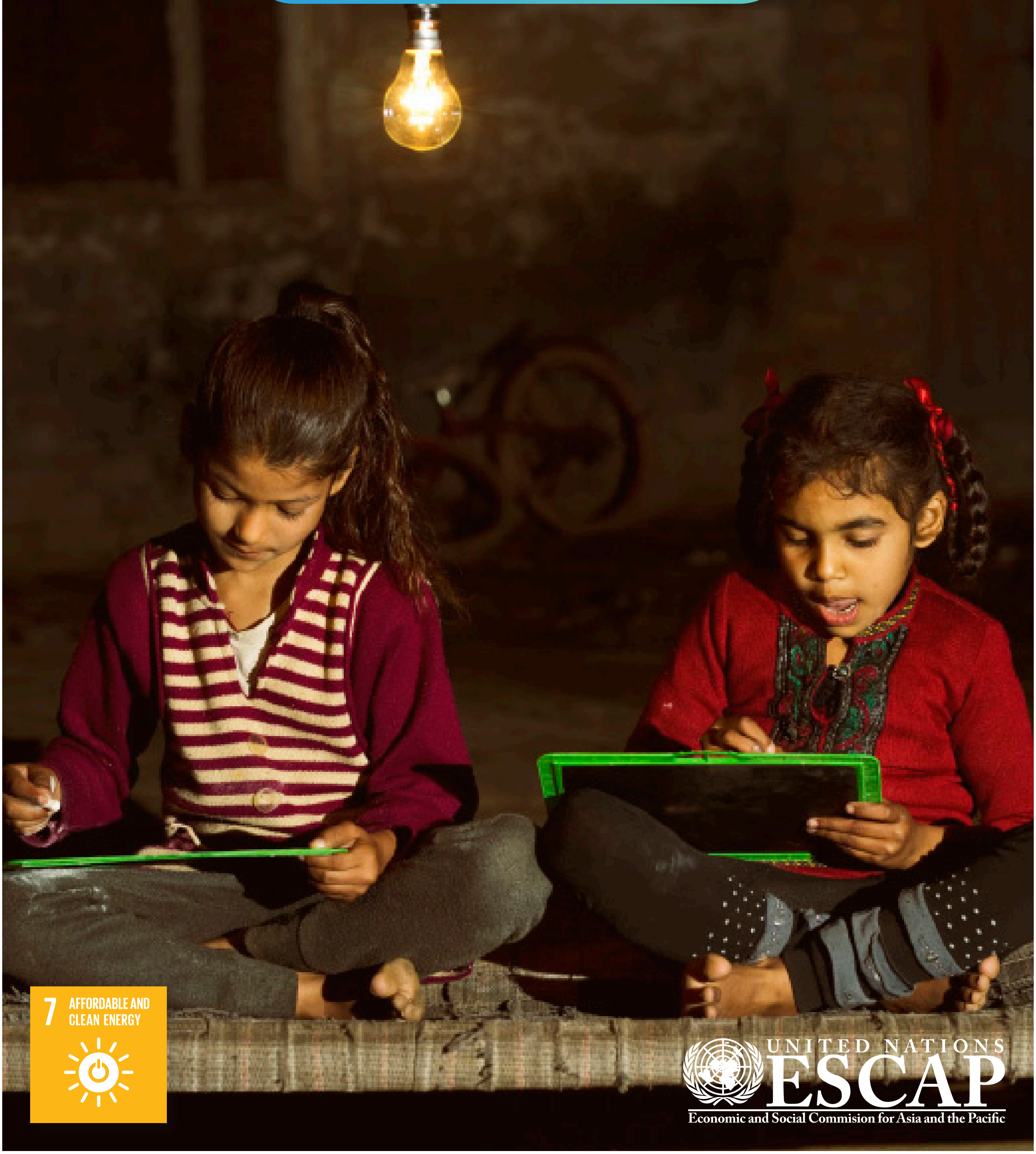
Systematic Review of

the Socio-economic Impacts of Rural Electrification



7 AFFORDABLE AND CLEAN ENERGY

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- Hannah Girardeau, Energy Specialist, Women at the Forefront,
- Luc Severi, Programme Manager, Powering Healthcare and Senior Specialist, Universal Integrated Energy Planning
- Alice Uwamaliya, Energy Analyst, Policy and Regulatory Frameworks

