likely each study record in our review would meet our inclusion criteria. This approach helped us screen more relevant studies to begin with, which meant that we could begin full-text screening and data extraction more efficiently.
- **Full-text screening:** A full text for each study that meet all the T&A inclusion criteria was retrieved. One reviewer examined each full text in detail against the protocol. In each case, a code was applied to each study that reflects whether the study was included, or why the study was excluded. Again, several codes were used to explain why studies were excluded. The output of this stage was a set of studies deemed suitable to include in the review.

[12] A software product that supports the management of and analysis in a systematic review. It manages references, stores PDF files and facilitate quantitative and qualitative coding and analysis.

3.4.2 Data extraction and critical appraisal

The following steps were taken to extract effect size information and appraise the quality of studies included in the review:

- **Quantitative data extraction:** Multiple reports of the same study were identified and linked together before data extraction. The review team extracted descriptive information about the studies included and interventions evaluated as part of the review, and quantitative information required to calculate effect sizes. This information was double-coded using procedures set out in a codebook developed as part of the review protocol.
- **Qualitative data extraction:** Data was extracted using line-by-line coding, to understand how interventions and context differ from one another using a code-set that was developed using a semi-inductive approach (Thomas 2008).
- **Quantitative critical appraisal:** Each included study underwent a critical appraisal that considers the risk of bias, across the categories of bias recommended by the Cochrane Non-Randomised Studies Group shown in Table 6. The risk of bias tool was developed by Hombrados and Waddington (2012). The tool was developed to allow consistent assessment of internal validity of social experiments and quasi-experiments including randomised controlled trials (RCTs), regression discontinuity designs (RDDs), non-randomised studies based on participant self-selection (panel data models, propensity score and covariate matching, and cross-sectional regression), and studies using instrumental variables estimation for causal identification.
- **Qualitative critical appraisal:** For all qualitative reports, we carried out a quality appraisal using an adaptation of the nine-item framework developed by the Critical Appraisal Skills Programme (CASP). Documents that provided supporting descriptive information on the design and/or delivery, and context of interventions did not undergo critical appraisal.

Table 6: Overview of sources of potential bias considered in the quantitative critical appraisal

Criterion	Brief description	QED	RCT
Mechanism of assignment	Was the identification strategy or mechanism of assignment of study units into treatment versus comparison groups appropriate?		
Group equivalence	Was the method of analysis adequate to ensure comparability of groups throughout the study?		
Unit of analysis	Is clustering accounted for in standard error calculations if the unit of randomisation differs from the unit of analysis?		
Attrition bias	Was any differential attrition from the study between the treatment and control groups adequately addressed?		
Motivation bias	Was the study adequately protected against differences in participation motivation and behavior as a result of programme implementation and/or monitoring?		
Spillovers, cross-overs, and contamination	Was the study adequately protected against spillovers, cross-overs, and contamination (i.e., between treatment and comparison groups)?		
Outcome measurement bias	Was the study adequately protected against various forms of outcome measurement bias (e.g., recall bias, interviewer bias, social desirability bias, differential timing of data collection for treatment versus comparison groups, etc.)?		

Criterion	Brief description	QED	RCT
Selective analysis reporting	Were the analyses conducted and reported appropriate, sufficient, and consistent with the protocol prior to data collection (e.g., as indicated in a pre-analysis plan)?		
Other bias	Was the study adequately protected from other risks of bias not elsewhere addressed in the assessment tool?		

Source: 3ie (2020). *Adapted from Hombrados and Waddington (2012).*

3.4.3 Data analysis

This subsection presents an overview of the data analysis approach taken to address each review question. A more detailed overview of the methods implemented can be found in Appendix A.

Calculating and synthesising effect sizes (SRQ1)

An effect size expresses the magnitude or strength of the relationship of interest (Borenstein et al., 2009; Valentine et al., 2015). We extracted data from each individual study to calculate standardised effect sizes for cross-study comparison where possible, and employed meta-analysis techniques to calculate overall effect sizes for using commonly understood formulae so that the results from different studies are presented on the same index and can be more easily compared. Where included studies did not provide the data required to calculate effect sizes, we contacted the authors. Where we did not get a response, we excluded the study from the meta-analysis but still included it in the descriptive and qualitative analysis.[13] Where multiple model specifications are provided, our first choice was always to extract the author's preferred model if it was stated as such. If the author did not state their preferred model, but presented a main model and then several robustness checks, the assumption was made that the main model was the preferred model. If the author did not state their preferred model and several models were presented as the main models, we chose the effect size from the model with the most controls.

The choice of a computational model for meta-analysis is based whether the studies are assumed to be functionally equivalent. If so, one may apply a fixed-effect model, which identifies the *best estimate of a single "true" intervention effect*, based on the assumption that the studies share a common mean and that differences in effect sizes are due to sampling error. In contrast, if the studies differed in important ways (e.g., subjects, interventions, context, etc.) that may affect the results and/or if the aim is to generalize findings to a range of scenarios or populations – both of which are true for this systematic review – one would apply a random effects model, which identifies the *average intervention effect across a distribution of effect sizes*. This meta-analysis adopts the random effects model, thus providing evidence of whether electricity access resulted in general changes to socioeconomic welfare *on average* and an indication of whether other factors beyond sampling differences influence effects.[14]

The metric we used to calculate standardised effect sizes in this review was the standardised mean difference (SMD), which quantifies the size of an intervention effect

[13] The omission of studies as a result of limited author engagement may have influenced results of the review although the direction of this influence is not clear, given the range of factors that may determine author engagement with the review team.

[14] Borenstein, M., Hedges, L.V., Higgins, J.P. and Rothstein, H.R., 2011. Introduction to meta-analysis. John Wiley & Sons.

in each study relative to the variability observed in that study. Specifically, we use Hedge's g, which is the SMD, with a correction for the bias induced by studies with small sample sizes.[15] The SMD is interpreted as the change in the outcome of interest attributable to the intervention, measured in terms of standard deviations. For example, an SMD of 0.5 indicates that the intervention caused the outcome to increase by 0.5 standard deviations.

To assess whether electricity access interventions affect evaluated outcomes in some way, we first pooled all standardised effect sizes together across the following five broad outcome domains:

- Electricity access and use (intermediate outcomes)
- Education
- Socio-economic welfare
- Health
- Environment

The pooled effect size (g) combines all effect size data in one outcome group to provide an overall measure of central tendency, taking advantage of samples across multiple populations. This approach provides an indication of the underlying differences across studies that may influence g. In this case, we use the I^2 metric to define the potential presence of variance across effect sizes, or effect size heterogeneity, in the analysis, that is not due to sampling differences.[16] This metric is provided as a percentage and a common rule of thumb is that an I^2 of 0-35, 35-65 and above 65 percent indicates low, medium, and high levels of heterogeneity, respectively. While these estimates account for differences across outcome group, they do not consider other factors that may influence effect size variance, as discussed in the following section. We also test how sensitive these effects are to outliers by re-running the analysis with outlier effect sizes, defined as effects that are more than three standard deviations away from the unweighted mean.

Assessing heterogeneity and underlying causal mechanisms (SRQs 2 and 3)

The approach presented above does not provide any understanding of what the other factors are that may influence variance in effect sizes. Given the wide array of electricity access interventions considered in this review, in terms of their design and implementation features and context, observed effect size heterogeneity is likely to be considerable. To address this, we implemented statistical models called meta-regressions, using quantitative effect size data, and a framework analysis of associated qualitative evidence provided.

Meta-regression analysis

Meta-regression models are comparable to multiple linear regression models whereby the observed variation in an outcome variable is predicted by a set of explanatory moderator variables, or covariates. In this case, the outcome variable of interest is the SMD for each effect size. We have selected covariates that relate to outcome type,

[15] Available at: https://bit.ly/2B3aon5. Date accessed: 03/05/2020.
[16] More information on this statistic is available at: https://bit.ly/2C37w9Z. Date accessed 02/06/2020.

intervention, study, and region characteristics to understand what factors influence heterogeneity in this context.[17] These covariates were selected by as a result of a priori assumptions about the theory of change and data availability, matching the descriptive classifications provided in Section 5. The regression coefficients derived from these models describe how the SMD changes with a unit increase in the explanatory covariates and whether these changes are statistically significant. In this way, meta-regressions address potential issues of confounding across the different selected covariates and provide more nuanced insight into the factors that influence heterogeneity. The analysis also estimates the residual I^2 that is present after accounting for the moderators of interest, and R^2, a more common diagnostic statistic used in regression analysis, which reflects the percentage of variance in effect size that is explained by the explanatory moderators in the meta-regression model. R^2 and I^2 are calculated separately and provide a signal of the explanatory power of the model only.

Where the results of these regressions do not provide a clear interpretation, we implemented further meta-regressions for outcome domain subgroup levels. For example, in addition to implementing a meta-regression for the education domain, we may also implement separate models for the outcomes that comprise this domain, such as school enrolment, study time, or grade progression. We also explore effect size variance for each intervention subgroup, using effect size data across all outcome domains. In doing so, we attempt to identify key factors that may have influenced programme effectiveness.

Subgroup analysis

To complement the analysis provided above, we also ran subgroup meta-analyses for outcomes that were determined to be theoretically similar, provided that there were at least two effect sizes that sought to measure the same outcome with comparable outcome measures. The results of these analyses and associated forest plots, which graphically present the underlying effect sizes, are presented in Appendix G.

Framework analysis

We used framework analysis to identify which intervention and contextual characteristics could explain outcomes. This qualitative method is aptly suited for applied policy research and incorporates a hybrid approach of inductive and deductive theme development.

Synthesising intervention cost evidence (SRQ4)

The research protocol called for standard approaches to synthesise economic appraisal evidence, depending on the available cost evidence (Shemilt et al., 2011; Shemilt et al., 2008). This was to include unit and total costs to implementers and participants (and non-participants, as relevant), and cost-effectiveness ratios, to provide a set of standardised benchmarks to compare interventions. Due to an absence of sufficient data, this analysis was dropped from the systematic review.

[17] The analysis implemented the following model specification: $\hat{\theta}_k = \theta + \beta_1 x_{1k} + \cdots + \beta_n x_{nk} + \epsilon_k + \tau_k$ where $\hat{\theta}_k$ is the predicted effect size for study k, β_n is the coefficient estimate for covariate n in study k, ϵ_k is the sampling error and τ_k is the error introduced as a result of the true effect size θ_k for study k is only part of a wider distribution of true effect sizes.

Publication bias

As with other reviews, this systematic review is vulnerable to publication bias, whereby research found in the published literature is systematically unrepresentative of the entire population of studies, for example, as a result of time lags, language use, small sample sizes or outcome reporting biases, such as under or non-reporting of null effects.

The review tested for publication bias through producing a funnel plot and undertaking trim and fill analyses (Duval & Tweedie, 2000) to test for variance in effect sizes when adjusting for assumed publication bias. However, the approach assumes there are no independent effect sizes. Because our models include dependent effect sizes, we complement this analysis by implementing a variant of Egger's regression, where we regress the standardised effect size with its standard error in a meta-regression. These results are presented in subsection 6.8.

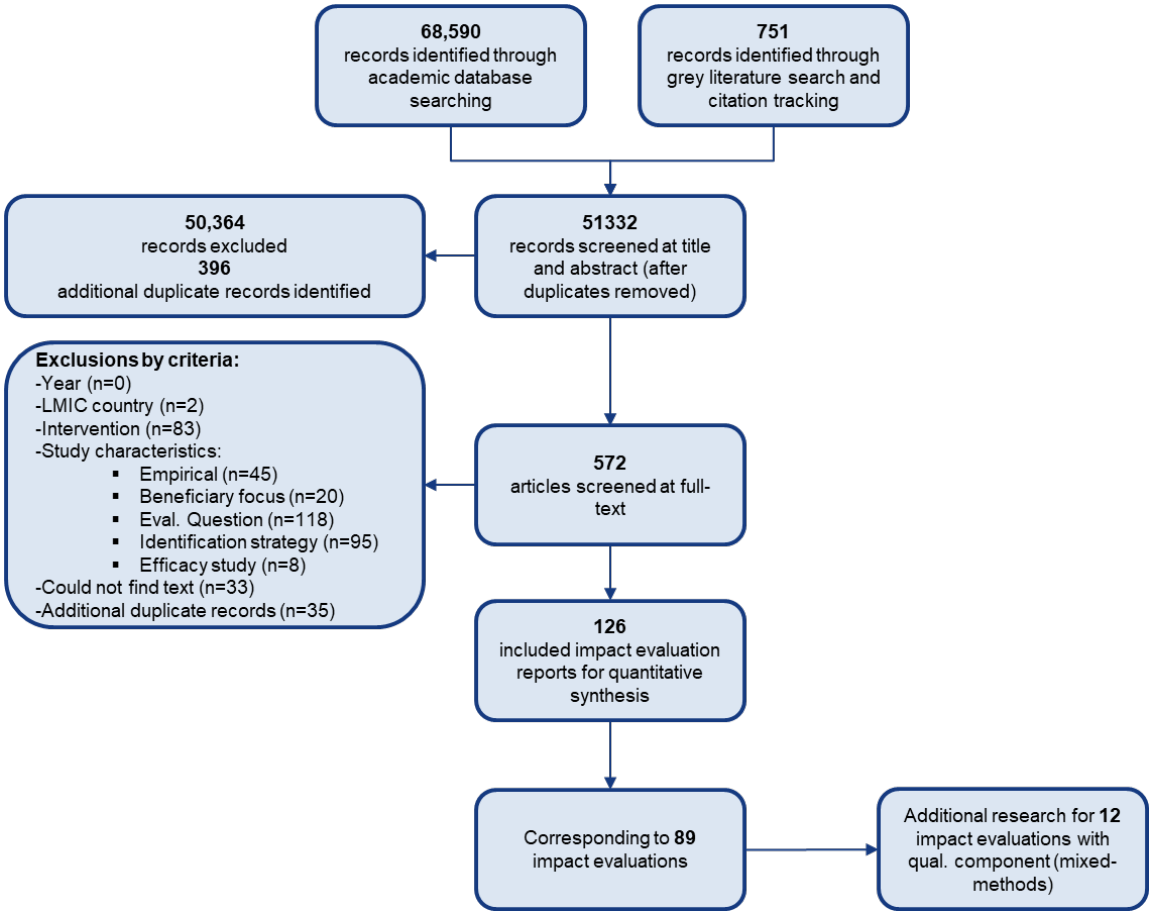
4. Descriptive results

This section presents the results of the literature search and a descriptive overview of the studies and interventions included in the review. It draws on metadata produced by the screening processes and descriptive information extracted from included study reports.

4.1 Search results

The electronic searching of academic databases produced a total of 68,590 records. Non-electronic searching and citation tracking produced a further 751 records for screening (resulting in 69,341 records). After removing 18,008 duplicate records, 51,332 study records were manually screened against the eligibility criteria using title and abstract information only. The main reasons for excluding at this stage were because a study did not focus on a relevant intervention and/or was not an impact evaluation.

Figure 3: Overview of search and screening process



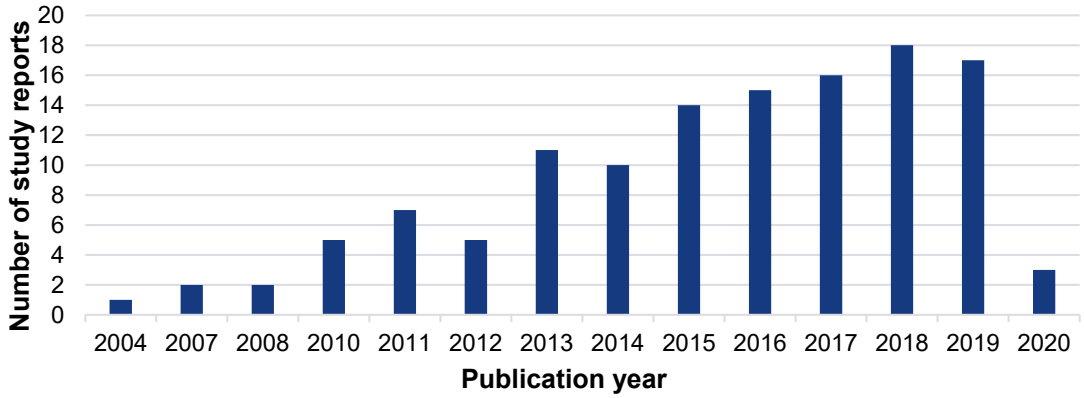
Source: 3ie (2020). *Analysis of review search results.*

After title-abstract screening, 568 records were still assessed as potentially relevant and retrieved for full-text review. In total, 126 records met all the eligibility criteria and were included in the review. These records correspond to 89 unique studies.[18] The discrepancy between the included records and number of studies is due to the fact that, in some cases, results of a single study were reported in more than one publication.

In total, 66 included study records were peer-reviewed journal articles (52 percent), with the remainder comprised of a combination of grey literature and unpublished academic manuscripts. In terms of publication activity by year, 104 study reports were published in or after 2013 (82 percent) as shown in the figure below.

[18] While there are 85 unique main reports, two of them describe a series of evaluations conducted in different countries, using different datasets. In the context of this review, these are treated as different studies and have been coded individually as if the evaluations had come from separate reports. This means a total of 89 studies (reported in 126 papers) were included in the synthesis.

Figure 4: Distribution of all included records by publication year



Source: 3ie (2020). *Analysis of 126 total included study reports.*

4.2 Characteristics of included studies

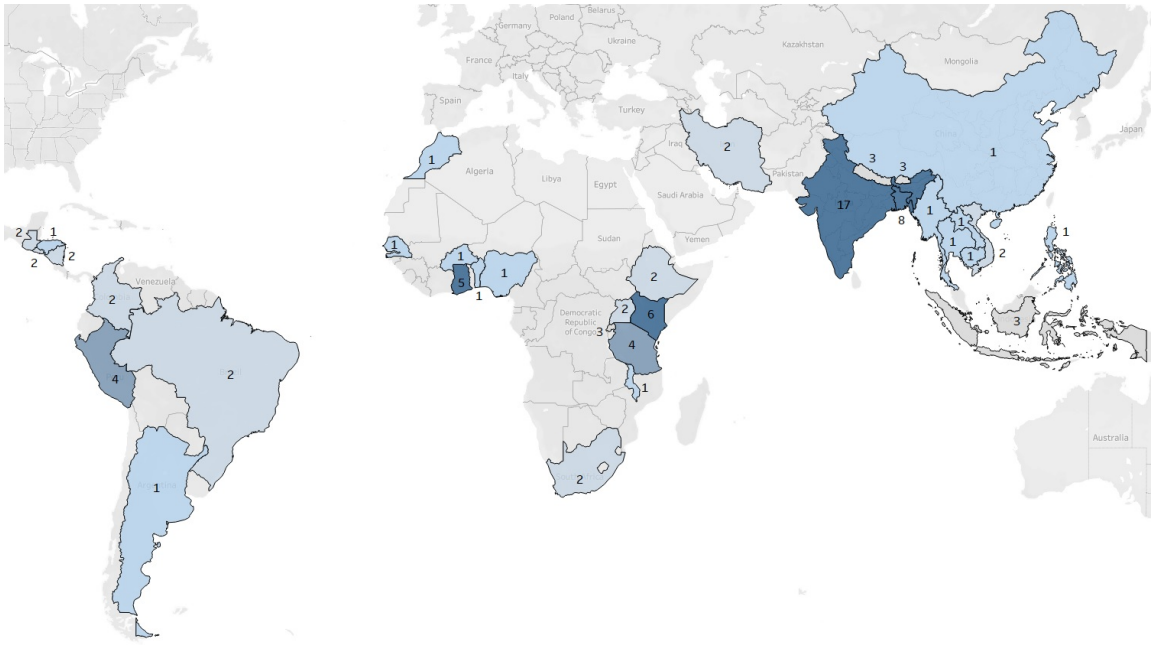
Analysis of study characteristics for all 89 included studies was completed. A full specification of multiple reports corresponding to one evaluation is provided in Appendix D. Because of the design of some studies, the review team was only able to identify specific interventions in 41 cases; intervention characteristics beyond the intervention type were only coded for this subset.[19] The key study features of unique impact evaluations included in the review, structured against the review PICOS are as follows:

4.2.1 Population

- **Geography:** Included impact evaluations were delivered across five geographic regions, as shown in Figure 5. South Asia was the region where the largest number of studies was implemented (31 studies), closely followed by Sub-Saharan Africa (28 studies).[20] This result is largely due to a high volume of studies in several countries, including India (17 studies), Bangladesh (8 studies), Kenya (6 studies) and Ghana (5 studies), as shown in Figure 5.3. Conversely, the regions associated with the least number of studies were East Asia and Pacific (9 studies) and Middle East and North Africa (3 studies).