Authors' contributions

The authors of this review include Lana Zaman, Faran Rana, Olivia Baldy and Maria Pia Daniela Locco Barias. Lana Zaman. served as team leader and developed the methodology. All authors contributed to the search, screening, and selection of included studies. All authors contributed to extracting data from studies. Faran Rana and Lana Zaman entered data into CMA, conducted and analysis, and interpreted the results. All authors drafted the final review.

Lana Zaman is an Associate Sustainable Development Officer to the United Nations Department for Economic and Social Affairs, Division for Sustainable Development Goals with over a decade of experience in economic analysis, evaluation, energy, and climate change. Lana Zaman previously worked in the ESCAP Energy Division, where she led the Division's energy access portfolio. Prior to that, she worked with the Washington D.C.-based Social Impact where she led and managed impact evaluations and research projects for clients including USAID and the United States Department of Agriculture. Faran Rana is an Energy Access Analyst at ESCAP where he supports the Energy Division's energy access portfolio. Prior to working for ESCAP, Faran provided analytical support on a project that explored wage inequality and migration in Thailand as well as another project that assessed climate change induced vulnerability of small-scale farmers in Pakistan. Olivia Baldy is a Research Assistant in the ESCAP Energy Division. Prior to that, she did research on job search monitoring policies in Belgium at the Research Centre for Applied Economics at the Solvay Brussels School and the Université Libre de Bruxelles (ULB). Maria Pia is an economist with six years of working experience in the financial services sector and the economic development field in Chile, the Netherlands, and the United Kingdom. She has worked on development, economics of education, financial inclusion, labour markets and public policy evaluation. Currently, she is pursuing a PhD in Economics at the University of Sussex, United Kingdom.

1 Abstract

Background: Provision of modern energy services to communities grappling with poverty and inequality can have a transformative effect on economic standing, health, education, poverty and inequality. The 2030 Agenda for Sustainable Development, with Sustainable Development Goal 7 (SDG 7) dedicated to energy, sets the target to achieve universal access to electricity by 2030. To date, countries have pursued a variety of policies and programmes in an effort to close the gap on electricity access.

Objectives: In the context of SDG 7 on achieving universal access to affordable, reliable and modern energy services, the objective of this systematic review is to: (a) assess whether and to what degree electrification interventions are leading to socio-economic development impacts; and (b)examine the distributional impacts of electrification based on gender, age and income. This review additionally examines the comparative effectiveness of various interventions and aims to identify specific challenges in the causal pathway.

Methods: This review includes quantitative studies, using experimental or quasi-experimental designs, to quantify the impacts of policies and programmes designed to provide electricity, including connections via national grids, mini-grids, micro-grids and off-grid systems, in low- and middle-income countries. Based on a search for literature in the Scopus electronic database as well as a search for gray literature using Google Scholar and other sources, the authors screened 2,627 papers from which 66 studies met the inclusion criteria. The authors systematically extracted data from the qualifying studies, assessed the risk of bias, and conducted meta-analyses on relevant outcomes to synthesize summative findings following the Campbell Collaboration Policies and Guidelines. The results are discussed in the narrative synthesis.

Results: On average, electricity access interventions increased income, consumption and expenditure, working time and employment status. These results are consistent and significant for all economic indicators examined, suggesting that electrification can play a very valuable role in economic development. The review also found that electricity access interventions led to positive educational outcomes for children, including an increase in study time and total years of schooling. Based on both quantitative and qualitative findings, electrification also demonstrates positive impacts on gender empowerment.

Authors' conclusions: The findings of this review indicate that electrification is a powerful tool for advancing economic development. Interestingly, while most populations benefited from electrification, there were some differential impacts based on wealth, gender and geography. Wealthier households often benefited more than poorer households, although this varied based on context. Qualitative evidence suggests that electrification also elevated the status of women in the households and their communities.