[19] This relates to intervention funding agency, off-grid energy source and some additional variables specified in Appendix D (column of intervention characteristics).
[20] World Bank geographic regions were used as they provide a common understanding of key regions across the world of interest.

Figure 5: Distribution of included impact evaluations by geography



Source: 3ie (2020). *Analysis of 87 impact evaluations, associated with a total of 126 study reports. The two multi country studies that did not disaggregate their analysis by country are removed from this chart to avoid overly distorting the result.*

- **Country income status:** Country income status[21] was classified for the first year that data were collected in each evaluation. This analysis shows that the highest proportion of studies were implemented in low income countries (50 studies), followed by lower-middle income (31 studies) and upper-middle income countries (6 studies).[22]
- **Study participants:** The majority of studies sampled rural areas (68 studies), mixed groups of men and women (75 studies) and both adults and children aged less than 18 years old (51 studies). Eleven studies only considered children and nine studied only women. Five studies did not provide any information to deduce gender and age of participants, but the unit of observation for four of them was manufacturing firms. In terms of descriptive statistics, most studies present the breakdown of individual household members or the household head by socio-economic status (63), education (56), age (54) and sex (46) respectively. Thirty-five do so for household size and thirty for housing conditions. A much smaller number disaggregate sample composition by ethnicity/race (13), religion (9), or disability (1).

[21] As defined by the World Bank. Available at: https://bit.ly/3hyWKbJ. Date accessed 02/05/2020.
[22] If the authors chose the date of publication or end line data collection for determining the classification of country income status, lower-middle income countries would have been the largest group.

4.2.2 Intervention

- **Subject of evaluation:** In many cases, authors used survey data that collected information on electricity access to evaluate the effect on a social outcome, and a named intervention was not specifically evaluated. While these studies provide a contextual overview of the state of electrification in the countries of interest in some cases, more often than not, attribution of any changes in outcomes to the electrification activities discussed was assumed, rather than evidenced. Given this issue, we have classified studies according to the specific facet of electricity access they sought to evaluate, as summarised in Table 7 below. Analysis shows that a majority of studies did not specifically identify a named intervention and instead considered all electrification efforts in a country of interest in the evaluation period. As Table 7 indicates, this was the case for 48 studies. They used predominantly national-level surveys to evaluate the effects of different levels of electricity availability (42), quality/reliability (11) or affordability (1). Another group of studies, 16 in total, though they did not evaluate a specific programme, evaluated effects of electrification status (15) or different levels of affordability (2), for example by randomizing vouchers at different prices. Finally, 25 studies explicitly evaluated a programme or a programme component to extend electricity access.

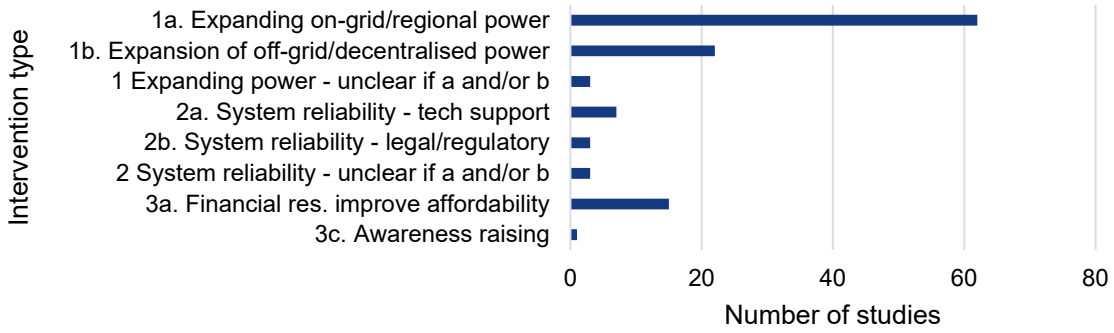
Table 7: Overview of the evaluation subject for each study

Subject of evaluation	No. studies
Different levels of electricity availability, reliability, or affordability	48
Different levels of electricity availability or affordability in the context of a wider programme	16
A programme or programme component to extend electricity access	25

Source: 3ie (2020). *Analysis of 89 impact evaluations, associated with a total of 126 study reports.*

- **Intervention type:** Figure 6 below shows that the majority of studies sought to evaluate the provision of new and/or improved grid access (62 studies), followed by the provision of new and/or improved off-grid electricity access (22 studies) and financial resources to improve affordability (15 studies). Seven studies sought to evaluate interventions that promoted technical support improvements and 3 studies evaluated legal/regulatory system reliability interventions. In three studies, the specific nature of the intervention forming the focus of the evaluation was not clear. One study evaluated the effect of an awareness raising demonstration programme. Finally, two studies measured the impact of blackouts, which we grouped with the technical support category (2a) for the purposes of the synthesis.

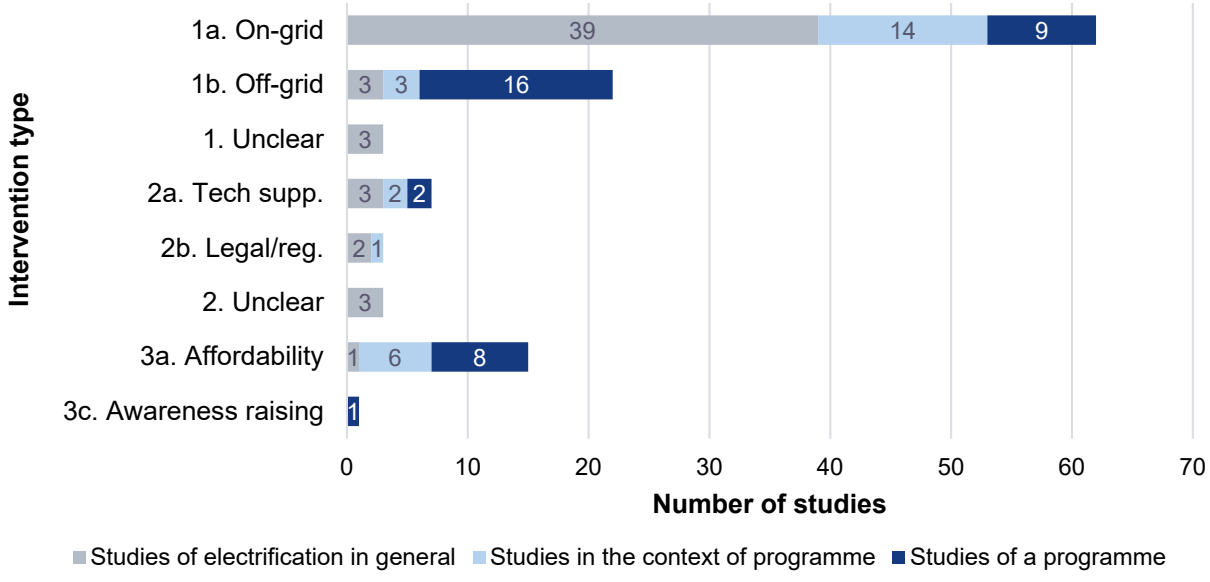
Figure 6: Distribution of included studies by intervention type



Source: 3ie (2020). *Analysis of 89 impact evaluations, associated with a total of 126 study reports. Multi-coding was permitted.*

- **Intervention type by subject of evaluation:** As Figure 7 indicates, whether evaluating a specific programme (14) or not (39), a majority of studies that examine different levels of availability, reliability and affordability evaluate the effects of grid connected status. However, for evaluations of specific programmes there are more off-grid interventions (16) than on-grid (9). Studies of a specific programme had a higher proportion of interventions aimed at promoting affordability through subsidies, consumer credit, or fee-for-service schemes.[23]

Figure 7: Distribution of included studies by intervention type and subject of evaluation



Source: 3ie (2020). *Analysis of 89 impact evaluations, associated with a total of 126 study reports. Multi-coding was permitted.*

[23] Studies of electrification in general rarely provide contextual details of activities so these results should be interpreted with caution.

- **Intervention type combinations:** Twenty-five studies were categorised under more than one dimension of electricity access. Most of them combined financial incentives with on-grid (8) or off-grid (7) physical access. In seven cases grid expansion was coupled with some sort of system reliability intervention, predominantly technical support. Six studies evaluated expansion of power using a mix of grid and off-grid. One of them was Samad and Zhang (2017), which evaluated different levels of electricity availability in the context of RERED Programme in Bangladesh which also had a technical support and affordability component.

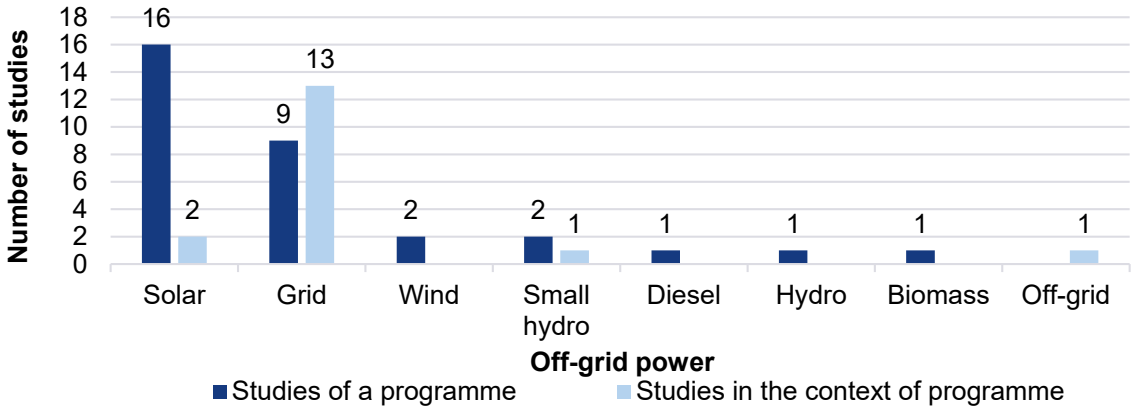
Table 8: Combinations for studies with more than one intervention type

Intervention type	1a.	1b.	2a.	2b.	3a.
1a. Expanding on-grid/regional power	X				
1b. Expansion of off-grid/decentralised power	6	X			
2a. System reliability - tech support	4	1	X		
2b. System reliability - legal/regulatory	1	0	0	X	
2 System reliability (unclear if a or/and b)	2	0	0	0	
3a. Financial res. improve affordability	8	7	1	0	X

Source: 3ie (2020). *Analysis of 25 impact evaluations with more than one intervention type: Samad (2017), Lee (2019), Kurata (2018), Kumar (2018), Koima (2019), Khandker (2014), Khandker (2013), Fuji (2018), Ding (2018), Dasso (2015), Chen (2019), Chaplin (2017), Chakravorty (2014), Blimpo (2018), Bezerra (2017), Bernard (2014), Bensch (2015), Bensch (2012), Barron (2017), Arráiz (2015), Alcazar (2007), Akpandjar (2018), Akpandjar (2017), Aevarsdottir (2017), Adusah-Poku (2019).*

- **Source of power:** As shown in Table 4.4, of the evaluations of a specific programme, sixteen evaluated photovoltaic products, nine the effects of grid connection and the remaining ones evaluated other off-grid technologies. Out of sixteen studies evaluating different levels of availability, reliability or affordability in the context of a programme, thirteen evaluated grid connection status, two solar technologies, one each for small hydro generators and an unspecified off-grid power source.

Figure 8: Evaluations of programmes or in the context of programmes by source of power



Source: 3ie (2020). *Analysis of 41 impact evaluations. Multi-coding was permitted.*

4.2.3 Outcomes

- **Outcomes:** Of all the intermediate and final social outcomes, 67 were measured primarily at an individual or household level. Another nine were analysed at the village or community level, four at the municipality level, and one at the province level. Manufacturing firms were the unit of observation for four studies, schools for two studies, and microenterprises and informal tailors for one study each. Overall, 45 studies reported effect size data on education outcomes, 32 studies reported on health outcomes, 73 studies reported socioeconomic welfare outcomes and 25 studies reported environmental outcomes. Moreover, 48 studies evaluated intermediate outcomes. A more detailed overview of the outcomes evaluated by study is provided in Appendix D.

4.2.4 Study design

- **Evaluation design:** Included studies employed a range of designs. Of the 89 studies included for this review, eleven studies implemented experimental designs,[24] while the remainder employed quasi-experimental study designs (QED). An overview of the designs employed is shown in Table 5.5, which shows that studies using statistical matching were most common (36 studies). 30 studies implemented multiple methods to support their identification strategy. The most common combination was statistical matching and difference in difference (9 studies).

Table 9: Overview of study evaluation designs

Methods used	Number of studies
Statistical matching	36
Instrumental variable estimation	32
Fixed effects estimation	23
Difference-in-difference	18
Randomized controlled trial	11
Regression discontinuity	2

Source: 3ie (2020). *Analysis of 89 impact evaluations, associated with a total of 126 study reports. Total is higher than the number of analysed impact evaluations as some studies employ multiple methods.*

4.2.5 Other study level characteristics

- **Critical appraisal (risk of bias assessment):** Just over half (52%) of the studies received a rating of “medium to high” or “high” risk of bias in at least one critical appraisal category. There were specific areas of uncertainty or concern for both quasi-experimental and experimental studies. Potential spill-overs were noted as an issue for both study types due to the difficulty of neatly differentiating between those with and without access to electrification interventions (e.g., due to demonstration effects, the potential for sharing electricity, and so forth), though the majority of authors acknowledged and sought to address or mitigate these concerns in some way. For the quasi-experimental studies, the most common

[24] While seven studies have been categorized as experimental during the Risk of Bias assessment, a further four studies have used a randomized encouragement design, which were classified as quasi-experimental.

risks related to confounding (23% rated as “Med-High” or “High” risk) and selection bias at baseline (22% rated as “Med-High” or “High” risk). These were often related to inadequate justification that the identification strategy would generate comparable treatment and comparison groups and the inability to account for potentially important covariates in the analysis respectively. In over a quarter of the studies, insufficient detail in the research reports made it difficult to assess the risk of bias, resulting in an “unclear” rating for four of the assessment criteria. In some cases, reviews did identify additional sources of potential bias. A fuller presentation of the critical appraisal results is provided in Appendix F.

- **Time of outcome measurements:** The review team attempted to collect information on the time elapsed between the electrification intervention and the latest outcome measurement. While it was unclear for 27 studies, 36 study reports indicated an exposure length of between 1-10 years. A length of above 10 years was reported for 16 studies while for the remaining 10, it was less than 12 months. The number of data collection points administered throughout the study was also captured. For a majority of studies (67 studies), only one or two outcome measurements were recorded.
- **Study and implementer funding agencies:** Study funding was provided by academic or research institutions (20 studies), international aid agencies (18), international financial institutions (17), government agencies (15), and foundations (4). However, it was not clear from the study reports reviewed what the study funding source was for the remaining 35 studies, or just under 40 percent of all included studies. Government agencies were the most common type of agency to fund named programmes included in the review (28 studies). This was followed by international aid organisations (7 studies), private sector organisations (4), international financial institutions (3), and non-profit organisations (1). It was not clear for two studies.
- **Independence:** A study was defined as independent by the review team when the evaluation team did not include any members of the team that delivered or funded the intervention under evaluation. In total, 83 studies (93 percent) were classed as independent, with three studies as partially or not independent; not enough information was provided in study reports to assess this for three studies. The independence of the data collection process was also assessed, whereby data collection collected by the evaluation team or a third party was classed as independent. Eighty-three studies were classed as having an independent data collection process, another three as not independent but again, with an insufficient level of information made available to assess this in the case of three studies. Finally, the review assessed the presence of conflict of information statements and found that fifteen studies (17 percent) reported a conflict of interest statement, whether there was a conflict or not.
- **Equity**: A majority of studies (38 studies) did not directly aim to address equity. Out of those that do, sex, place of residence, and socio-economic status were the main groups considered. The most common method employed to address equity considerations was to account for heterogenous effects using a sub-group analysis by sex (33 studies). About 20 percent of studies (21 studies) target a vulnerable population, predominantly in isolated rural areas. Third are sub-group analyses by equity dimensions other than sex (14 studies), mostly by age or

education levels of study participants. Other analyses of heterogeneity using interaction terms or quantile regressions are less common (8 studies) and have analysed differential effects based on participants' income, consumption level, or sex. Three studies included a gender equality measure as an outcome and the same number employed an equity-sensitive method or theoretical framework for their analysis. Four studies (4.5 percent) provided reference to an ethical or institutional review board approval, which is markedly lower than the average in 3ie's international development evidence repository (25 percent).

4.3 Results of the search for additional documents (SRQ3)

In total, 545 additional documents were screened for relevance on title and abstract, and of these 89 were manually examined on full text. Searching within the EPPI-Reviewer database identified 268 potentially relevant items and a further 260 resulted from searching Google and Google Scholar. The authors of 28 included studies responded to our request for additional information, suggesting 17 documents. Of these, three documents were relevant to the review: one addressed Review Question 3; one reported on an impact evaluation that we had so far not identified; and one was a linked study report (i.e. reported on an impact evaluation already in the review).

The search for additional evidence on barriers to and facilitators of programme effectiveness identified 12 new documents. Thus, the thematic analysis drew upon the included impact evaluations (most of which provided some level of information on barriers and facilitators), additional qualitative evidence (often a component of the included impact evaluation), and other documents relating to the intervention or context.

5. Synthesis of results

5.1 Introduction

This section presents the synthesis of results completed as part of the review. It was informed by data extracted from included studies, in addition to qualitative research and evidence from process evaluations that are linked to included studies.