Key lessons and recommendations: Countries stand to benefit from setting unified goals and targets for universal electrification as well as continuing to enhance the quality of access through more reliable and affordable connections. Instituting targeted policies to support marginalized groups can further enhance the benefits of electrification, while ensuring that no one is left behind. In addition, bundling electrification services with other benefits, such as increased access to finance, provision of information and communication technologies, investment in human capital and development of complementary infrastructure, can help unleash the full potential of electrification, particularly in remote rural areas. Finally, where grid extension is not financially feasible, mini-grid and off-grid solutions based on renewable energy provide cost-effective and sustainable solutions. Policymakers may best choose among these options in accordance with local contextual needs.

2 Plain language summary

2.1 The systematic review in brief

The global review suggests that on average, rural electrification programmes and policies have successfully increased income, education, employment and women's empowerment.

2.2 What is the review about?

Globally, 786 million people (10% of the world population) do not have access to electricity, of whom 200 million people reside in Asia and the Pacific (4.4% of the region's population).[1] This gap maps inextricably onto poverty-stricken areas and will be the hardest to reach. This leaves people without the necessary means to satisfy their basic needs, let alone climb the socio-economic ladder. Filling this gap and attaining universal access by 2030, as stipulated under the 2030 Agenda for Sustainable Development, presents a paramount challenge. Despite decades of effort and recent progress, the full benefits of electrification have yet to be realized. Implementation of effective policies and programmes could help to accelerate affordable, reliable and universal electrification in line with SDG 7.

This systematic review examines the impacts of past policies and programmes aimed at electrification to assess whether they have successfully increased income, education and employment of electrified households. In addition, this review examines heterogeneous findings between different evaluations in order to discuss what types of policies and programmes led to success or the lack thereof.

2.3 What types of studies are included?

This review includes quantitative studies using experimental or quasi-experimental designs to quantify the impacts of policies and programmes designed to provide electricity, including connections via national grids, mini-grids, micro-grids and off-grid systems in low- and middle-income countries. All the studies needed to have a valid counterfactual to allow for isolation of impacts. Included studies examined economic outcomes, education outcomes and/or gender outcomes. The specific economic outcomes examined included income, consumption-based measures and employment measures and educational outcomes, including time spent studying and years of schooling. Last, gender outcomes included fertility in terms of the number of children born over a given period as well as other gender-based metrics.

The authors screened 2,627 papers, of which 66 studies met the criteria of the systematic review. A meta-analysis was conducted on 27 papers, covering a total of 654,378 households.[2]

1 ESCAP, Asia-Pacific Energy Portal, 2020. Available at https://asiapacificenergy.org/

2 Of the 27 studies, 23 cover a total of over 654,378 households; three papers cover a total of 50,166 individuals; and one paper covers 137 villages.

2.4 What are the findings of this review?

This systematic review finds that on average, electricity access interventions increased income, consumption and expenditure, working time and employment status. These results are consistent and significant for all economic indicators examined, suggesting that electrification can play a very valuable role in economic development. These benefits were largely attributed to: (a) increased hours of productivity due to lighting; (b) greater exposure to information, which enabled access to opportunities and resources; and (c) increased productivity due to the use of appliances for both housework and income-generating activities. In terms of who benefits most, qualitative analysis suggests that benefits accrue across all income groups, but in most cases, richer households benefit more, possibly because they can afford more electricity and productivity-boosting appliances. However, these impacts vary based on local context. Preliminary evidence also suggests that women benefited more than men in terms of gaining employment after electrification. Similarly, this trend may vary based on local gender norms and labour market characteristics.

The review found that electricity access interventions led to positive educational outcomes for children, including an increase in study time and total years of schooling. These benefits were largely attributed to: (a) lights, which enable study in the evenings; and (b) productivity increases, which freed up time for children who might otherwise have been helping parents with housework or other activities. The effects were stronger for studies in which beneficiary communities were electrified for longer, suggesting that educational benefits further increase over time.

Based on both quantitative and qualitative findings, electrification also demonstrates positive impacts on gender empowerment. The study authors suggest that electrification can improve women's decision-making ability, financial autonomy, reproductive freedom and social participation, often due to increased labour market participation. Several studies found that electrification reduced women's time spent on housework such as gathering and preparing fuel. Preliminary evidence also suggests that electrification can reduce acceptability of intimate partner violence, due to greater media exposure. This systematic review found that, on average, electrification may have led to a reduction in fertility, as measured by total number of children; however, this result was not significant. Only a few studies examined electrification's impacts on gender empowerment and fertility. Additional studies could help shed light on this important pathway for change.

Based on the assessment of bias risk using the Risk of Bias in Non-randomized Studies (ROBINS-I) tool,3 the risk of bias in the included studies was relatively low. Any studies with high risk of bias were excluded.

2.5 What do the findings of this review mean?

The findings of this review indicate that, on average, electrification interventions play a highly beneficial role in socio-economic development. Based on a range of indicators, electrification improved economic status as well as children's education. Based on qualitative findings, electrification can also improve gender equity. Interestingly, while most populations benefited from electrification,

3 Cochrane Methods. Robins-I Tool. Available at https://methods.cochrane.org/methods-cochrane/robins-i-tool

there were some differential impacts based on wealth, gender and geography.

2.6 Key lessons and policy recommendations

Based both on the summative findings of the meta-analysis and the qualitative information within the individual studies, the authors identify the following lessons learnt and provide recommendations:

1. Electrification is a powerful tool for advancing economic development; countries stand to benefit from setting unified goals and targets for universal electrification and continuing to enhance the quality of access through more reliable and affordable connections;

2. While electrification programmes generally benefit everyone, studies demonstrate differential impacts for different subpopulations, based in particular on wealth status, gender and geography. By instituting targeted policies to support marginalized groups and ensure that electricity and the associated appliances are affordable for all, policymakers can further enhance the benefits of electrification, while ensuring that no-one is left behind;

3. Electricity access is only as beneficial as the amenities it supports. Bundling electrification services with other benefits, such as increased access to finance, the provision of information and communication technologies, investment in human capital and development of complementary infrastructure can help unleash the full potential of electrification, particularly in remote rural areas;

4. Both grid-extension and decentralized solutions show evidence of benefits, and policy makers may best choose among these options based on local contextual needs. Where grid extension is not financially feasible, mini-grid and off-grid solutions based on renewable energy provide cost-effective and sustainable solutions. Continuous technological improvement can further enhance decentralized solutions;

5. In the light of the COVID-19 pandemic, electricity access will be critical to the distribution of vaccines as well as to achieving economic recovery. As many Governments issue recovery packages, directing some of these funds and initiatives towards electricity access in low-income communities could help to create jobs quickly, while building towards much-needed long-term economic growth.

2.7 How up-to-date is this review?

The team conducted the electronic search for papers in August 2020.

3 Introduction

Provision of modern energy services to communities grappling with poverty and inequality can have a transformative effect on economic standing, health, education, poverty and inequality. Electricity access can satisfy basic needs such as lighting, cooking, heating and cooling as well as allowing the productive use of energy for income generation, education, access to information, employment and better health. In the context of COVID-19, access to electricity is an essential requirement for transport, distribution and storage of vaccines. However, 736 million people (10% of the world population) do not have access to electricity, of which 200 million people reside in Asia and the Pacific (4.4% of the region's population). 4 This leaves people without the necessary means to satisfy their basic needs, not to mention climbing the socio-economic ladder.

The 2030 Agenda for Sustainable Development prioritizes universal access to electricity under SDG 7 on energy. This goal includes three targets by 2030: (a) to ensure universal access to affordable, reliable and modern energy services, including access the electricity and access to clean fuels and technologies; (b) to increase substantially the share of renewable energy in the global energy mix; and (c) to double the global rate of improvement in energy efficiency. Among the three targets, universal access to electricity has made the most progress. However, the deficit in Africa still stands at 55.5 per cent of the population (567 million people). In Asia and the Pacific, it is 4.4% of the population (200 million people), while the Latin America and Caribbean region and other countries/areas5 stand at 1.7% (11 million people) and 5 per cent (9 million people) of unelectrified population remaining respectively. These last areas will be the hardest to reach.