The remainder of this section is structured as follows. For each of the five broad outcome domains, we present the number of studies for which we were able to calculate effect sizes, as defined in the Methodology Section (Section 3). We then provide a descriptive overview of the outcomes evaluated by studies only, as the distribution of intervention and study characteristics broadly follows that presented in Section 5. We then present the results of the quantitative analysis, and provide a narrative synthesis of studies not included in the quantitative analysis. The section ends with an exploratory analysis of the influence of intervention categories, an assessment of the likely presence of publication bias, and a summary discussion of the key results.

5.2 Intermediate outcomes

There are a number of intermediate steps in the theorised causal pathways between the implementation of an electricity access programme and the realisation of a change in a given social outcome. These intermediate outcomes relate to programme implementation, uptake, and/or a target population's response to an intervention. These

may include, for instance, new household connections to electricity, changes in energy consumption, lighting use, reliability of an electricity supply, or other outcomes.

We identified 35 studies reported in 44 study reports that evaluated the effect of an electricity access intervention on an intermediate outcome. We were able to calculate effect sizes relating to intermediate outcomes for all of these studies.

Within this outcome domain, we grouped outcomes into the following categories:

- **Electricity connectivity:** The extent to which an intervention resulted in changes to a target population's connection to an electricity. In all cases, outcomes evaluated reflect whether on-grid electricity access was achieved or whether electricity access was provided in some form.
- **Electricity reliability:** Changes in the reliability of an electricity source were approximated using the hours of electricity available in a given period or the occurrence of reliability indicators, such as frequency of brown or black-outages.
- **Electricity price:** Two studies based in India and Peru, respectively, evaluated electricity price changes as a result of the implementation of an electricity access intervention (Alcazar 2007, Numminen 2018). We considered the price level from the perspective of an end consumer and assumed that a price decrease was a socially improving outcome. This means a positive SMD in the meta-analysis reflects a decrease in the price of electricity.
- **Lighting use:** Eight studies evaluated changes in lighting use as a result of an electricity access intervention. These were measured in the amount of time lighting was reportedly used for.
- **Energy use:** Eighteen studies considered energy use across four main areas: electricity, batteries and traditional energy sources such as wood, kerosene, or dung. A positive relationship was assumed between changes in an outcome and the SMD, except in the case of traditional fuel use, where we assumed a decrease in the effect was socially improving; a positive SMD in the meta-analysis reflects a decrease in traditional energy use.
- **Electrical appliance ownership and use:** As new and/or improved electricity access is provided to target populations, it may be the case that beneficiaries increase their ownership of electrical appliances to make more productive use of electricity. Seventeen studies evaluated changes in appliance ownership and use as a result of an electricity access intervention.

A summary of the set of included studies that evaluated intermediate outcomes is provided in Table 10.

Table 10: Overview of studies that evaluated intermediate outcomes

Main study	Country	Outcome measure						
		Electricity			Light use	Energy use	App own.	App. use
		Connect	Price	Reliable				
Adusah-Poku (2019)	Ghana	■						
Aevarsdottir (2017)	Tanzania				■	■		■
Aklin (2017)	India	■	■		■			
Akpandjar (2017)	Ghana					■	■	
Alcazar (2007)	Peru		■	■		■		
Bahaj (2019)	Kenya	■						
Barron (2019)	El Salvador	■				■	■	
Bensch (2011)	Rwanda				■			
Burlig (2016)	India				■	■	■	■
Chakravorty (2014)	India	■	■					
Chakravorty (2016)	Philippines	■						
Chaplin (2017)	Tanzania	■			■	■	■	■
Chen (2017)	Uganda				■			
Chen (2019)	India	■						
Dang (2019)	Vietnam						■	
Dendup (2019)	Bhutan					■	■	■
Dinkelman (2011)	South Africa					■		
Gonzalez-Eiras (2007)	Argentina						■	
Grimm (2013)	Burkino Faso						■	■
Grimm (2015)	Indonesia						■	
Grogan (2015)	Colombia						■	
Grogan (2018)	Guatemala					■	■	
Groth (2019)	Tanzania				■	■		■
Karumba (2018)	Kenya				■	■		
Khandker (2012)	Bangladesh					■		
Khandker (2014)	Bangladesh					■		

Main study	Country	Outcome measure						
		Electricity			Light use	Energy use	App own.	App. use
		Connect	Price	Reliable				
Kurata (2018)	Bangladesh							
Kumar 2018	Bhutan							
Lee (2019)	Kenya							
Litzow (2019)	Bhutan							
Numminen (2018)	India							
Samad (2017)	Bangladesh							
Thomas (2018)	India							
van de Walle (2017)	India							
Samad (2019)	India							
Total number of studies		10	5	2	8	18	15	7

Source: 3ie (2020). *Analysis of study information extracted by review team.*

5.2.1 Synthesis of results

Overall, electricity access interventions resulted in an average positive change of 0.17 standard deviations (95% CI: [0.08, 0.26]) in the treatment group relative to the comparison group for the intermediate outcomes included in the meta-analysis. Sensitivity analysis showed this pooled effect decreased to 0.12 standard deviations when outliers were removed, which suggests the result is in part sensitive to the overall distribution of effect sizes. Finally, the high level of heterogeneity between the studies (I^2=99 percent) support the need for moderator analysis.

Our analysis of potential moderating factors estimated that interventions providing a combination of system management, policy, and affordability components are statistically significantly associated (p<0.01) with an average positive increase of 0.51 standard deviations (95% CI: [0.13, 0.90]) in intermediate outcomes after accounting for variance across the type of intervention implemented, outcomes measured, and study characteristics. The results of the analysis are presented in Table 11. None of the other moderators significantly influenced the pooled SMD for intermediate outcomes.

Table 11: Meta-regression output – Intermediate outcomes

Explanatory moderator	Estimate	Standard error	p-value	95%CI lower bound	95CI% upper bound	Sig.
Intercept	-77.46	42.02	0.07	-159.82	4.89	
Outcome						
Electricity connectivity	0.15	0.15	0.32	-0.14	0.44	
Electricity reliability	0.19	0.19	0.33	-0.19	0.57	
Electricity price	0.19	0.30	0.53	-0.40	0.79	
Energy use	0.11	0.14	0.45	-0.17	0.39	
Light use	0.13	0.19	0.49	-0.24	0.50	
Electrical appliance ownership	-0.03	0.16	0.84	-0.34	0.28	
Electrical appliance use	0.17	0.16	0.28	-0.14	0.48	
Intervention						
On-grid expansion (1a)	-0.50	0.51	0.33	-1.49	0.49	
Off-grid expansion (1b)	-0.41	0.49	0.40	-1.36	0.54	
Technical support (2a)	-0.36	0.53	0.50	-1.39	0.68	
Legal/reg reform (2b)	0.00	0.68	1.00	-1.33	1.32	
Affordability (3a)	-0.58	0.49	0.23	-1.53	0.37	
Awareness (3c)	-	-	-	-	-	
1+2 (expansion + support)	0.26	0.63	0.68	-0.97	1.49	
1+3 (expansion + affordability)	0.64	0.53	0.23	-0.41	1.68	
2+3 (support + affordability)	0.51	0.20	0.01	0.13	0.90	**
Study						
RCT	-0.09	0.13	0.46	-0.35	0.16	
Publication year	0.04	0.02	0.06	0.00	0.08	
High risk of bias	0.19	0.16	0.23	-0.12	0.51	

Explanatory moderator	Estimate	Standard error	p-value	95%CI lower bound	95CI% upper bound	Sig.
Measurement take in/after 5 years	-0.04	0.09	0.66	-0.22	0.14	
Baseline elec. access	-0.06	0.27	0.83	-0.60	0.48	
East Asia & Pacific	0.10	0.40	0.79	-0.67	0.88	
Latin America	0.11	0.21	0.62	-0.31	0.52	
Middle East & North Africa	-	-	-	-	-	
South Asia	0.12	0.18	0.48	-0.22	0.47	
Sub-Saharan Africa	-	-	-	-	-	
Residual unexplained heterogeneity (I^2) = 99.5 percent						
Explained variance in effect size (R^2) = 9 percent						

Source: 3ie (2020). *N.B. Significance codes: p-value< 0 '***' 0.001, '**' 0.01, '*' 0.05, '.' 0.1, ' ' 1, i.e. the higher the number of stars, the higher the significance of the result. Redundant covariates, marked with '-' are dropped from the model and not reported. The rows with numbered interventions indicate the effect of different combinations of intervention groups.*

We were also able to calculate standardised effect sizes for two studies relating to the uptake and use of electricity, but did not evaluate outcomes conceptually similar enough those specified in this domain. One study considered the effects of offering incentives to local contractors to collect grid-electricity tariff revenues in rural India (Rains 2018). It estimated that the incentives offered resulted in some revenue collection improvements among hard to reach groups, residual levels of non-payment were considerably high, and concluded that the capacity of local institutions or energy supplier more generally to collected tariff revenue was a limiting factor in this case. Another study considered the effect of technology demonstrations on the creation of markets for solar home systems (Urpelainen 2017). The study found no effect of these demonstrations on uptake and use, despite those that adopted systems reporting high levels of satisfaction, suggesting marketing campaigns alone may not be sufficient to increase uptake. Additional survey evidence found that the availability of credit in rural areas was potentially a more acute barrier. Both of these studies highlight the potential importance of appropriate community engagement, both prior and post-implementation, for access interventions.

5.3 Education outcomes

Access to electricity is often assumed to improve education outcomes and there are several potential and theorised causal pathways for how this may occur. New and/or improved lighting, by extending the effective school day and permitting flexible home study, was the main mechanism highlighted in included studies. However, other potential mechanisms exist – for example, the increased use of electrical devices and digital working aids and the attraction and retention of high-quality teaching staff. These changes are expected to improve the education process in some way and enable more investment in education by learners, both in school and home environments. As a result, we expect that learner participation would increase - for example, enrolment, grade progression and years of schooling – which would ultimately produce positive learning outcomes, such as improved test scores or literacy rates.

In this review, we identified 46 studies that measured education outcomes, of which 37 studies (made available in 46 individual reports) provided sufficient information to calculate standardised effect sizes. We were able to extract effect size information for the following educational outcome subgroups:

- **School enrolment:** We were able to calculate standardised effect sizes for 13 studies that evaluated changes to child school enrolment. These were typically measured in rates of enrolment, shares of children in school, and the probability of being enrolled.
- **Study time:** We identified 16 studies (in 19 reports) that estimated the effect of electricity access programmes on study time. While the majority of studies estimated changes in total time allocated to studying, five studies also evaluated evening or night time study time (Banerjee 2011; Bensch 2012; Chaplin 2017; Groth 2019; Khandker 2014).
- **Grade progression:** Five papers considered the effects of changes to electricity access on child grade progression. Four papers measures this in terms of whether children had completed their current grade or progressed to the next grade. One study (Dang 2019) evaluated whether a household member had dropped out of high school in the evaluation period.
- **Years of schooling:** We were able to calculate standardised effect sizes for 12 studies included in the review that evaluated the additional number of total or mean schooling years completed by children. One study also considered the minimum and maximum years of schooling achieved by the sample (van der Walle 2017).
- **Learning outcomes:** Effect size data on tests scores was calculated for five studies. Scores in a range of subjects were evaluated, as well as the shares of children in the highest levels in specific subjects. In addition, effect size data on household literacy rates was calculated for three studies.

A summary of the set of included studies that evaluated intermediate outcomes is provided in Table 12 below.

Table 12: Overview of studies that evaluated educational outcomes

Main study	Country	Outcome measure				
		Enrolment	Study time	Grade prog.	Years of schooling	Learning outcomes
Aevarsdottir (2017)	Tanzania					
Aguirre (2017)	Peru					
Aklin (2017)	India					
Akpandjar (2017)	Ghana					
Banerjee (2011)	Nepal					
Barron (2019)	El Salvador					
Bensch (2011)	Rwanda					
Bensch (2012)	Senegal					
Berkouwer (2018)	Kenya					
Bridge (2016)	Nepal					
Burlig (2016)	India					
Chaplin (2017)	Tanzania					
Chen (2017)	Uganda					

Main study	Country	Outcome measure				
		Enrolment	Study time	Grade prog.	Years of schooling	Learning outcomes
Dang (2019)	Vietnam					
Dasso (2015)	Peru					
Groth (2019)	Tanzania					
Guarcello (2004)	El Salvador					
Guarcello (2004)	Ghana					
Guarcello (2004)	Guatemala					
Guarcello (2004)	Morocco					
Jahangir (2019)	Bangladesh					
Karumba (2018)	Kenya					
Khandker (2012)	Bangladesh					
Khandker (2013)	Vietnam					
Khandker (2014)	Bangladesh					
Koima (2019)	Kenya					
Kudo (2019)	Bangladesh					
Kumar (2018)	Bhutan					
Kurata (2018)	Bangladesh					
Lee (2019)	Kenya					
Litzow (2019)	Bhutan					
Nigussie (2015)	Ethiopia					
Saing (2018)	Cambodia					
Salehi-Isfahani (2014)	Iran					
Samad (2017)	Bangladesh					
Samad (2019)	India					
van de Walle (2017)	India					
Total number of studies		12	17	5	10	8

Source: 3ie (2020). *Analysis of study information extracted by review team.*

5.3.1 Synthesis of results

Electricity access interventions had a small positive effect on education outcomes of 0.05 standard deviations on average (95%CI: [0.03, 0.07]) in the treatment group relative the comparison group for the educational outcomes included in the analysis.[25] This estimate is associated with a considerable level of heterogeneity (I^2=75 percent). To account for this, we controlled for a set of additional potential explanatory moderators, the results of which are presented in Table 13. This analysis highlighted several factors that influenced effect size variation within the education outcome domain.

[25] A full specification of pooled effects at the outcome level is provided in Appendix G.

Table 13: Meta-regression output – Educational outcomes

Explanatory moderator	Estimate	Standard error	p-value	95%CI lower bound	95CI% upper bound	Sig.
Intercept	0.82	0.23	0.00	0.37	1.27	***
Outcome						
Enrolment	0.04	0.04	0.23	-0.03	0.11	
Grade progression	0.04	0.04	0.29	-0.03	0.11	
Study time	0.18	0.04	<.0001	0.09	0.27	***
Years of schooling	0.05	0.04	0.17	-0.02	0.13	
Literacy rate	-	-	-	-	-	
Test scores	0.02	0.03	0.47	-0.04	0.08	
Intervention						
On-grid expansion (1a)	-0.48	0.12	<.0001	-0.70	-0.25	***
Off-grid expansion (1b)	-0.25	0.05	<.0001	-0.34	-0.15	***
Technical support (2a)	0.02	0.03	0.51	-0.04	0.09	
Legal/reg reform (2b)	-	-	-	-	-	
Affordability (3a)	-0.03	0.03	0.30	-0.08	0.02	
Awareness (3c)	-	-	-	-	-	
1+2 (expansion + support)	-	-	-	-	-	
1+3 (expansion + affordability)	-	-	-	-	-	
2+3 (support + affordability)	0.13	0.06	0.02	0.02	0.25	*
Study						
Female	0.01	0.00	0.12	0.00	0.02	
Child (aged <18 years)	0.21	0.04	<.0001	0.13	0.28	***
RCT	-	-	-	-	-	
Publication year	-	-	-	-	-	
High risk of bias	-0.29	0.09	0.00	-0.48	-0.10	**
Measurement take in/after 5 years	-0.03	0.02	0.23	-0.07	0.02	
Baseline elec. access	-0.54	0.12	<.0001	-0.77	-0.30	***
East Asia & Pacific	-	-	-	-	-	
Latin America	0.20	0.05	0.00	0.10	0.30	***
MENA	-0.12	0.02	<.0001	-0.16	-0.07	***
South Asia	-	-	-	-	-	
Sub-Saharan Africa	-	-	-	-	-	
Residual unexplained heterogeneity (I^2) = 14 percent						
Explained variance in effect size (R^2) = 99 percent						

Source: 3ie (2020). *N.B. Significance codes: p-value< 0 '***' 0.001, '**' 0.01, '*' 0.05, '.' 0.1, ' ' 1, i.e. the higher the number of stars, the higher the significance of the result. Redundant covariates, marked with '-' are dropped from the model and not reported.*

First, the analysis indicates that electricity access resulted in a significant increase in study time by 0.18 standard deviations. Surprisingly, we found that interventions that expand access alone resulted in a decreased effect size, while the combination of system and policy management and affordability components were associated with an increase in effect size. Finally, in terms of study setting, we found no significant differences in effects by sex and a significant effect on children (0.21 standard

deviations). We also find that there was a significant decreased in the pooled effect size for study populations based in Latin America and the Middle East and North Africa, studies with high risk of bias, and for studies in countries with a high average nationwide level of electricity access.

5.4 Socio-economic welfare outcomes

Electricity access is expected to produce transformative benefits across multiple areas of society, ranging from livelihood generation, increased productivity, improved socio-economic well-being, and ultimately, reduced poverty. These benefits are expected to arise through a number of different mechanisms. New and/or improved access is expected to result in increased home and economic productivity and open up new economic opportunities, increasingly those that are not related to agriculture. Potential increases in household and firm wealth may produce positive externalities, for example by increasing demand for local services and attracting residential and commercial migration, resulting in increased labour supply. Finally, access to electricity is expected to improve well-being, both through the improved set of opportunities described but also by improving the quality of social interaction and local safety.

This subsection presents a synthesis of all outcomes relating to socio-economic development. We were able to calculate standardised effect sizes for 59 studies found in 72 reports that assessed at least one socio-economic outcome from the following domains: assets, household output, labour supply, time allocation, business performance, safety, social cohesion, and well-being.

We grouped effect sizes in the socioeconomic domain into the following categories:

- **Assets:** Seven studies considered the extent to which improved access resulted to changes in household or community assets. Outcomes either measured the value of assets or the presence of local amenities or household plumbing.
- **Household wealth:** A large volume of studies sought to measure the accumulation of wealth by households. Evaluators deployed a wide range of indicators, which we grouped broadly into income (27), expenditure (24), consumptions (5), savings (2), and poverty (10). Within income and expenditure, authors typically distinguished between different types to understand a particular aspect of the theory of change underpinning electricity access - for example, several authors distinguish between income derived from farm and non-farm source, under the assumption that improved electricity access may result in an increased number of non-farm economic opportunities, as described in Section 2.
- **Labour supply:** We grouped studies that measured labour supply into those that evaluated increased chances of household participants entering the labour force (16) or levels of employment (18). We account for levels of labour force participation and employment separately in the analysis.
- **Time allocation:** Study authors sought to understand how time allocation to an array of different activities may have changed as a result of changes to electricity access. This included time allocated to paid and non-paid work, collection of traditional fuels, leisure, and rest. A decrease in the time allocated to collecting traditional fuels is denoted by an increase in the SMD. In some cases, authors made the distinction between men, women and children. We account for allocation of time to these sources separately in the analysis where possible.