In collaboration with the Energy Foundation of China (EFC) the ESCAP Energy Division undertook the current study to quantify the impacts of electrification on socio-economic outcomes for users, with a view towards informing of evidence-based policy for attaining universal access. The review will help to create better understanding of: (a) whether electrification interventions are successfully leading to socio-economic development; and (b) the distributional impacts of electrification across gender, children and different income groups, where possible.

This study is the second of two systematic reviews that the Energy Division has undertaken on the subject of energy access. The current study focuses on the impacts of electricity access programming on socio-economic outcomes for target populations. A prior study looked at clean cooking interventions on clean cooking adoption and health.

4 ESCAP, 2020, Asia Pacific Energy Portal. Available at https://asiapacificenergy.org/

5 Curaçao, French Southern Territories, Heard Island and McDonald Islands, Kuwait, Jordan, Israel, Lebanon, Norfolk Island, Iraq, Palestine, State of Qatar, Pitcairn, Saint Barthélemy, Syrian Arab Republic, United Arab Emirates, Sao Tome and Principe, Tokelau, Saudi Arabia, Yemen, Oman, Åland Islands, South Georgia and the South Sandwich Islands, Wallis and Futuna, Taiwan, Province of China, United States Minor Outlying Islands, Cocos (Keeling) Islands, British Indian Ocean Territory, Bahrain, Bouvet Island, Antarctica, Christmas Island

3.1 The issue

Despite recent progress, the world is not on track to meeting SDG 7 on energy. With less than a decade remaining, and the disruptive onset of COVID-19 on energy access programmes, the world is not on track to achieve universal electrification by 2030.6 The remaining pockets of unelectrified regions will be the hardest to reach. The simultaneous increase in income inequality has left those without access to electricity even further behind. Even in areas with access, the full benefits of electrification have yet to be realized. For this to happen, electricity access needs to be reliable, affordable and equitable as well as bundled with other amenities that support productive use of energy.

For example, while electricity is critical to the operation of schools and hospitals, providing service does not guarantee that health care and education will improve. Benefits sometimes have differential impacts by gender. Where electrification enables household activities to be more productive, this may result in more free time. However, such benefits may be disproportionally allocated, as men may find more time for leisure while women or children may end up allocating freed-up time to household chores.

Redirecting efforts to stay on track for universal electrification will require evidence-based policy and programming that will not just get more electricity out there but package it in a way that can have transformative impact on communities.

6 Access to electricity – SDG 7: Data and Projections – Analysis – IEA.

3.2 Why it was important to do this review

While development literature often discusses the critical importance of rural electrification to improve economic and social wellbeing, there has been little rigorous evidence of the specific nature and magnitude of these benefits. Positive impacts are often used to justify projects, but documentation of specific health, education or income impacts is limited.7 In addition, impacts can vary based on the quality of access, which is not captured in the binary definition of access as is widely used today.

The distribution of these benefits with regard to existing inequalities in wealth, gender and social standing is also poorly understood. Many studies that compare the outcomes of people with and without access to electricity do not account for other differences between these groups. Populations with electricity access may be wealthier to begin with, and can take better advantage of electrification – for example by investing in more efficient appliances and reducing their energy expenditure. Hence, positive outcomes cannot be attributed solely to the provision of electricity. Other studies examine socio-economic outcomes before and after electrification without accounting for other factors, such as macroeconomic shocks or accompanying infrastructure development that might have contributed to any detected improvements. Impact evaluation is a specific type of analysis that addresses these issues by using a counterfactual and isolating the impact of electrification.