- **Business performance:** Several studies sought to assess changes in revenue, profits, and productivity. In some cases, a distinction was made between the business performance of firms that derive the majority of their income from farm and non-farm sources. We assumed that increased business performance across all areas resulted in a socially improving outcome. However, as mentioned in Section 2, changes to performance are only expected to produce sustained benefits through changes in firm productivity. Without this, any changes are likely to be due to displacement of economic activity, although benefits may still be accrued if resources are transferred to more productive firms through the displacement process.
- **Safety:** Nine studies measured changes in safety. We grouped these outcomes into changes in public safety, the presence of fire hazards, and violence against women. The first group focused on decreased levels of crime, improved perceptions of local safety and increased agency to travel at nigh time, while the second included outcome measures that indicated the extent to which fires had occurred and whether household members had been burnt as a result. Finally, two studies sought to understand changes to violence against women by measure levels of violence and 'eve-teasing' and acceptability of violence by women (Aklin 2017; Sievert 2015).
- **Female empowerment:** Several studies sought to measure a range of factors relating to female empowerment. Two studies sought to measure overall changes in empowerment using indices (Khandker 2014; Samad 2019), while the remainder focused on specifically measuring female agency and female involvement in family, family planning, and economic household decision making. We assumed that increased agency and decision making was a socially improving outcome.
- **Social cohesion and wellbeing:** Finally, we grouped four studies sought to assess broad measures of social cohesion relating to social participation, awareness, and position, and four studies that assessed changes in measures of happiness and life satisfaction as a result to changes in electricity access.

An overview of included studies is provided in Table 14.

Table 14: Overview of studies that evaluated Socio-economic welfare outcomes

Main study	Country	Outcome measure														
		Assets	Household					Labour force part.	Emp.	Time alloc ate.	Bus. perf.	Safety	VAWG	Fem. Empo.	Social coh.	Well-being
			Inc.	Exp.	Con.	Saving	Pov.									
Adusah-Poku (2019)	Ghana			■			■									
Aevarsdottir (2017)	Tanzania		■	■		■		■	■	■		■				■
Aklin (2017)	India			■		■		■				■	■	■		
Akpandjar (2017)	Ghana		■					■	■	■	■					
Alcazar (2007)	Peru		■	■						■						
Allcott (2016)	India		■					■	■		■					
Arvate (2018)	Brazil											■				
Bahaj (2019)	Kenya		■	■			■								■	
Banerjee (2011)	Nepal		■	■						■				■		
Barron (2019)	El Salvador		■					■	■	■						
Bensch (2011)	Rwanda		■	■												
Bensch (2012)	Senegal											■		■		
Bezerra (2017)	Brazil		■				■									
Bhattacharyya (2017)	India			■												
Blimpo (2018)	SSA														■	
Bridge (2016)	Nepal			■	■						■					
Bridge (2019)	Nicaragua		■													
Burlando (2014)	Tanzania									■						
Burlig (2016)	India	■	■				■	■	■							
Chakravorty (2014)	India		■								■					

Main study	Country	Outcome measure														
		Assets	Household					Labour force part.	Emp.	Time alloc ate.	Bus. perf.	Safety	VAWG	Fem. Empo.	Social coh.	Well-being
			Inc.	Exp.	Con.	Savi ng	Pov.									
Chakravorty (2016)	Philippines		■	■			■		■	■						
Chaplin (2017)	Tanzania	■	■	■	■		■	■	■	■		■				
Chauvet (2018)	Myanmar										■					
Chen (2017)	Uganda		■	■						■		■				
Chen (2019)	India	■														
Chowdhury (2010)	Banglades h							■		■						
Dang (2019)	Vietnam		■							■						
Dasso (2015)	Peru		■	■				■	■	■						
Ding (2018)	China		■					■								
Dinkelman (2011)	South Africa	■							■							
Fetter (2020)	India								■							
Grimm (2013)	West Africa									■	■					
Grimm (2015)	Indonesia							■	■							
Grogan (2013)	Nicaragua							■		■						
Grogan (2015)	Colombia								■							
Grogan (2018)	Guatemala	■					■	■		■						
Groth (2019)	Tanzania			■						■						
Karumba (2018)	Kenya			■						■						
Khandker (2012)	India		■	■			■			■						
Khandker (2013)	Vietnam		■	■												
Khandker (2014)	Banglades h	■	■	■						■				■		
Koirala (2019)	Nepal										■					
Kumar (2018)	Bhutan		■													

Main study	Country	Outcome measure														
		Assets	Household					Labour force part.	Emp.	Time alloc ate.	Bus. perf.	Safety	VAWG	Fem. Empo.	Social coh.	Well-being
			Inc.	Exp.	Con.	Savi ng	Pov.									
Kurata (2018)	Banglades h		■		■							■				
Lee (2019)	Kenya	■	■	■	■		■		■	■		■			■	■
Litzow (2019)	Bhutan								■							
Mensah (2014)	Ghana			■												
Nigussie (2015)	Ethiopia							■						■		
Numminen (2018)	India				■											■
Peters (2011)	Benin										■					
Poczter (2017)	Indonesia										■					
Pueyo (2018)	Kenya										■					
Rathi (2018) [India]	India		■						■	■						
Rathi (2018) [S. Africa]	South Africa		■						■	■						
Saing (2018)	Cambodia			■												
Samad (2017)	Banglades h		■	■				■		■				■		
Samad (2019)	India			■			■	■	■	■				■	■	
Sievert (2015)	SSA												■			
van de Walle (2017)	India			■					■	■						
Total number of studies		**7**	**27**	**24**	**5**	**2**	**10**	**16**	**18**	**25**	**10**	**8**	**2**	**7**	**4**	**3**

Source: 3ie (2020). *Analysis of study information extracted by review team.*

5.4.1 Synthesis of results

Overall, we estimated that electricity access interventions resulted in an average positive change of 0.04 standard deviations (95%CI: [0.03, 0.06]) in the treatment group relative to the comparison group for socioeconomic welfare outcomes included in the analysis. This estimate is associated with a high level of heterogeneity (I^2=91 percent). As above, we sought to account for this by implementing a meta-regression model, the results of which are presented in Table 15.

This model estimated a negative relationship between the overall effect size and time allocation to non-paid work and interventions that implemented a combination of expansion and system policy and management components. Surprisingly, we also estimated a weakly significant but negative relationship between the implementation of technical support and the overall effect size. Socio-economic effects were also estimated to be positively associated to women, indicating that effects sizes relating to women were 0.03 standard deviations higher than those related to men on average. Socio-economic outcomes that were disaggregated by sex included those relating to labour supply, time allocation, household expenditure and income, safety and violence against women, and female empowerment.

We also found that firm productivity and off-grid expansion interventions were negatively associated with the overall effect size while measures of well-being were positively related. However, these results are weakly significant and should be taken with some caution.

Table 15: Meta-regression output – Socio-economic welfare outcomes

Explanatory moderator	Estimate	Standard error	p-value	95%CI lower bound	95CI% upper bound	Sig.
Intercept	-8.30	13.47	0.54	-34.70	18.10	
Outcome						
Household assets	-	-	-	-	-	
Community assets	-	-	-	-	-	
Household income	-	-	-	-	-	
Household expenditure	0.02	0.05	0.66	-0.07	0.12	
Household consumption	-0.06	0.05	0.23	-0.16	0.04	
Household savings	-	-	-	-	-	
Household poverty	-	-	-	-	-	
Labour force participation	-0.03	0.04	0.54	-0.11	0.06	
Employment	-0.04	0.04	0.31	-0.12	0.04	
Time allocation – paid work	-0.05	0.05	0.27	-0.14	0.04	
Time allocation – non-paid work	-0.10	0.04	0.02	-0.18	-0.02	*
Time allocation – traditional fuel collection	0.00	0.06	0.98	-0.12	0.12	
Time allocation – leisure	0.05	0.05	0.28	-0.04	0.14	
Time allocation – rest	-0.10	0.05	0.06	-0.20	0.01	
Business income	-	-	-	-	-	

Explanatory moderator	Estimate	Standard error	p-value	95%CI lower bound	95CI% upper bound	Sig.
Firm value added	-	-	-	-	-	
Firm productivity	-	-	-	-	-	
Safety	0.00	0.12	0.97	-0.22	0.23	
Violence against women	-0.09	0.08	0.28	-0.24	0.07	
Female empowerment	-0.03	0.05	0.51	-0.14	0.07	
Well-being	-	-	-	-	-	
Intervention						
On-grid expansion (1a)	0.03	0.06	0.62	-0.09	0.15	
Off-grid expansion (1b)	0.01	0.04	0.75	-0.06	0.08	
Technical support (2a)	-0.24	0.10	0.01	-0.44	-0.05	*
Legal/reg reform (2b)	-	-	-	-	-	
Affordability (3a)	-0.06	0.05	0.21	-0.15	0.03	
Awareness (3c)	-	-	-	-	-	
1+2 (expansion + support)	0.29	0.13	0.02	0.04	0.55	*
1+3 (expansion + affordability)	-	-	-	-	-	
2+3 (support + affordability)	-	-	-	-	-	
Study						
RCT	0.08	0.08	0.30	-0.07	0.23	
Publication year	0.00	0.01	0.53	-0.01	0.02	
Female	0.03	0.01	0.03	0.00	0.06	*
High risk of bias	0.08	0.05	0.16	-0.03	0.18	
Measurement take in/after 5 years	0.01	0.04	0.81	-0.06	0.08	
Baseline elec. access	-0.09	0.11	0.41	-0.30	0.12	
East Asia & Pacific	-0.02	0.06	0.77	-0.13	0.09	
Latin America	0.00	0.04	0.95	-0.08	0.09	
Middle East & North Africa	-	-	-	-	-	
South Asia	-0.01	0.04	0.76	-0.09	0.07	
Sub-Saharan Africa	-	-	-	-	-	
Residual unexplained heterogeneity (I^2): 94 percent						
Explained variance in effect size (R^2) = 28 percent						

Source: 3ie (2020). *N.B. Significance codes: p-value< 0 '***' 0.001, '**' 0.01, '*' 0.05, '.' 0.1, ' ' 1, i.e. the higher the number of stars, the higher the significance of the result. Redundant covariates, marked with '-' are dropped from the model and not reported.*

Two studies also considered the impact of access interventions on levels of migration. We decided not to include migration in the domain because we found it to be sufficiently different from a conceptual standpoint that the other outcomes considered. These studies find mixed results on the effect of electricity access interventions on migration. ADB (2010) found that the probability of rural-urban migration and the number of migrants in a household was significantly higher in electrified households. Although these results did not triangulate with qualitative evidence collected as part of the evaluation, which suggested a perception that rural-urban migration had decreased, post

implementation. Chaplin et al. (2017) found no effect on migration to the locality where grid access had been provided, despite an increase in the price of residential land in the same area. These results suggest that the relationship between electricity access and migration is complex and is influence by a range of factors.

5.5 Health outcomes

As discussed in Section 2, there two main mechanisms though which new and/or improved electricity access can result in improved health outcomes. First the decreased use of traditional fuels is expected to result in better air quality in residential and commercial areas, which in turn lowers the risk of health problems caused by pollutants. Second, electricity access is expected to improve the quantity and quality of health services available in a vicinity, resulting in the improved provision of healthcare than otherwise would have been achieved.

We were able to calculate effect sizes for 33 studies published in 38 study reports as part of this review and we grouped all health-oriented outcomes into the following subcategories along the expected causal chain:

- **Traditional energy use:** In total, 17 studies considered the effects of electricity access interventions on the use of traditional energy sources. We include this sub-outcome group from the intermediate outcome domain here because its inclusion is conceptually relevant to the realisation of health outcomes, i.e., through the reduction of pollutants which affect the prevalence of respiratory and gastrointestinal symptoms. For this outcome group, an increase in the standardised effect reflects a decrease in traditional energy use.
- **Health services and information:** Two studies considered the extent to which information relating to HIV was effectively disseminated to target populations as a result of changes to electricity access. In addition, Chen (2019) also measures changes in the delivery of health services, such as the probability of receiving vaccines and certain treatments. An increase in effect size relates to an increasing information sharing and likelihood of being vaccinated and receiving testaments.
- **Fertility:** Nine studies considered the effects of electricity access on fertility. Outcome measures relate the prevalence of contraception use, the shares of women giving birth, the average number and desirability of births. Given the contexts of the studies under review, we assumed that an increase in the use of contraception and a decrease in the rate of fertility were socially improving outcomes and associated with positive standardised effect sizes.
- **Health symptoms:** Studies that considered health symptoms either focused on the prevalence of illness or infirmity in the general sense or specified the specific type of ailment. We were able to group ailments reports into three categories: general, respiratory and air, and gastrointestinal. We assumed that a decrease in reported symptoms was a socially improving outcome. As such, an increase in the standardised effect size is associated with a reduction in reported symptoms.
- **Health outcomes:** Finally, few studies collected outcome data relating to health outcomes. These studies approximated improvements to health outcomes by attempting to measure birth weights, mortality, and life expectancy among target populations. An improvement in health outcomes was linked to a decrease in mortality rates and low birth weights and an increase in life expectancy.

An overview of these studies is provided in Table 16 overleaf.

Table 16: Overview of studies that evaluated health outcomes

Main study	Country	Outcome measure					
		Traditional energy use	Health services	Health info.	Fertility	Health symptoms	Health outcomes
Aevarsdottir (2017)	Tanzania	■				■	
Akpandjar (2017)	Ghana	■					
Akpandjar (2018)	Ghana				■		
Bahaj (2019)	Kenya						
Banerjee (2011)	Nepal				■	■	
Barron (2017)	El Salvador	■				■	
Bezerra (2017)	Brazil						■
Burlig (2016)	India	■					
Chaplin (2017)	Tanzania	■		■	■	■	
Chen (2017)	Uganda					■	
Chen (2019)	India		■	■			
Dang (2019)	Vietnam					■	
Dendup (2019)	Bhutan	■					
Dinkelman (2011)	South Africa	■					
Fetzer (2016)	Colombia	■			■		
Fuji (2020)	Bangladesh				■		
Fujii (2018)	Bangladesh						
Gonzalez-Eiras (2007)	Argentina						■
Grimm (2015)	Indonesia				■		■
Grogan (2015)	Colombia				■		
Grogan (2018)	Guatemala	■					
Groth (2019)	Tanzania	■					
Karumba (2018)	Kenya	■					
Khandker (2012)	Bangladesh	■					
Khandker (2014)	Bangladesh	■			■	■	
Kurata (2018)	Bangladesh	■				■	
Kumar (2018)	Bhutan						■
Lee (2019)	Kenya					■	
Litzow (2019)	Bhutan	■				■	
Salehi-Isfahani (2014)	Iran				■		
Samad (2017)	Bangladesh	■					
Samad (2019)	India					■	
van de Walle (2017)	India	■					
Total number of studies		17	1	2	9	11	4

Source: 3ie (2020). *Analysis of study information extracted by review team.*

5.5.1 Synthesis of results

We found that the implementation of electricity access interventions had an average positive effect on health outcomes of 0.11 standard deviations (95%CI: [-0.01, 0.22]) in the treatment group relative to the comparison group. One outlier was identified in this domain related to a decrease in fertility rate (g=1.91).[26] When this effect was removed from the analysis the overall pooled effect for the health domain decreased to 0.05 standard deviations, which shows the result is sensitive to the overall distribution of effects sizes and largely driven by the improvement in fertility mentioned.

When we considered heterogeneity, the overall model was associated with a high level of heterogeneity (I^2=99 percent). To explore and interpret variation in outcomes, interventions and study features, we implemented a meta-regression, the results of which are presented in Table 17. We estimated that being located in Latin America or the Middle East and North Africa and South Asia is associated with a decrease in the pooled effect size for the health domain, by -0.55, -0.91 and -0.37 standard deviations respectively. We also find that baseline access had a significant and positive effect on the variance in pooled effect size and that high risk of bias studies were associated with lower effect sizes.

Table 17: Meta-regression output – Health outcomes

Explanatory moderator	Estimate	Standard error	p-value	95%CI lower bound	95CI% upper bound	Sig.
Intercept	71.37	46.96	0.13	-20.67	163.42	
Outcome						
Traditional energy use	-0.22	0.19	0.25	-0.58	0.15	
Health information	-0.04	0.24	0.87	-0.51	0.43	
Health service delivery	0.02	0.24	0.93	-0.45	0.49	
Fertility	-0.05	0.19	0.78	-0.44	0.33	
Health symptoms	-0.24	0.19	0.20	-0.61	0.12	
Health outcome	0.22	0.37	0.55	-0.51	0.95	
Intervention						
On-grid expansion (1a)	-0.09	0.15	0.57	-0.38	0.21	
Off-grid expansion (1b)	-0.08	0.21	0.71	-0.50	0.34	
Technical support (2a)	-0.12	0.11	0.26	-0.33	0.09	
Legal/reg reform (2b)	-0.77	0.67	0.25	-2.08	0.54	
Affordability (3a)	0.15	0.08	0.07	-0.01	0.31	.
Awareness (3c)	-	-	-	-	-	
1+2 (expansion + support)	-	-	-	-	-	
1+3 (expansion + affordability)	-	-	-	-	-	
2+3 (support + affordability)	-	-	-	-	-	

[26] Akpandjar (2018) found that electrification contributed to a significant fall in fertility among rural women by between one and three children.

Explanatory moderator	Estimate	Standard error	p-value	95%CI lower bound	95CI% upper bound	Sig.
Study						
RCT	-0.12	0.11	0.26	-0.33	0.09	
Publication year	-0.04	0.02	0.13	-0.08	0.01	
High risk of bias	-0.29	0.12	0.01	-0.53	-0.06	*
Measurement take in/after 5 years	0.11	0.08	0.15	-0.04	0.26	
Baseline elec. Access	0.52	0.24	0.03	0.05	0.98	*
East Asia & Pacific	-	-	-	-	-	
Latin America	-0.55	0.14	<.0001	-0.81	-0.28	***
Middle East & North Africa	-0.91	0.26	0.00	-1.41	-0.40	***
South Asia	-0.37	0.12	0.00	-0.60	-0.14	**
Sub-Saharan Africa	-	-	-	-	-	
Residual unexplained heterogeneity (I^2) = 99 percent						
Explained variance in effect size (R^2) = 20						

Source: 3ie (2020). *N.B. Significance codes: p-value< 0 '***' 0.001, '**' 0.01, '*' 0.05, '.' 0.1, ' ' 1, i.e. the higher the number of stars, the higher the significance of the result. Redundant covariates, marked with '-' are dropped from the model and not reported.*

5.6 Environmental outcomes

As set out in the strategic rationale for intervention in Section 2, electricity access interventions may produce a range of effects on environmental outcomes. The key mechanism through which these changes are expected to arise is by substituting the use of polluting fuels with the use of electricity, primarily in households, although these benefits may be sorted out as target populations make increasing use of electricity, which places further demands on electricity production.

Of the 25 included studies that we identified, we were able to calculate standardised effect sizes for 17 (provided in 24 study reports). The review considered the 16 studies that measured the use of traditional energy sources that were specified in health domain descriptive overview and three studies that evaluated measures of pollution. To make the results consistent, the sign of the standardised effect sizes reported for traditional energy use were reversed such that an increase in the effect reflected a decrease in the use of traditional energy sources.

A summary of the set of studies included by key outcome area is provided in Table 18.

Table 18: Overview of studies that evaluated environmental outcomes

Main study	Country	Outcome measure	
		Pollution	Traditional energy use
Aevarsdottir (2017)	Tanzania		
Akpandjar (2017)	Ghana		
Barron (2019)	El Salvador		
Burlig (2016)	India		
Chaplin (2017)	Tanzania		
Dendup (2019)	Bhutan		
Dinkelman (2011)	South Africa		
Grogan (2018)	Guatemala		
Groth (2019)	Tanzania		
Karumba (2018)	Kenya		
Khandker (2012)	Bangladesh		
Khandker (2014)	Bangladesh		
Kurata (2018)	Bangladesh		
Litzow (2019)	Bhutan		
Samad (2019)	India		
Samad (2017)	Bangladesh		
van de Walle	India		
Total number of studies		3	17

Source: 3ie (2020). *Analysis of study information extracted by review team.*

5.6.1 Synthesis of results

We estimated that electricity access interventions had a modest effect on improving environmental outcomes for treatment groups relative to comparison groups on average (g=0.07 95%CI: [0.01, 0.14]; I^2=97 percent), with a high degree of potential heterogeneity (I^2>65 percent). As with the previous domains, we implemented a meta-regression to understand what factors might influence the pooled effect size and explain some of the reported heterogeneity.

The results, as shown in Table 19, indicate that the pooled effect size was negatively affected by studies evaluating interventions that provided on-grid electricity expansion. However, the level of unexplained heterogeneity present is still high (88 percent).

Table 19: Meta-regression output – Environmental outcomes

Explanatory moderator	Estimate	Standard error	p-value	95%CI lower bound	95CI% upper bound	Sig.
Intercept	0.09	0.05	0.06	-0.01	0.18	.
Outcome						
Traditional energy use	-	-	-	-	-	
Pollution	-	-	-	-	-	
Intervention						
On-grid expansion (1a)	-0.09	0.04	0.03	-0.17	-0.01	*
Off-grid expansion (1b)	-	-	-	-	-	
Technical support (2a)	-	-	-	-	-	
Legal/reg reform (2b)	-	-	-	-	-	
Affordability (3a)	-	-	-	-	-	
Awareness (3c)	-	-	-	-	-	
1+2 (expansion + support)	-	-	-	-	-	
1+3 (expansion + affordability)	-	-	-	-	-	
2+3 (support + affordability)	-	-	-	-	-	
Study						
RCT	0.02	0.02	0.39	-0.02	0.06	
Publication year	-	-	-	-	-	
High risk of bias	-	-	-	-	-	
Measurement take in/after 5 years	-0.01	0.02	0.51	-0.06	0.03	
Baseline elec. access	-	-	-	-	-	
East Asia & Pacific	-	-	-	-	-	
Latin America	-	-	-	-	-	
Middle East & North Africa	-	-	-	-	-	
South Asia	-	-	-	-	-	
Sub-Saharan Africa	-	-	-	-	-	
Residual unexplained heterogeneity (I^2) = 88 percent						
Explained variance in effect size (R^2) = 0 percent						

Source: 3ie (2020). *Analysis N.B. Significance codes: p-value< 0 '***' 0.001, '**' 0.01, '*' 0.05, '.' 0.1, ' ' 1, i.e. the higher the number of stars, the higher the significance of the result. Redundant covariates, marked with '-' are dropped from the model and not reported.*

5.7 Exploratory analysis

To complement the main results of the review presented above, we undertook two additional analyses. First, we present a meta-regression analysis to understand the effects of intervention type on all outcome groups. Second, we present subgroup analysis at the sub-outcome group level, to support an understanding of variance by

outcome. This subgroup analysis does not account for other factors that may influence effect size variance so the results, which are summarised here and presented in full in Appendix G, should be taken with caution.

5.7.1 Analysis by intervention

We extended the analysis by grouping all effect sizes information across all outcome domains by intervention type. In this case, we are interested in the factors that are important to consider for improving all outcomes with respect to each intervention of interest. Here we control for outcome domains and study characteristics.

We estimated that implementation of on-grid, technical support, and affordability interventions were positively related to changes in intermediate outcomes, but that on-grid and technical support interventions were negatively associated with environmental outcomes, and socioeconomic welfare outcomes in the latter case - although the effects related to the provision of technical support are weakly significant and should be taken with caution.

In terms of study features, we found that high risk of bias studies were associated with lower effect sizes in the case of off-grid interventions and studies located in Latin America. We also estimated that effect sizes were significantly higher when measured after at least five years in the case of off-grid interventions and significantly lower in the case of technical support provision.

Table 20: Meta-regression output by intervention type

Intervention	Access expansion				System and policy management				Incentives	
	On-grid		Off-grid		Technical support		Legal and regulatory		Affordability	
Explanatory moderator	**Est.**	**se.**	**Est.**	**se**	**Est.**	**se.**	**Est.**	**se.**	**Est.**	**se.**
Intercept	-5.55	5.65	27.2*	11.66	1.63	9.15	-0.08	0.21	-11.34	14.26
Outcome										
Intermediate	0.15***	0.02	0.06	0.04	0.10***	0.03	0.01	0.07	0.15**	0.03
Education	0.01	0.02	-0.03	0.02	-0.01	0.02	-	-	0.02	0.04
Socioeconomic	0.02	0.01	-0.01	0.02	-0.03*	0.01	-0.03	0.07	0.01	0.02
Health	0.04	0.03	-0.05	0.03	-0.01	0.02	0.12	0.10	-0.02	0.04
Environmental	-0.15***	0.04	0.13*	0.06	-0.12*	0.05	-	-	-0.10	0.05
Study										
RCT	0.02	0.02	-0.03	0.02	-	-	-0.02	0.07	-0.04*	0.02
publication year	0.00	0.00	-0.01*	0.01	0.00	0.00	-	-	0.01	0.01
High risk of bias	0.01	0.03	-0.13***	0.04	-0.08	0.08	-	-	-0.02	0.03
Measurement take in/after 5 years	-0.02	0.01	0.16***	0.04	-0.06**	0.02	-	-	0.06	0.03
Baseline elec. access	0.02	0.05	0.11	0.09	0.23*	0.11	0.11	0.21	0.02	0.08

Intervention	Access expansion				System and policy management				Incentives	
	On-grid		Off-grid		Technical support		Legal and regulatory		Affordability	
LATAM	-0.06	0.03	-0.27***	0.08	-	-	-	-	-0.05	0.05
MENA	-0.03	0.12	-	-	-	-	-	-	-	-
S. Asia	-0.01	0.03	-0.08	0.04	-0.06	0.06	-	-	-0.04	0.04
E. Asia & Pac.	0.01	0.04	-	-	-0.06	0.09	-	-	-	-
SSA	-	-	-	-	-	-	-	-	-	-
Residual I^2 (%)	99		98		97		37		99	
Exp. var. R^2 (%)	9		9		27		14		6	

Source: 3ie (2020). *N.B. Significance codes: p-value< 0 '***' 0.001, '**' 0.01, '*' 0.05, '.' 0.1, ' ' 1, i.e. the higher the number of stars, the higher the significance of the result. Redundant covariates, marked with '-' are dropped from the model and not reported.*

5.7.2 Analysis by outcome subgroup

For each domain, we also calculated pooled effect sizes for specific outcome groups that included effects from at least two studies. These synthesised effects provide a weighted average treatment effect for particular outcomes. Of note, these estimates do not account for other explanatory factors beyond outcome sub-group that may influence effect size variance, and should be considered only as a complement to the main results presented this section. We present a high-level summary of the results here; a table summarising all estimated effects and forest plots to visually represent the results are provided in Appendix G.

Overall, we estimated no negative effects and several null and positive effects as a result of implementing electricity access interventions

- **Intermediate outcomes:** We found that the implementation of electricity access interventions resulted in significant improvements to reliability (g=0.07), price (g=0.05) and electricity use (g=0.22), as well as electrical appliance ownership (g=0.17) and use (g=0.15).
- **Education:** Electricity access had positive and significant effects on educational outcomes including child school enrolment (g=04), study time (g=0.09) - in particular evening or night time study time (g=0.18) - and years of schooling (g=0.07), but no effect on grade progression or literacy rate in treatment groups, relative to comparison groups.
- **Socio-economic welfare:** We found several positive effects across multiple outcomes measuring some aspect of socioeconomic well-being. These included improvements to household assets (g=0.06), income, including income derived from farm and non-farm sources (g=0.06), food expenditure (g=0.07), and poverty measures (g=0.08). We also estimated positive effects on firm employment (g=0.02) and agricultural productivity (g=0.4), and that respondents increased time allocated to paid work (g=0.05) and leisure (g=0.07) while decreasing time allocated to collecting traditional energy sources (g=0.10). Finally, we found positive effects on measures of female empowerment (g=0.03).
- **Health:** Electricity access interventions had a positive but insignificant effect on average, for all health outcomes.

- **Environment:** We estimated electricity access interventions had a positive but insignificant effect on levels of pollution on average. relative to comparison groups. Again, this suggests traditional energy is a key driver of improving health outcomes.

5.8 Publication bias

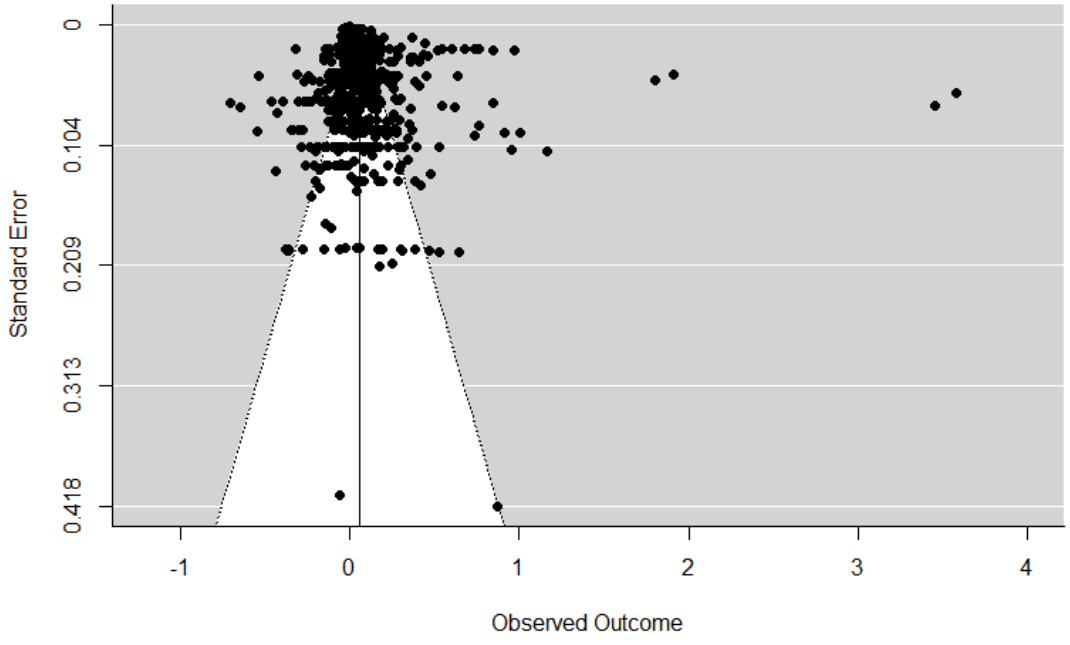
This section presents the evidence on the extent to which there has been selective reporting of positive significant findings, or publication bias. Publication bias is a type of reporting bias where published research is systematically unrepresentative of the true population of studies completed. This is a particular issue for studies with small sample sizes and/or those reporting no effects.

We adopted two approaches to assess the presence of publication bias in this review. Both of which seek to establish a relationship between the effect size and study population, assuming that if a relationship is present, then there may be an underlying risk of publication bias.

First, we ran a basic random effects model that includes all effect size data to estimate the overall pooled point estimate. We then created a funnel plot, which is an inverted scatter plot of the effect size against the standard error for each study, denoted by a black dot. It is assumed that these is less chance of publication bias if these plots exhibit a high level of visual symmetry around the null.

Visual inspection of the plot in Figure 9 suggested there is potentially some asymmetry, because fewer studies are present in region of negative significance, when compared to the regions of positive significance, i.e., there are missing dots in the lower left region of the plot, where it is more plausible for negative study findings to 'disappear' when study sample sizes are sufficiently small.

Figure 9: Funnel plot used to assess the presence of publication bias



Source: 3ie (2020). *Analysis of effect size data extracted from included studies.*

Visual inspection is inherently subjective and we implement Egger's test, which regresses standardised effect sizes on their standard errors. Publication bias is suggested to be plausible if the regression intercept is expected to significantly different from zero. When implementing this test, we rejected the null that the intercept is equal to zero (z = 4.5888, p < .0001), which again suggests publication bias might be present.

However, the approach assumes there are no independent effect sizes. Because our models include dependent effect sizes, we complement this analysis by implementing a variant of Egger's regression, where we regress the standardised effect size with its standard error in a meta-regression.[27] Again, if we find a relationship between the two then this suggests publication bias could be present. Implementing this, we find a significant relationship between the effect size and standard error (β_1=0.81, SE=0.03; p-value<0.0001), which suggested that publication bias may be present. To test whether this result varied by outcome, we implemented this regression for each outcome domain and found a positive and significant relationship between the effect size and standard error for all outcome domains.

While asymmetry is defined above could be due to publication bias, it could also arise for a number of other reasons, including chance, low methodological quality of small N studies, the presence of other reporting biases, or true heterogeneity in effects. As such, the results presented in this section should be taken with caution.

5.9 Thematic analysis (SRQ3)

This section presents the results of a thematic analysis of barriers to and facilitators of programme effectiveness. We have established that there was considerable variability in estimations of the impacts of electrification among the studies in the review. In the previous section, we explored the role of differences in outcomes, interventions, and study characteristics in explaining the variation across studies. In this section, we build on the evidence presented on overall and heterogeneous treatment effects to try to make sense of the factors that make the difference between successful and disappointing intervention implementation and results.

The results we have on factors enabling or preventing positive effects of electrification should be treated as suggestive. An insufficient number of studies to derive robust conclusions means we are not able to produce comprehensive findings about the multiple and interacting causal pathways in electrification interventions. However, we can point to a few specific factors where there is some evidence to suggest that they should be targeted to increase effectiveness of future programmes in low and middle-income countries.

The thematic synthesis of qualitative and informal data suggests the following three different types of factor had some role in influencing programme effectiveness: structural and cultural barriers and facilitators; intervention design and implementation barriers and facilitators; and beneficiary-related barriers and facilitators. Each of the following

[27] The analysis implemented the following model specification: $\hat{\theta}_k = \theta + \beta_1 x_{1k} + \epsilon_k + \tau_k$ where $\hat{\theta}_k$ is the predicted effect size for study k, β_1 is the coefficient estimate for a unit change in the standard error for effects in study k, ϵ_k is the sampling error and τ_k is the error introduced as a result of the true effect size θ_k for study k is only part of a wider distribution of true effect sizes.

subsections presents a descriptive overview of the main barriers and facilitators, as well as a summary table that indicates that number of studies that contribute evidence to a particular theme, where these studies were set, and key examples to illustrate the themes raised. Where possible, we also present the subset of studies where the evidence presented links a barrier or facilitator to a specific outcome of interest.

5.9.1 Structural and cultural barriers and enablers

While the importance of taking account of context in systematic reviews is now widely recognised (Booth et al. 2019), this is often challenging due to included primary studies providing an inappropriate level of contextual detail. Our review identified that the effects of electricity are likely to be contingent upon a variety of contextual factors, defined as the political, economic and social conditions within which programme implementation is embedded. Based on the thematic analysis, the main structural and cultural barriers likely to impede intervention effectiveness were as follows: political situation; economic performance, other interventions, and gender and cultural norms. The themes that may have worked as structural or cultural barriers and facilitators are presented in Table 24, and the remainder of this section provides a narrative overview of the factors identified in the review.

Political situation

The political situation or structures of a region or country can affect the market for energy supply and may constitute an important barrier to obtaining the desired outcomes for electrification programmes:

- **Government favouritism:** In some contexts, government favouritism can lead to government-controlled companies monopolising electricity markets and electric grid investments being diverted towards districts that are favoured by a ruling party. Or newly elected government officials might reverse commitments made by their predecessors and favour alternative investments resulting in delays or even cancellation to the planned provision of new and/or improved electricity access. Membership of an opposition political party could also impede household grid connection during village electrification.
- **Political unrest, conflict or instability:** Alternatively, the presence of political unrest, conflict or instability in an area can impede the large-scale rollout of electricity as well as prevent repairs to damaged infrastructure, imposing a barrier to beneficiaries making use of energy services and obtaining desired social outcomes.

Economic performance

Our analysis revealed one of the factors influencing programme effectiveness was regional/country and local economic performance during or before the study period:

- **Economic unrest, conflict or instability:** The presence of economic unrest, conflict, or instability (e.g. as a consequence of an environmental disaster) is likely to reduce demand for electricity services and can affect residential and non-residential access to and consumption of electricity.
- **Existing economic infrastructure:** Grid electricity may improve outcomes where implementation has been in:
  - Areas with better transport and links to neighbouring commercial centres;
  - Areas with existing industries that can benefit from cheaper sources of power;

    - Areas experiencing rising income levels during the study period, for example as a result of increased agricultural yields and income.
    - Areas where labour productivity could be influenced by intangible factors such as social capital and entrepreneurial characteristics among the target population, cultural dimensions, and religion.

Other interventions

The delivery of other energy programmes or complementary interventions in the same locality might also affect programme effectiveness on key outcomes of interest in some way:

- **Other energy programmes:** Other energy programmes delivered at the same time as the intervention, for example electricity market reforms which result in decreased electricity tariffs, as well as government subsidies for alternative fuels such as kerosene or bottled gas (e.g. to avoid voter backlash), can influence electricity consumption patterns.
- **Complementary programmes:** Initiatives to expand access to electricity may not produce meaningful economic and non-economic impacts unless they are combined with complementary programmes, such as those to facilitate household and non-residential purchases of electrical appliances or efforts to promote and raise awareness about the benefits of domestic and agricultural applications of electricity.
- **Electricity markets:** The performance and activities of associated energy sectors can possibility explain the presence or lack of positive effects on outcomes. Increased market competition or technology developments, for example, may reduce the cost of electrical appliances or the costs of hiring electricians to install or repair equipment or electrical appliances, affecting electricity access and consumption behaviour.

Gender stereotypes and cultural barriers

The benefits of electrification also depend on structural factors like social ideologies and gender norms which shape individuals' perceptions of appropriate role-related behaviours for women/girls and men/boys.

A likely mechanism through which the effects of electrification are realised is that access to modern energy sources can reduce the hours devoted to unpaid physical labour, including the gathering of fuel sources, which mainly falls on women, allowing them to enter paid employment, perform labour market tasks more productively, and possibly earn larger incomes. This may improve women's bargaining power within the household and bring welfare gains across several other dimensions. However, some of the benefits are only realised by those women who are able to access jobs. In some contexts, it may be the case that social norms and gender discrimination prevent women from engaging in income earning activities or otherwise shape and constrain women's choices.