Developing a deeper understanding of electricity's impact on socio-economic development can further inform public policy (Jiminez, 2017). This can further ensure that

7 Impact Analysis of Rural Electrification Projects in Sub-Saharan Africa – Tanguyy Bernard.

electrification projects are progressively placed to bring the poorest households into the fold and engender a transformative socio-economic impact. This study will place a particular focus on rural electrification in low- and middle-income countries, as this is where the gaps are most profound. It will also explore the nuances of access quality and its associated benefits where data are available. Understanding the benefits of lower-tier qualities – for example mini- and off-grid solutions – will help to provide an evidence-based case for policymakers to allocate resources to these technologies or, instead, opt for national grid extension.

3.3 About the research team

This systematic review has be-n undertaken by ESCAP, which is the regional development arm of the United Nations Secretariat for the Asia-Pacific region. ESCAP serves 53 member States and nine associate members by promoting cooperation among countries to achieve inclusive sustainable development. The work of ESCAP falls into three primary streams: (a) research and knowledge products to support evidence-based policy; (b) capacity-building and technical assistance; and (c) intergovernmental dialogue. The current review supports streams (a) and (b).

ESCAP's mission on energy is to ensure access to affordable, reliable, sustainable and modern energy for all in Asia and the Pacific. The current review supports this goal by helping to inform on policymaking on energy access. The review is led by a Principal Investigator, Research Analyst and two Research Assistants, henceforth referred to as the "research team" or "authors".

3.4 How the intervention might work: Theory of change for outcomes

To address the gaps in electricity access, many Governments, donors and implementers have implemented rural electrification programmes to bring electricity through grid-connection as well as decentralized solutions to unelectrified areas. This theory of change is detailed in figure 1.

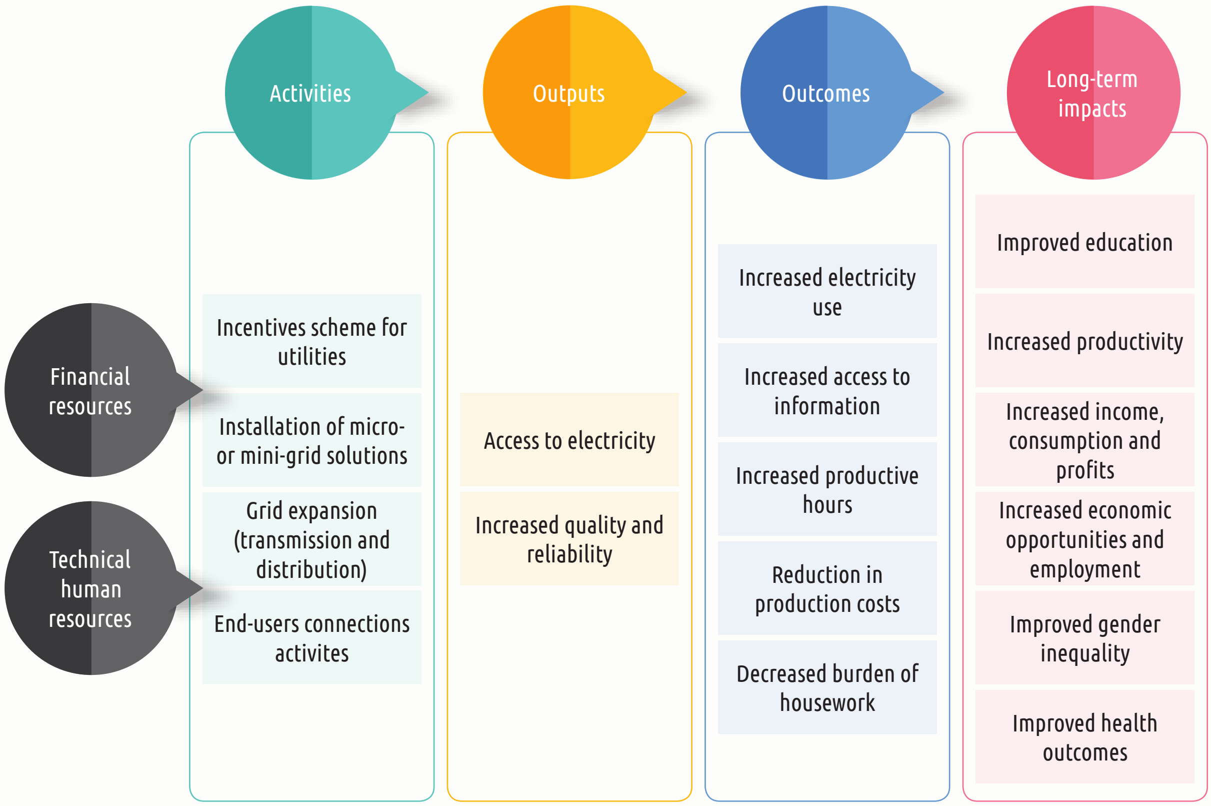
As shown in figure 1, activities such as grid extension, installation of mini-grid solutions, incentive schemes for utilities, and other activities to support end-users, can help to boost access to electricity and improve its quality and reliability in keeping with SDG 7. This, in turn, increases electricity usage, information access and productive hours, while reducing pollution and the burden of housework. Ultimately, this has the potential to improve education, increase economic standing, improve health and benefit gender equality, as detailed in figure 1. While this theory of change is not exhaustive, it illustrates some of the main benefits that electricity access may bring.