Table 21: Structural and cultural barriers and enablers

Theme (no. studies coded with theme)	Countries	Evidence examples	Correspondence between themes and study outcomes
Political situation (13)	Argentina, China, Colombia, Honduras, India, Nicaragua, Senegal, South Africa, Sub-Saharan Africa (aggregated data), Vietnam	It is important to consider the political economy in Bihar when researching whether consumers will be interested in or satisfied with cheaper alternatives. Our finding is that micro grids are not perfect substitutes for grid electricity. If politicians promise to deliver grid electricity during political campaigns, non-grid alternatives may not be politically feasible, and constituents may not accept them. Rains and Abrahams (2018). p. 295.	3 of the 17 studies [1,12,20] contributing to this theme consider the influence of government involvement in the electricity sector on socio-economic impacts. Of these, 2 studies [1,12] suggest poor outcomes were likely due to inefficient investment and mismanagement by the government. In the 3rd study with positive outcomes [20], authors described good management and coordination between the national government and local governments and stakeholders.
Local / regional economic performance (14)	Argentina, Benin, Bhutan, Honduras, India, Kenya, Senegal, South Africa, Tanzania, Vietnam	Impact of large-scale investments in India's RGGVY grid electrification programme is crucially tied to local economic conditions, and higher in villages that simultaneously benefited from a boom in the price of a local commodity (guar plant). Fetter and Usmani (2020). p.4.	3 of the 14 studies [4,24,25] attempt to explain why business owners were not reaping the benefits of improved energy supply. All 3 studies attributed this to saturated local markets and limited access to external sources of demand from regional or national markets.
Other interventions (11)	Bhutan, India, Iran, Peru, Rwanda, Senegal, Vietnam	India's kerosene subsidies reduce the opportunity cost of using kerosene, possibly explaining the lack of positive effects derived from setting up solar microgrids in villages. In settings with non-electrified rural communities and more expensive kerosene due to lack of subsidies (for example, many Sub-Saharan African countries), the intervention could have performed better. Aklin (2017). p. 4.	There is evidence from 2 studies [10,23] highlighting the influence of complementary interventions initiated by governments during implementation of the electrification programme (e.g. resettling initiatives; road developments that remote villages closer to road points; and connection subsidies). Both studies suggest that they facilitated connections to the grid by optimising cost per connection.
Gender stereotypes and cultural barriers (8)	Bangladesh, India, Nicaragua, South Africa	"In India, female members of a household are predominantly responsible for collecting cooking fuel such as firewood. Access to modern technology	There is evidence from 8 studies [8,11,17,21,28,29,30,33] that gender norms/roles affect the labour supply effect of electrification differently for men

Theme (no. studies coded with theme)	Countries	Evidence examples	Correspondence between themes and study outcomes
		via electricity therefore frees up women's time, which they may use for income generating activities either within or outside the home." Rathi et al. (2018). p.357.	and women. There is broad agreement that a likely mechanism for the impact of having access to electricity is that it reduces the time women spend collecting cooking fuel such as firewood and increases the productivity of household tasks through improved technology, thereby freeing up women's time, which they may use for income generating activities either within or outside the home. However, while most suggest that this accounts for women benefitting more than men, 2 studies [8,33] highlight that as household income increases, social norms may prevent women from performing jobs that are available. Redistribution of household chores may result in men dropping out of the workforce.

Key			
1. Aklin (2017) 2. Allcott (2016) 3. Arráiz (2015) 4. Bahaj (2019) 5. Bensch (2012) 6. Bhattacharyya (2017) 7. Chaplin (2017) 8. Chowdhury (2010) 9. Dasso (2015)	10. Dendup (2019) 11. Dinkelman (2011) 12. Ding (2018) 13. Fetter (2020) 14. Fetzer (2016) 15. Gonzalez-Eiras (2007) 16. Grimm (2017) 17. Grogan (2013) 18. Grogan (2015)	19. Izadi (2016) 20. Khandker (2013) 21. Khandker (2014) 22. Kumar (2018) 23. Lenz (2017) 24. Peters (2011) 25. Pueyo (2018) 26. Rains (2018) 27. Rao (2013)	28. Rathi (2018) 29. Rathi (2018) 30. Samad (2019) 31. Sievert (2015) 32. Squires (2015) 33. Van de Walle (2017)

Source: 3ie (2020).

5.9.2 Intervention design and implementation barriers and enablers

What does an effective electrification programme intervention look like? In the context of this review, the answer to that question will differ according to whether the focus is on encouraging new connections to the national electricity transmission network (grid electrification) or take-up of new renewable technologies that use energy from natural resources such as the sun (off-grid solutions). In any event, there will be critical intervention design and implementation features (or components) associated with effectiveness. Some will be key to success and others less important.

While the quantitative analysis accounted for differences in broad intervention categories, the set of programme design and implementation characteristics that make up the design space of electricity access interventions is complex. The thematic analysis sought to go beyond these categories to identify key design and implementation factors that were thought to influence programme effectiveness in some way. These factors cover the costs of connecting to an electricity source and ongoing consumer business models, partnerships, the quality and type of implementation, and the reliability of supply. The set of key themes are summarised in Table 22 and presented narratively in the following subsection.

Affordability - connection charges

Connection costs relate to the costs associated with preparing a dwelling for receiving electricity as well as the connection itself. These costs are paid prior to receiving electricity and were typically higher for centralised grid services, prototype services and services that relied heavily on imported goods. The presence of up-front connection costs set by providers can potentially limit the extent to which target populations connect to an electricity source, even in areas with high levels of existing electricity infrastructure.

If connection costs are a barrier, target beneficiaries either do not connect to an electricity source or connect informally (for example, by making a bribe, or connecting to a neighbour's existing connection). As a result, beneficiaries may consume less electricity, be limited to lower-tiered energy services, and/or face reliability issues. These factors are likely to have knock-on effects for achieving positive change in social outcomes. The ability to pay for up-front connection costs could also be affected by a range of beneficiary and implementer characteristics, as discussed below (for example, the use of credit instruments to spread connection costs over a longer time frame may connection costs more feasible for some in a target population).

Affordability - electricity business models/tariffs

Tariffs are often key to incentivising private investment in electricity infrastructure, especially for high-tier electricity access in rural or hard-to-reach areas. In most cases, tariffs include a services fee that was proportional to the energy services used, but some also included equipment rental and security and maintenance cover. Tariff systems can also be supported payment technology and credit or debt instruments.

Tariffs could act as a barrier to effectiveness because of repayment challenges and wider acceptability issues. If tariff barriers are deemed too high, target populations may only make use of a limited number of energy services (such as basic lighting), may default on payments, or may not fully substitute away from the use of traditional fuels. However, implementation of technology and focused credit instruments have the potential to facilitate timely repayment and decrease default rates – for example, through the use of pre-paid metering, or context-specific technologies like mobile payments.

Organisational partnerships

Interventions to improve access to electricity often involve more than one implementing organisation and seek to engage target populations for specific reasons. These types of partnership activities and agreements may have influenced the effectiveness of electrification programmes in some way, including:

- **Use of local networks for off-grid expansion:** The use of existing organisations and networks could support uptake of off-grid solutions, such as solar charging points or solar home systems. This could include the use of existing networks maintained by banks, local governments, other energy providers and schools were key in raising awareness and reaching potential customers and users. However, efforts to improve uptake may be constrained by the extent to which those whose networks are drawn on have the opportunity to be trained in the technical characteristics of the products they are supporting. Without full understanding of the underlying expected benefits of electricity access products, these networks may not be an effective distribution channel.
- **Gain access to new inputs:** The ability to draw on technical expertise and capabilities from other organisations, especially those with an international and/or development remit, could have an effect on the quality of implementation – for example these types of partnership could provide new access to higher quality materials and skills. However, challenges in maintaining new infrastructure implemented in part by international organisations may present a barrier to the long-term effectiveness of such investments, and differences in culture and ways of working, for example across private and public organisations may create delivery challenges, at least in the short term.
- **Community participation and engagement:** Engagement with target populations is expected to support the design and delivery of an intervention. Engagement could occur at different stages, from involving communities in the planning, construction and maintenance, and in the monitoring process. Engagement like this may affect stakeholder buy-in, create a sense of pride in electricity projects, or highlight user challenges and issues.
- **Management:** Unsurprisingly, adopting a clear programmatic approach to deliver projects, in line with standard project management and delivery practices, was highlighted in some studies as likely to influence programme effectiveness. This included the specification of roles and responsibilities, governance arrangements, milestones and timelines for delivery in advance with key stakeholders. In one study, effective government decision making was suggested to have increased uptake, specifically as a result of developing clear institutional project management arrangements relating to ownership between parties involved and cost sharing.

Intervention location

The more difficult to access and less economically dense a location is, the costlier installation of an electricity access solutions is, especially in the case of on-grid services (e.g. areas with considerable forests/jungles, mountains, islands, or with low population densities). These areas create affordability challenges as described above and may prevent socially optimal use of electricity services. This issue could become more challenging when intervention locations have limited infrastructure and institutions to draw on more generally outside of the energy sector – for example, road networks to transport construction materials.

Intervention logistics

The success of any infrastructure project is underpinned by sound logistical planning and preparation. Limited opportunities to effectively plan for implementation logistics or

account for unexpected changes in context may result in delays to deployment and full implementation of electrification programmes. Logistical challenges could be a result of a number of factors, including:

- Low demand for connections which initially delayed the finalisation of plans
- Mismanagement in communication between implementers and communities
- Challenging climate and terrain
- Supplier negotiations and shortage of supplies when they were needed
- Requirement to gain spatial permissions for infrastructure construction
- Delays in the tendering process for implementers

Implementer resources (quality and/or quantity of)

Challenges in obtaining the optimal quantity and quality of resources to support implementation and on-going delivery is likely to affect programme effectiveness. The thematic analysis identified the role of several such factors:

- **Post-implementation technical support:** Beneficiaries in some contexts are found to value access to technical staff to resolve issues, including technical faults, meter readings, maintenance, and billing. However, technical issues were not always addressed within the time frame suggested by implementers. In these cases, studies highlighted a range of possible issues, including limited technical capabilities of local staff, especially in rural, geographically constrained areas. Having local staff trained in routine maintenance and security in the case of higher tier systems, and access to technical support and reference materials in the case of small tiered systems, are also emphasised.
- **Contractor performance:** Contractual arrangements used to procure contractors to support implementation may not have been sufficient in optimising contractor performance, which may have effects of implementation costs, especially in countries with known corruption issues or weak institutions.
- **Local employment for community projects:** In the case of community-led programming, making local hires into the management and maintenance teams was suggested to have improved uptake and use of newly provided electricity. However, improving the local skills base may result in local staff changing roles, which reflects a wasted investment and a potential barrier to long-term sustainability of these types of projects.

Implementation monitoring

Implementation and use are assessed in part through programme monitoring (for example, of consumer usage, payments and technical performance). Without monitoring, it is expected that target populations cannot make socially optimal use of electricity for energy services when they need to. A thematic analysis of studies identified that improper monitoring could be a barrier to effectiveness for the following reasons:

- **Reliability issues:** Limited monitoring of electricity infrastructure was suggested to be a source of reliability issues, which are discussed in more detail below.
- **Limited tariff collection:** In some contexts, inadequate monitoring of tariff collection can lead to energy providers facing challenges in terms of collecting fees. This issue relates not only to willingness to pay (WTP), but also a provider's ability to bill domestic and business customers and collect payments.

Where uptake issues are a concern, monitoring of consumer commitments to make use of electricity access products may help facilitate increased uptake and use.

Reliability of supply

In line with the discussion presented in Section 2, the thematic analysis suggests restricted or poor supply of electricity negatively affects uptake and use, reducing the expected benefits of electrification as a result. Where reliability concerns were strongest, target populations are likely to respond by stockpiling traditional fuels such as kerosene, effectively treating electricity as a complementary good to their existing energy consumption, rather than as a substitute to it. Time allocation to household production may also increase, suggesting that the underlying tasks, such as fuel collection and household chores, become less productive as a result of reliability issues.

The thematic analysis identified several key factors that seemed to influence the reliability of electricity, which were thought to have had some effect on programme effectiveness:

- **Managing increased demand:** Induced demand as a result of new and or improved access may result in disruptions to service, with a common cause suggested to be a lack of sufficient back-up capacity. However, the use of fail-safe mechanisms, such as circuit-breakers, could ameliorate these types of concerns, especially in the case of high-tier energy sources.
- **Challenging geographies**: Areas with more challenging geographies were suggested to be associated with a higher level of reliability issues; in particular, transmission lines going through mountains, forests, elevated terrain or other adverse geographic features, as well as lines that rely on hydropower in areas affected by extreme weather events.
- **Urban focus:** In the event of reliability or scarcity issues, urban areas often receive preferential supply, which in turn creates critical access issues for rural areas.
- **Mishandling/improper use:** Lower-tiered systems that cater for low intensity energy services, such as phone charging and basic lighting, were often found to have reliability issues where products were not used or maintained correctly.
- **Residual technical issues:** Technical faults with equipment supplied or incorrect use, especially in the case of low-tier products, was a source of reliability issues, as this either constrained or prevented the use of products until issues were resolved.
- **Specification of universal standards:** The introduction of universal standards for electricity supply quality, monitored by independent authorities, may have a positive effect on the reliability of electricity supply as the required standard for different tiers are clearly articulated and checked.

Table 22: Intervention design and implementation barriers and enablers

Theme (no. studies coded with theme)	Countries	Evidence example	Correspondence between themes and study outcomes
Affordability - connection charges (23)	Bangladesh, Benin, Bhutan, Brazil, China, El Salvador, Ethiopia, India, Kenya, Nepal, Nicaragua, Rwanda, Tanzania, Vietnam	The program reached its limits in connecting areas closer to the grid and the average cost per connection increased, creating a challenge to take electricity to isolated areas far from the existing grid. In this context, less expensive technological alternatives should be considered when utilities pressure for high tariffs to compensate this situation. Capital costs to electrify most isolated communities can be twice as high than new grid connections. Observing the connections made by year, it can be noted that fewer new connections were made as time passed. Bezerra et al. (2017). p 4.	9 studies [8,9,13,14,17,35,41,42,46] found specific financial barriers to connecting to an energy source, including high upfront costs to prepare and connect dwellings, increased average costs per connection, which limited connections to electricity. There is evidence from 3 studies [8,13,41] that subsidising the costs of connecting to an electricity source in some way contributes to higher levels of connection to electricity sources. Other studies infer that schemes for free or discounted connections are likely to increase uptake.
Affordability - electricity business models/tariffs (14)	Bangladesh, Benin, Burkina Faso, El Salvador, Guatemala, Kenya, Nepal, Peru, Rwanda, Senegal, Uganda, Vietnam	After first Solar Home Systems (SHS) were marketed in mid-2009, Yeelen Ba, the local company supplying SHS, experienced slow and low uptake of their panels. One contributing factor relates to the business model of renting without the option to purchase, which is not appreciated by many. Some do not understand that they must pay a fee each month for something of which they will never acquire ownership. Even those who understand this novel concept would often prefer to buy their panel. Bensch et al. (2015). p 76.	4 studies [3,10,11,48] found that high tariffs and restrictive or unsustainable business models were associated with increased levels of payment defaulting and/or limited the use of electricity to subsistence requirements based on what would be required to perform basic functions such as lighting. This likely constrained the benefits of final socio-economic outcomes – for example, limited use of labour-saving electrical appliances which could have permitted a reallocation of time to paid work away from home production. Flexible business models and innovative methods and fee structures have been implemented to remedy this issue and were identified as a key enabler in 7 studies

Theme (no. studies coded with theme)	Countries	Evidence example	Correspondence between themes and study outcomes
			[4,6,19,20,28,31,37], leading to higher electricity use. Examples include spreading tariff plans over a longer time period using credit instruments and the option to use pay-as-you-go or mobile payment systems.
Organisational partnerships (27)	Argentina, Bangladesh, Bhutan, Brazil, China, India, Indonesia, Kenya, Myanmar, Peru, Rwanda, Senegal, Tanzania, Uganda, Vietnam	ACCIONA Microenergia Peru (AMP) seems to have achieved a balance between financial viability and a focus on low-income customers. Working in coordination with the Peruvian government and having obtained the first rural electric concession based exclusively on solar PV systems, AMP has reduced the likelihood of an unexpected power grid expansion that would eat into its customer base before it recoups its investment in equipment. This coordination reduced the risk to the fee-for-service model and gives it financial viability. Arráiz (2015). p 20.	Partnerships forged with actors in the supply chain were acknowledged in 5 studies [6,17,19,37,42] to be beneficial in planning interventions and may have improved uptake and use. A smaller number suggested this feature could be a major influence on final outcomes. This included involving beneficiaries in the planning, delivery and monitoring of interventions, but also local financiers and businesses with existing sales networks and strong access to potential electricity consumers. The delivery of new and improved access was often supported by several delivery partners. These included country governments in the case of large infrastructure projects, but also multilateral organisations with specific capabilities. These partnerships were acknowledged to facilitate implementation in 2 studies [6,17] through support with fund mobilisation, appropriate equipment and technology, and guidance on execution. Their influence was implicit in other studies.
Intervention location (26)	Argentina, Bangladesh, Bhutan, Brazil, Colombia, India, Indonesia, Iran, Kenya,	Impacts of electrification on poor households were markedly different in backward states that suffer from low levels of development and income, and inferior quality of infrastructure. Poor	It was frequently reported that geographical location and topography posed challenges to providing electrification and limited the extent to which companies will invest in ongoing maintenance repairs.

Theme (no. studies coded with theme)	Countries	Evidence example	Correspondence between themes and study outcomes
	Myanmar, Nicaragua, Peru, Rwanda, South Africa, Africa (aggregated data), Tanzania, Vietnam	households in backward states experienced limited welfare improvements from electrification, or lower increases in monthly expenditures than those in non-backward states, possibly reflecting the limited economic opportunities and facilities in such states. Bhattacharyya et al. (2017). p 27.	There is evidence from 4 studies [1,6,43,54] that utility companies prioritise urban centres and other areas of high population density due to their greater potential for business development, which has implications for energy services in rural areas which may be neglected or charged more for access.
Intervention logistics (3)	Kenya, Rwanda, Tanzania	Low demand may be partly attributable to the lengthy and bureaucratic process of obtaining an electricity connection. In the experiment of expanding electric grid infrastructure in rural Kenya, households waited 188 days on average after submitting their paperwork before they began receiving electricity. The delays were mainly caused by time lags in project design and contracting, as well as in the installation of meters. Lee et al. (2019). p. 24.	3 studies [17,28,41] reported challenges to implementation, including less-than-optimal stakeholder engagement during design, a lengthy applications process, supply shortages, and issues with procuring and managing contractors. These challenges create.
Implementer resources - quality and/or quantity of (10)	Bhutan, El Salvador, Ethiopia, India, Kenya, Nepal, Rwanda, Senegal, Tanzania	After one year of operation, one of the technicians in the mini-grid project had started his own business near the trading centre selling electrical goods and services. This highlights the difficulty in retaining staff who are trained as part of a mini-grid project and then use their new skills to obtain improved employment opportunities elsewhere. The project also trained three managers some of whom have moved on to other jobs in the sub-location. Bahaj et al. (2019). p 14.	10 studies [6,7,8,10,17,28,39,45,58,59] highlighted challenges related to financial, organisational or technical resources that intervention agencies had access to, and their influence on implementation or ongoing delivery. A smaller number suggested this feature could be a major influence on the success of electrification programmes [6,17,28,45].

Theme (no. studies coded with theme)	Countries	Evidence example	Correspondence between themes and study outcomes
Implementation monitoring (5)	Bangladesh, India, Kenya, Rwanda, Uganda	Monitoring visits among recipients of the Pico-PV systems each two months was conducted to ensure the proper functioning of the systems and remind users of their commitment not to sell the systems. In line with expectations, a few Pico-PV kits disappeared, but the number of non-compliant treatment households remained manageable. 87 percent of the kits were still in use in the treatment group at the time of the follow-up. Grimm et al. (2017).	2 of the 5 studies [41,50] contributing to this theme highlighted that the lack of robust monitoring and evaluation systems contributes to problems such as outages and theft, keeping electricity access levels low. There is evidence from 3 studies [19,28,37] that implementing periodic monitoring of the technical and management quality of installations and post-installation services can improve levels of consumption. This included monitoring visits to ensure proper functioning of off-grid technologies and ways of reducing theft (e.g. through applying contracts that households had to sign and declare not to sell or misuse the kit).
Reliability of supply (27)	Argentina, Bangladesh, Benin, Burkina Faso, China, Colombia, Ghana, India, Indonesia, Kenya, Myanmar, Nepal, Nigeria, Rwanda, Vietnam	Roughly 60 percent of schools that have installed other energy sources report having done so after they were connected to the electricity grid. The fact that grid electricity is not always reliable provides one potential rationale for why we find limited impacts of electrification on secondary schooling outcomes. Berkouwer et al. (2018). p 11.	A common barrier across studies was low reliability of power supply. Several studies reported that increased demand as a result of new or improved access resulted in service disruptions, with a common cause suggested to be insufficient back-up capacity. In the event of reliability or scarcity issues, urban areas might receive preferential supply, which in turn creates critical access issues for rural areas. Several studies [2,7,34,35,36,49,53,57] make the point that reliability issues can result in people stockpiling kerosene or alternative fuels, which has implications for outcomes such as household wealth and respiratory diseases; similarly, businesses may allocate capital resources towards back-up capacity, lowering profits. In cases where universal

Theme (no. studies coded with theme)	Countries	Evidence example	Correspondence between themes and study outcomes
			standards for electricity supply quality were established and monitored by independent authorities, study authors suggested this had a positive effect on the reliability of electricity supply. In 1 study [6], consumption management of a mini grid was achieved through two levels of circuit breakers installed in the consumer meter unit and the grid distribution pole away from the premises. This limited the use of high-demand appliances and electricity theft.

Key

1. Aklin (2017)
2. Akpandjar (2017)
3. Alcazar (2007)
4. Arráiz (2015)
5. Arvate (2018)
6. Bahaj (2019)
7. Banerjee (2011)
8. Barron (2017)
9. Bensch (2011)
10. Bensch (2012)
11. Bensch (2015)
12. Berkouwer (2018)
13. Bernard (2014)
14. Bezerra (2017)
15. Bhattacharyya (2017)
16. Chakravorty (2014)
17. Chaplin (2017)
18. Chauvet (2018)
19. Chen (2017)
20. Dang (2019)
21. Dendup (2019)
22. Ding (2018)
23. Fetter (2020)
24. Fetzer (2016)
25. Fujii (2018)
26. Gonzalez-Eiras (2007)
27. Grimm (2015)
28. Grimm (2017)
29. Grogan (2013)
30. Grogan (2015)
31. Grogan (2018)
32. Groth (2019)
33. Izadi (2016)
34. Karumba (2018)
35. Khandker (2012)
36. Khandker (2013)
37. Khandker (2014)
38. Kudo (2019)
39. Kumar (2018)
40. Kurata (2018)
41. Lee (2019)
42. Lenz (2017)
43. Litzow (2019)
44. Nigussie (2015)
45. Numminen (2018)
46. Peters (2011)
47. Poczter (2017)
48. Pueyo (2018)
49. Rao (2013)
50. Rains (2018)
51. Rathi (2018)
52. Rathi (2018)
53. Salmon (2016)
54. Samad (2017)
55. Samad (2019)
56. Sievert (2015)
57. Smith (2016)
58. Thomas (2018)
59. Urpelainen (2017)
60. van de Walle (2017)

Beneficiary-related barriers and enablers

Fixing supply-side problems is not enough to make electrification programmes popular among beneficiaries and close the gap from electrification uptake to continuous and sustained usage over time. Not all eligible households and non-household consumers take up available opportunities to connect to modern energy services, even when some or all of the costs are met through subsidisation. Even a well-designed and properly functioning electrification programme may not satisfy many beneficiaries since they might be constrained by a variety of individual and community level factors that do not allow them to fully benefit from it. There is evidence from 61 studies that beneficiary-related factors can also significantly affect the effectiveness of interventions. This group of barriers and enablers were organised within three broad themes.

Types of beneficiaries

Implementation and results may be influenced by the type of beneficiary taking up the intervention. Income constraints was one of the most frequently reported barriers that prevent adoption and sustained usage of grid or off-grid electricity services by households and businesses. In some contexts, wealthier households are likely to be better positioned to benefit from access to electricity, by virtue of their ability to purchase more electrical appliances or exploit new business opportunities opened up by access to modern energy sources. Since connecting to the grid often requires large up-front investments, seasonal variations in income (e.g. in the agricultural and fishing sectors) make it difficult for poor households and non-residential consumers to pay for larger expenses during certain months of the year.

Consumer knowledge, understanding and skills

These barriers and facilitators can relate both to the intervention (grid or off-grid) and the processes and mechanics that underpin it:

- **Lack of knowledge and misperceptions**: Potential customers (residential and non-residential) may underestimate or have limited knowledge of the benefits of electricity; the capabilities and limitations of different energy sources that are currently available; or the application or connection processes. Barriers to connection include awareness of the long wait to get connected; perceptions of unfairness; confusion around how to apply; and a lack of awareness in some communities of project timelines.
- **Understanding of costs**: Low connection rates have also been linked to low levels of understanding of initial costs, such as for wiring, versus usage costs. For example, beneficiaries might not understand the high associated costs of different appliances. Disappointment with the usage costs of electricity can lead to discontinued usage of appliances. Alternatively, there may be issues for the beneficiaries around complex billing or payment systems, where low levels of understanding may deter potential customers from signing up for an intervention in the first place.
- **Technical knowledge and skills**: In some contexts, low human capital may mean that some beneficiaries do not have the knowledge and skills to operate, maintain or repair decentralised energy systems (e.g. solar PV installations) or complex appliances or machinery, which impacts on key outcomes in some way. Inadequate technical capacities and knowledge to resolve problems on-site can influence uptake and usage. Providing these to users is thought to be an essential element of technology transfer. Awareness meetings with community members and intensive training by implementers in the operation of the equipment, preventive maintenance tasks, and procedures for participating in the programme, are highlighted as an important means of addressed human capital challenges.

Consumer attitudes, preferences and beliefs

The studies also contained a wealth of data regarding barriers and enablers related to consumer attitudes, preferences and beliefs about electrification and about change in general.

- **Attitudes**: Attitudes are likely to constitute an important barrier to obtaining the desired outcomes for electrification programmes. In some contexts, there may be maximum values that consumers are willing to pay. They may perceive electricity as a luxury good rather than a productive investment and use energy services sparingly (e.g. for lighting but not for charging phones or powering radios). Dissatisfaction with the connection process may result in discontinued use. Attitudes toward adoption of technological innovation may also play a role.
- **Social influence and imitation**: Connection to electricity carries a social status so that peer influence can also change consumer attitudes and behaviour. In some contexts, the individual decision to connect is strongly influenced by neighbours living in close proximity. Customers change their energy purchases and consumption based on that of their neighbours or community members. Learning from opinion leaders and wider social networks about the attributes of new technology may also be important in household decisions to adopt.
- **Preferences:** Beneficiaries might reject or discontinue use of more efficient household energy technologies due to a preference for traditional cooking, rather than electric cooking which is rarely adopted, or because they like to be in control of fuel supply, if there are many outages. In some contexts, electricity from a reliable grid is preferable in terms of service (it is traditionally perceived as superior). Expectations of the main grid's imminent arrival in their area can lead consumers to be wary of investing in off-grid alternatives.
- **Beliefs**: In some contexts, the levels of trust in governments and government agencies were much higher than levels of trust in local companies. Negative perceptions towards the involvement of the private sector may hinder acceptance and uptake of initiatives led by private companies looking to invest in electrification.

Table 23: Beneficiary-related barriers and enablers

Theme (no. studies coded with theme)	Countries	Evidence example	Correspondence between themes and study outcomes
Beneficiary knowledge, understanding and skills (9)	Bangladesh, Benin, Burkina Faso, India, Peru, Rwanda, Tanzania, Uganda	One explanation for why those that connect to the grid have on average lower profits than comparable firms in the non-access region may be a lack of familiarity with electricity-using production technologies, and an associated inability to assess the level of output needed to make profits using these technologies. Even when this level is known, the manufacturer may overestimate the product's market potential	Two of the 10 studies [25,37] contributing to this theme studied the impacts of electrification on economic outcomes. Both suggested that the negative findings observed for firm profits were influenced by deficiencies in human capital.

Theme (no. studies coded with theme)	Countries	Evidence example	Correspondence between themes and study outcomes
		in relation to the total cost curve. Peters et al. (2011). p 781.	
Beneficiary attitudes, preferences and beliefs (29)	Bangladesh, Bhutan, Burkina Faso, Colombia, El Salvador, Ethiopia, Ghana, India, Indonesia, Kenya, Laos, Myanmar, Nepal, Nicaragua, Nigeria, Peru, Rwanda, Senegal, Tanzania, Uganda	Community leaders described situations in which jealous neighbours created obstacles to others connecting to the grid; for example, some household owners who could not afford electricity would not allow lines to pass by their homes and property to connect adjacent households. Chaplin et al. (2017). p. 30.	There is evidence from 3 studies [11,14,18] that an individual's decision to connect is strongly influenced by electrified neighbours living in proximity. A further 4 studies [24,27,41,45] found there are spill-over effects from which unelectrified neighbours can benefit (e.g. television, better lighting, or mobile charging can be easily shared). In 1 study [45] the external effect appears to come with a shift in consumption behaviour, whereby households without electricity themselves shift their spending toward other goods, possibly associated with an attempt to maintain status.
Type of beneficiary (27)	Bangladesh, Benin, Bhutan, Brazil, Burkina Faso, Cambodia, El Salvador, Ghana, India, Indonesia, Kenya, Nepal, Nigeria, Peru, Rwanda, Tanzania	Electrification efforts made by the Luz para Todos (LpT) programme seem to have achieved more success in municipalities that had a low electricity access rate but a relatively high Human Development Index, implying that the drive to bring electricity to the countryside brought the most benefits to municipalities that were already doing relatively well in other development-relevant measures. Municipalities that previously had both low electrification rates and a low level of socio-economic development appear to have fallen further behind. Bezerra et al. (2017). p 9.	There is evidence from 11 studies [1,3, 4,5,11,13,18,30,34,39,41] that household income level and purchasing power have an influence on the uptake of electrification projects. Connecting to the grid often requires a large upfront investment (e.g. for building materials or off-grid technologies) and ongoing costs. Wealthier households tend to be closer to transmission lines, which could also be a reason why less well-off households are less likely to be connected. Other obstacles include low-quality housing and buildings which tend to have low roofs that cannot support the hooks and brackets needed to connect wires [18]. One study [11] found that having an existing informal grid connection increased the likelihood of households connecting.

Theme (no. studies coded with theme)	Countries	Evidence example	Correspondence between themes and study outcomes
Key			
1. Adusah-Poku (2019) 2. Aevarsdottir (2017) 3. Aguirre (2017) 4. Aklin (2017) 5. Akpandjar (2017) 6. Akpandjar (2018) 7. Allcott (2016) 8. Arráiz (2015) 9. Bahaj (2019) 10. Banerjee (2011) 11. Barron (2017) 12. Bensch (2011)		13. Bensch (2015) 14. Bernard (2014) 15. Bezerra (2017) 16. Bridge (2016) 17. Burlando (2014) 18. Chaplin (2017) 19. Chauvet (2018) 20. Chen (2017) 21. Chowdhury (2010) 22. Dendup (2019) 23. Fetzer (2016) 24. Fujii (2020	25. Grimm (2013) 26. Grimm (2015) 27. Grimm (2017) 28. Grogan (2013) 29. Groth (2019) 30. Khandker (2014) 31. Koima (2019) 32. Koirala (2019) 33. Kumar (2018) 34. Lenz (2017) 35. Nigussie (2015) 36. Numminen (2018)	37. Peters (2011) 38. Pueyo (2018) 39. Saing (2018) 40. Salmon (2016) 41. Samad (2017) 42. Samad (2018) 43. Samad (2019) 44. Urpelainen (2017) 45. van de Walle (2017)

5.10 Synthesis of cost evidence (SRQ4)

This review sought to assess the unit cost, cost-efficiency, cost-effectiveness or benefit-cost evidence on electricity access interventions. Of the 89 studies included in the review, 24 presented some form of cost information. The units and approaches used to present this information, and the incompleteness of the information presented, made it challenging to address SRQ4 as part of this review. In particular, studies that did report this information, often only reported the overall cost of a programme and did not disaggregate costs by line items or over time. To some extent, this is indicative of a broader issue of limited use of cost evidence in impact evaluations of development interventions. Brown and Tanner (2019), for instance, estimated that fewer than one in five impact evaluations incorporates analysis using cost data.[28]

[28] Available at: http://documents.worldbank.org/curated/en/862091571145787913/Integrating-Value-for-Money-and-Impact-Evaluations-Issues-Institutions-and-Opportunities. Date accessed: 14/05/2020.

6. Discussion

This section discusses the key results in this report, covering key responses to the review research questions, agreement or disagreement with previous synthesis activities, and set of the authors' own preliminary conclusions for practice and research are presented. It concludes with a set of limitations of the review.

6.1 Summary of findings

This subsection provides a summary discussion of the review results, drawing on the descriptive analysis of included studies, meta-analysis, and thematic analysis.

6.1.1 Understanding the evidence base

A descriptive analysis of the studies included in the review provides the following results:

- **Studies address a variety of outcomes, with different – and often implicit – causal pathways:** The literature is unsurprisingly varied in terms of the outcomes evaluated and underlying theories of change. For instance, investigating how access to a solar panel with the capacity to power a light and charge a mobile phone affects child study time is very different from investigating the organisation-level effects of a grid connection enabling a business or health facility to power refrigeration or temperature control systems or power other appliances, machines, and equipment. These variations, combined with limited theoretical narrative, add considerable complexity to this type of synthesis and underscore the importance of careful consideration of how to approach any meta-analysis (see Section 7.2 for further details).
- **Research spans much of the globe but is disproportionately conducted in a few countries:** Though the studies were conducted in over thirty-five countries across five World Bank geographic regions, a majority were in either South Asia or sub-Saharan Africa (esp. East and West Africa), with the highest concentration of studies in India (17), Bangladesh (8), Kenya (6), Ghana (5), and Tanzania (4). Substantial portions of the globe are not represented at all in the research, including most of the Middle East; much of northern, central, and southern Africa; and the South Pacific.
- **Most study designs are quasi-experimental:** Quasi-experimental designs dominate the literature of rigorous evidence on electrification, representing 82 of the 89 included studies. This is likely driven by the large share of studies evaluating large scale electrification programmes. These studies employ matching, panel, and instrumental variable methods fairly evenly but only two studies employ a regression discontinuity design.
- **Risk of bias concerns**: Just over half (52 percent) of the studies received a rating of "medium to high" or "high" risk of bias in at least one critical appraisal category. These risks were largely driven by common threats to quasi-experimental study designs, which represented the majority of the included studies (82 out of 89). Many studies, both quasi-experimental and experimental, faced some risk of spill-overs, given the difficulty of neatly differentiating between those with and without access to electrification interventions (e.g., due to demonstration effects, the potential for sharing electricity, and so forth), though many authors acknowledged and sought to address this.

- **Emerging literature on additional changes to a wider set of social outcomes:** More recent literature expands the evidence base for some previously understudied outcomes – such as respiratory illness, air pollution, and fertility – as well as for some new ones, such as malaria incidence, health systems and service delivery outcomes, and other health-related measures. This suggests the literature has increased its focus on a broader set of indicators that are not as focused human-capital or income-centric measures of well-being.
- **Many interventions evaluated focused on levels of electricity availability, often rural grid connections:** The most commonly evaluated intervention was changes in access to electricity, typically through on-grid access, although some did consider changes to electricity quality or reliability. Of all the types of electrification interventions studied in the included papers, a majority focused on connections to the grid in rural or peri-urban areas. Few studies assessed interventions to stimulate demand for electricity access.
- **There is a stark lack of evidence on causal mechanisms or cost:** Though the search strategy targeted all linked implementation or program reports, process evaluations, qualitative studies, and cost information associated with each of the included impact evaluations, the yield was thin, with only 12 studies providing additional qualitative or process evidence. This poses a particular challenge for this field given the considerable heterogeneity across multiple dimensions of electrification interventions (e.g., intervention type, system capacity, quality, reliability, outcomes and beneficiary type). These evidence gaps are consistent with the above observation that a large proportion of the studies were quasi-experimental designs retrospectively inferring effects of electrification based on reported levels of electricity access in existing survey data.

6.1.2 Impact of electricity access interventions (SRQ1)

We found that electricity access interventions produce positive effects for treatment groups relative to the control groups on average across all outcome domains, as summarised in Table 24. These effects are significant but small, and draw on effect size data from a range of different contexts. The intermediate outcomes domain was estimated to have the most pronounced pooled effect. This result makes sense, given changes to access and use of electricity for energy services reflect the first key step in the theory of change. However, this effect is still small, and this result may partly explain small effects in social outcomes further along the causal chain.

Table 24: Summary overview of the synthesis of results by outcome domain

Outcome domain	Estimate (SMD)	95%CI [low, high]	I^2	No. studies in analysis
Intermediate outcomes	0.17***	[0.08, 0.26]	99	35
Education	0.05***	[0.03, 0.07]	75	37
Socioeconomic welfare	0.04***	[0.03, 0.06]	91	59
Health	0.11*	[-0.01, 0.22]	99	33
Environment	0.07**	[0.01, 0.14]	96	33

Source: 3ie (2020). N.B. Significance codes: p-value< 0 '***' 0.001, '**' 0.01, '*' 0.05, '.' 0.1, ' ' 1, i.e. the higher the number of stars, the higher the significance of the result.

6.1.3 Assessing heterogeneity in effects (SRQ 2 and 3)

Estimates for all domains were potentially associated with considerable levels of heterogeneity, as determined by the high I^2 values, which supports the need to interrogate potential factors that influence programme effectiveness. Accounting for differences in outcome, intervention and study design characteristics provide a more nuanced understanding of the heterogeneity present.

Differences by outcome group

We estimated that electricity access interventions had a positive additional effect on study time and a negative effect on time allocated to non-paid work, which featured in the education and socio-economic welfare domains, respectively. In the case of study time, subgroup analyses presented in Appendix F highlight this is especially true for evening and night-time study. Elsewhere, we found that that controlling for the outcome measured did not result in any other significant effects on pooled effect sizes.

Differences by intervention type

We find evidence that different combinations of interventions appear to be more effective in improving outcomes across different domains. In particular, the combination of system management policy and financial support interventions resulted in additional improvements to intermediate and educational outcomes, and the combination of access and system management policy components resulted in additional improvements to socio-economic outcomes. We also found a weakly significant effect on health outcomes from interventions with an affordability component.

The analysis also produced some negative results relating to the type of intervention. Educational and environmental outcomes are negatively affected by interventions focusing only on expanding access relatively to other intervention types, which could suggest that residual issues relating to reliability and affordability are experienced. And socio-economic welfare outcomes are negatively affected by interventions that include legal and regulatory reform components. Again, these results are relative to other intervention types.

The exploratory intervention-level results presented here broadly align with a subset of those reported at the outcome domain level: that achieving intermediate and educational outcomes are somewhat dependent on the combination of reliability and affordability components; environmental outcomes are negatively affected by on-grid expansion projects; and the type of intervention does not seem to influence the health outcomes evaluated. Achieving the same results across multiple methods in this way provides additional confidence in these findings.

That said, the results from the intervention and outcome domain analyses do not always triangulate. Specifically, we find electricity expansion interventions had no effect on educational outcomes at the intervention-level but negative effects in the outcome-level analysis and no effect on legal and regulatory effects here but a weak negative effect in the outcomes level analysis. Finally, we find a positive effect on socioeconomic outcomes as a result of the combination of expansion and reliability components but no effect in the intervention analysis present here. Where we were not able to triangulate findings in these cases, we encourage caution when interpreting the findings.

Differences by study characteristics

With respect to study design, we found that the study-related factors had no effect on intermediate, socio-economic welfare, or environmental outcomes. However, several key findings did emerge:

- **Gender and sex:** We find that the effect on educational outcomes is more pronounced in children, which is expected, given the focus of the majority of studies that evaluate education outcomes is children. There is no significant difference in effect by sex for educational outcomes, though socio-economic outcomes are marginally more pronounced for women than men.
- **Risk of bias**: In the education and health outcome domains, studies with high risk of bias were shown to result in a decrease in the effect size.
- **Baseline electricity access:** In the case of the education domain, the effect size was shown to have a small negative relationship with baseline electricity access. This highlights that marginal gains to education are more pronounced when interventions are delivered in areas with limited access originally. However, the opposite is true for health outcomes, with a unit increase in baseline access resulting in a small improvement in health outcomes. This could mean that in the context of health, a minimum level of access is required prior to realising benefits, or that when a critical level of access is achieved, marginal gain to outcomes increase for any additional changes to electricity access.
- **Region:** In terms of region, we found that education and health outcomes were negatively affected, relative to other regions, if the study was located in Latin America or the Middle East and North Africa, with South Asia also negatively affecting outcomes in the health domain.

6.1.4 Thematic analysis of barriers and facilitating factors

Even after controlling for the stated factors relating to outcome, intervention and study design, all models, except for the education domain, were still suggested to be associated with high levels of heterogeneity. This signals that there are likely to be other factors that influence effect size variance beyond those that were captured by the analysis. In an attempt to address this, we sought to synthesis the available qualitative evidence associated with included evaluations and found the following key results:

- **Qualitative and process evidence is limited:** A small proportion of included studies already included process and/or qualitative evidence. A detailed targeted search for relevant documents and contacting authors yielded 12 additional documents – far fewer than we had anticipated. As such, we also coded experience-based or speculative evidence provided as commentary by study authors.
- **There are three key groups of conditions and may influence effectiveness:** An iterative coding process resulted in the identifications of three key groups of factors that were suggested to have influenced intervention effectiveness: structural and cultural factors; intervention design and implementation factors; and beneficiary-related conditions.
- **Structural and cultural factors:** Authors of 33 studies highlight or reported on the importance of pre-existing structural and cultural conditions in achieving improvement to social outcomes. Areas with limited political and economic unrest that are economically dense with base levels of infrastructure and access to established institutions are likely to be associated with larger changes in social

outcomes than areas with these pre-existing conditions. Authors also suggest that public subsidies for substitute and complementary products will negatively and positively affect demand for electricity, respectively.

- **Intervention design and implementation factors:** Analysis of design and implementation characteristics across 60 studies highlighted several key barriers to programme effectiveness. Commercial connection fees and tariffs could not always be reconciled with the willingness and ability of target populations to pay for electricity services. These cost issues were made more acute given electrification priority areas were often in rural or complex geographies, which had knock-on effects for implementation delivery timescales and on-going reliability. However, authors identified the involvement of existing local networks to support delivery, the use of context-specific credit and payment tools, timely access to skills and expertise, and regular technical monitoring completed in conjunction with communities were key enablers of effectiveness.
- **Beneficiary-related conditions**: In total, 45 studies discussed factors related to the characteristics of the beneficiaries, specifically consumer knowledge; understanding and skills; attitudes, preferences, and beliefs; and beneficiary characteristics. Authors suggested that consumer demand for electricity was negatively affected when knowledge of potential benefits, costs, and operational procedures was limited and implementation suffered from delays. However, a subset of authors suggested that training community members in basic monitoring and maintenance may have enabled sustained use.

Assessing the causal chain

To provide some understanding of where along the causal chain these factors are most pertinent, we can broadly group the factors discussed into those that affect uptake and use and those that affect final outcomes:

- **Authors predominantly report on barriers affecting uptake and use:** The majority of studies commented on key barriers and facilitators with respect to the determinants of uptake and use of electricity – a key intermediate step in the causal chain - rather than causal links relating to social outcomes of interest. This focus could reflect the challenges in increasing uptake and use, as shown in the results above. In particular, our analysis showed that challenging baseline local political and economic conditions, limited baseline infrastructure, affordability constraints, competing government incentives, and limited consumer awareness were potentially key barriers in this regard.
- **Design characteristics can mitigate some of these uptake and use challenges:** Several design characteristics were highlighted that could enable improvements to uptake and use. These included the ability to draw on international technical expertise, existing sales and distributions networks to reach target populations, locally used credit instruments, and payment technologies.
- **Residual barriers were identified during and post-implementation:** Despite efforts to account for context-specific implementation challenges, several barriers were identified once an intervention moved to being implemented. First, bureaucratic, logistical or contractor performance issues resulted in significant time delays to implementation, especially for on-grid projects. Second, on-going reliability issues made sustained use of energy services when they were needed challenging. These reliability issues were made more acute by insufficient levels

of technical monitoring and on-going service support and insufficient protocols in place to manage increased levels of demand for energy services in the case of grid-based interventions. Finally, in areas that are less economically dense it may be unreasonable to expect significant changes in social outcomes given the likely limited levels of economic opportunities. Rural and geographically challenging areas were suggested to suffer more from these types of issues.

- **These results have potential implications for how the theory of change operate:** These insights provide more nuance to the theory of change we presented for electricity access interventions in Section 2. Interventions ultimately seek to introduce new and/or improved electricity infrastructure to a setting. Without sufficiently considering the determinants of uptake and sustained use of energy services, it is likely that connections and access to new and/or improved electricity sources are not socially optimal. Either people do not seek out access or they do but only consumer electricity for basic energy services for small amounts of time. Non-existent or limited consumption of electricity for energy services is likely to limit any changes to intermediate outcomes relating to time allocation and appliance ownership and use, which will constrain the realisation of expected social outcomes across all domains.

The results of the thematic analysis indicate that understanding and assessing the context-specific determinants of uptake and use of electricity infrastructure is key for yielding positive changes in social outcomes. The findings highlight the need for consideration of a range of factors, at multiple stages in the policy cycle, from the specification of business and planning proposals through to the monitoring and evaluation of interventions.

However, while these factors are discussed in articles, the prevalence of discussion associated with each factor may not directly correlate with the relative importance of the issue in a given context. There may be opportunities to further integrate the results of the thematic analysis and meta-analysis in order to provide an understanding of the magnitude of influence some of these factors had on effect sizes calculated.

6.2 Implications for policy, practice, and research

Based on the emerging results present in this review, the review team has developed as set of implications for policy and practice and research in the sector:

6.2.1 Policy and practice

- **Small changes to outcomes:** Electricity access interventions included in the review produce positive and small effects for outcomes relating to education, socio-economic, and environmental outcomes. These effects are also realised across a range of different contexts and settings and persisted after accounting for a variety of study factors, including design, such as length of follow up, the type of outcome evaluated, or other factors. Consequently, policymakers and practitioners from a variety of contexts may consider the results to represent a plausible range in the magnitude of the potential impact of electrification interventions on these outcomes.

- **Small improvements in electricity access and quality may be a limiting factor**: Though only a subset of studies assessed intermediate outcomes (e.g., electricity connectivity, reliability, lighting use, etc.), the generally small increases in these measures may partly explain the more modest effects in the final outcomes. Further exploration of the reasons for limited improvements in this step of the causal pathway may yield valuable insights for improving the design and implementation of electrification interventions.
- **Improved results in interventions targeting multiple constraints:** There is evidence to suggest that interventions targeting multiple constraints (e.g., electricity infrastructure and reliability, or reliability and affordability) yield better results than interventions only targeting one of these constraints. Similarly, interventions focusing exclusively on expanding physical access to electricity (on-grid or off-grid) may produce relatively smaller benefits than interventions targeting reliability, affordability, or a combination of the two, as was observed within the education domain.
- **Consider mechanisms of impact:** Given the multiple potential interventions to improve socioeconomic and educational outcomes, policymakers and practitioners will naturally compare the costs and expected benefits of different options. Though the available evidence did not permit analysis of cost effectiveness, the small effect sizes presented here imply that very expensive interventions (e.g., large-scale expansion of the electrical grid) may not seem like a favourable investment if the objective is to increase household income or educational attainment. Though future research may identify other types of social outcomes with higher returns to electrification, in the short term it may be useful for policymakers and practitioners to consider not only the direct social effects of electricity access, but also the instrumental role electricity may play in multi-component interventions.
- **Fund rigorous research to fill evidence gaps, with information requirements:** The combination of the small number of impact evaluations, wide variation in types of electrification interventions, and limited detail on intervention specifics, causal mechanisms, and costs leaves a substantial gap in the evidence base. Funding for additional research on this topic – including process evaluations and qualitative research accompanying impact evaluations of specific electrification interventions – can help fill this gap, especially if the funding comes with specific requirements for researchers to provide sufficiently completed and detailed information on each of the above points.

6.2.2 Research

- **Expand the evidence to fill key gaps:** The review highlighted two priority evidence gaps that could be usefully targeted. This include:
    - **Demand-side interventions:** Studies that seek to understand the effect of demand-side interventions and the combinations of demand- and supply-side interventions. Of the studies that addressed demand, the majority focused on reducing cost barriers by testing voucher or subsidy interventions; reliability, consumer preferences, social acceptance, regulatory constraints, and other factors affecting demand were not addressed.

    - **Theory-based mixed-method evaluations:** Just under 15 percent of studies included a qualitative component. Mixed-method studies provide an insight into the magnitude of effects but also why and how they arise, and in what contexts. The specification of studies in this way will provide practitioners with more nuanced insights that can support the formation of new policy and interventions (White 2009).
- **Describe interventions characteristics and context in detail**: Describing the intervention as clearly and comprehensively as possible is particularly important for retrospective studies using existing datasets, which tended to have much less detail about the intervention and context, thus making it difficult for readers to interpret how those factors may have influenced implementation and/or outcomes (Hoffman 2017; Booth 2019). Several efforts already exist to support transparent and comprehensive reporting of impact evaluation results, including CONSORT trial reporting checklist and 3ie impact evaluation reporting guidelines.[29]
- **Refer to relevant energy access frameworks:** Building on the previous point about describing characteristics, future studies could be strengthened by characterising interventions according to relevant energy access frameworks. The multi-tier framework proposed by the Energy Sector Management Assistance Program (ESMAP), for instance, categorises types of household electricity supply into one of five tiers for each of several attributes. A system with a power capacity of 3-49 watts or 12-199 watt-hours – enough for task lighting and phone charging – is in Tier 1, while a system with a capacity of 2+ kilowatts or 8.2+ kilowatt-hours – enough for general household lighting and multiple appliances, including very high-power appliances – is Tier 5. Though some of the attributes in this framework will be difficult to characterise precisely, even the attempt may generate valuable detail beyond the level currently included in many papers.
- **Plan for and account for spill-overs**: Given the inherent challenge of neatly separating the "treated" population from the comparison group in electrification interventions, it is important to at least identify and anticipate the most likely types of spill-over and account for it in the analysis. If feasible, process evaluations and qualitative work may be useful to help characterise the phenomena. As was done in some of the included studies, researchers may consider accounting for geographic locations of (and proximity to) electrified households, firms, or communities, whether to inform sample selection, address spill-over in the analysis, or some combination. Though perhaps most obvious for studies collecting new data, spatial analysis within existing household survey datasets is becoming increasingly feasible through the use of geographic displacement or masking.
- **Emphasise theories of change as a driver of study design and analysis**: Given the substantial heterogeneity of electricity access interventions, outcomes, and potential causal pathways – which sometimes conflict with each other (e.g., electricity as an enabler of establishing or expanding home-based income-generation vs. power source for TV entertainment vs. other uses) – there is a

[29] CONSORT trial reporting checklist is available here: http://www.consort-statement.org/. Date accessed: 15/05/2020. 3ie reporting guidance for 3ie funded impact evaluations is available here: https://www.3ieimpact.org/sites/default/files/2019-01/final-report-guide_0.pdf. Date accessed: 15/05/2020.

need for clearly articulated theories of change. This would help: identify key outcomes of interest; highlight the need to consider timescales to impact; equity considerations for different subgroups (women in particular); enhance consideration and analysis of rival explanations for results; and, improve readers' ability to meaningfully interpret study findings. While this is a general best practice for impact evaluations, it is particularly relevant to the current body of evidence on electrification.

- **Consider measuring outcomes relating to quality of life and social experience:** Though educational and economic outcomes of electrification have been the most studied, the evidence base continues to point toward modest effects in these areas. Though additional research carefully accounting for intervention details and theories of change may yield clearer findings on differential effect sizes depending on beneficiary groups, intervention types, and various contextual factors, it seems unlikely that the magnitude of the effect sizes for these outcomes will increase dramatically. At the same time, it is important to consider that these are not the only – and may not even be the most important – effects of electrification. A few studies have measured other plausible outcomes, such as quality of life, but both the theoretical and empirical work in this area is limited.

6.3 Strengths and Limitations

The review is associated with the following strengths and limitations which may have affected the robustness of the results produced to some extent:

Strengths

- **Current:** At the time of reporting, this review provides the most up-to-date systematic review of the available evidence relating to electricity access impact evaluations, complemented with process evaluations and qualitative studies where it is possible to do so.
- **Timely:** A key criticism of the systematic review approach is that they provide evidence to policy makers in an untimely fashion, meaning policy makers are not able to make decisions on the best available evidence. This review was commissioned in response to a directly policy need, and the review protocol was developed and implemented in a six-month period, drawing in the latest advances in process management for systematic reviews.
- **Broad:** The scope of the review is broad, and outcome information was collected across all intermediate and final outcomes reported in studies. This provides are more nuanced overview of the theories of change that underpin electricity access interventions.

Limitations

- **Data gaps:** In some cases, study reports do not always provide information required to run analysis as part of the review. These could include quantitative data used to calculate standardised effect sizes, but also descriptive information to enable a more nuanced assessment of heterogeneity. While authors were contacted in these cases, it was not possible to fill all data gaps in time made available.

- **Limited availability of complementary evidence:** Only 12 additional documents associated with impact evaluations included in the review reported additional research that sought to understand other important aspects relating to effectiveness, including acceptability, implementation and the role and influence of other contextual factors. While authors were contacted, a common response was that there were no relevant studies available; in some cases, the review team did not receive a reply. Without this evidence, it is challenging to define generalisable conclusions about the relative importance of these underlying factors in determining effectiveness of electricity access interventions.
- **Representativeness:** Because of the diversity and heterogeneity of included studies, even within outcome domains, the findings should not be interpreted as predicted effect sizes for any specific type of electrification intervention.
- **Unit of analysis:** While we reviewed included studies for unit of analysis errors, due to time and data constraints, we did not correct standard errors before including study effect sizes in the meta-analyses.

7. Information about the review

7.1 Acknowledgements

We would like to thank all members of the review's stakeholder advisory group who provided timely, relevant and invaluable guidance and insight at key points throughout the review process.

- Chen Chen, Monitoring and Evaluation Associate, World Resources Institute
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7.2 Contribution of authors

Authors of the review contributed to its development in the following ways:

- **Review design:** The review protocol was designed and drafted by Douglas Glandon (DG) and Nick Moore (NM) with support from Birte Snilstveit (BS). The team was supported by an advisory group of academics and policy makers with specific expertise in electricity access.
- **Information retrieval:** The electronic search terms and platform search protocols were developed by John Eyers with the support of DG, NM and BS. NM managed a team of research assistants (RAs) to undertake the screening of titles and abstracts and online sources. Daniela Anda (DA) DG, Tomasz Kozakiewicz (TK), NM and Rami Zelfo (RZ) screened studies at full text.
- **Data collection:** RAs collected descriptive, quantitative and qualitative data from included studies; a process managed by TK, NM and Janice Tripney (JT). DA, DG, TK, NM, Shannon Shisler (SS) and RZ and one RA completed risk of bias assessments.
- **Analysis:** DG and NM conducted the meta-analysis and BS and SS provided guidance. JT led on the framework synthesis. All authors contributed to the development of conclusions and implications.
- **Reporting and revisions:** NM, DG and JT led on report drafting and revisions with support from TK and BS.

7.3 Declarations of interest

None of the 3ie team members have any conflict of interest, financial or otherwise, that may have influenced judgements made as part of this review.

7.4 Differences between protocol and review

We made two key changes to the methods outlined in the protocol:

- **Refinement of eligibility criteria:** The screening process identified several areas where our eligibility criteria were not sufficiently explicit with respect to the type of intervention of interest, for example, studies that evaluated energy efficiency interventions. In these cases, we discussed as a team how relevant studies should be considered and updated the protocol with more explicit guidance.
- **Updated outcomes framework:** We intended to use the framework specified in Mathur et al. (2015) to map outcomes. However, we adopted an iterative outcomes-data driven approach instead to develop overall domain and outcome groupings instead. This approach produced a framework that was more aligned to the data that was made available as part of this review.

7.5 Sources of support

This review is funded by the Asian Development Bank (funding contract number: TA9636).

Online appendix

https://www.3ieimpact.org/sites/default/files/2020-11/SR45-ADB-electricity-interventions-Online-appendix.pdf

References

This section presents the list of references used to compile the systematic review. The reference list is divided into the following four categories:

- **Included reports:** The main reports included in the review that are used to represent related groups of linked reports.
- **Linked reports:** Systematic reviews have studies, rather than reports, as the unit of interest, and so multiple reports of the same study need to be identified and linked together before data extraction. These other reports (the ones not marked as the main report) are usually termed linked reports.
- **Additional linked reports:** Additional documents sourced through a targeted search to support the review team answer SRQ3.
- **Other synthesis outputs:** Previously published synthesis products on or related to, the area of electrification in Low- and Middle-income countries.
- **Additional references:** Studies or reference materials that were used to develop the background or underlying systematic review protocol.

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