3.5 Literature review

Current literature shows that in many cases, electricity access programmes have increased income and employment, improved education and reduced poverty. Evidence suggests that electricity's impact on income occurs through four main pathways. First, electric lighting can increase hours of productivity.[8] Second, with access to radios, television and mobile phones can have better economic opportunities, such as employment and entrepreneurship and access to information about prices. Third, depending on the programme and context, electrification

8 World Bank, Gender, 2006, Time Use, and Poverty in Sub-Saharan Africa. Washington, D.C..

Figure_1 **Causal chain from electricity to development**



Source: Adapted from Raul Jimenez, 2017, "Development effects of rural electrification", Policy Brief No. 261, Washington, D.C., Inter-American Development Bank..

may reduce expenditures on more expensive fuels, such as kerosene.[9] Fourth, households and firms may invest in electrical equipment to support income-generating activity, such as agricultural machines or equipment for entrepreneurial activity. This can result in the development of small micro-enterprises and local industries, which can lead to higher employment in addition to bringing more women into the local economy.

Additionally, electricity has an impact on education through two main pathways. First, electric lights allow children to study more during the evenings. Second, the improvement in productivity may reduce the amount of time that children would otherwise have spent helping parents with housework or other activities. This can free up additional time for studying. The gains in employment and education also increase the opportunity cost of having kids and as a result, lead to a decline in fertility.

These results are consistent with development literature findings. As households attain access to more appliances and quality electricity, their socio-economic benefits progressively

9 Shahidur R. Khandker, Douglas F. Barnes and Hussain A. Samad, 2013, "Welfare impacts of rural electrification: A panel data analysis from Vietnam", Economic Development and Cultural Change, vol. 61, No. 3.

increase.[10] Maintaining and continuing to improve electricity quality is critical to fully realizing potential benefits. Evidence has shown that economic and social benefits continue to improve incrementally as electricity quality improves. Programmes have taken targeted initiatives to ensure that girls benefit at least as much as boys, particularly with regard to education.

Existing literature reports a positive association between electrification and income, education and employment (ADB, 2019 and 2020; IEG, 2015; Jeuland, 2020; Jimenez, 2017)[11]. While Bayer *et al.* (2020) has also found similar results, some evidence suggests a reduction in female labour market participation[12]. ADB (2019 and 2020) further reports a positive impact of electrification on health and environmental outcomes. However, the Independent Evaluation Group (2015) found the evidence on health to be weak – the review also showed mixed evidence with regard to women's empowerment. It is essential to note that from the studies mentioned, the ADB (2020) study is the most recent and follows an exhaustive research strategy and rigorous methodology. In addition, Köhlin *et al.* (2011) found that electrification was associated with longer working days, better access to information, better and safer lighting, greater efficiency in domestic and caring responsibilities, and expanded opportunities for income generation[13]. In addition, electricity provision was found to potentially promote gender equality and women's empowerment. A summary of existing evidence on the impact of rural electrification is provided in Annex 10.

Based on existing literature, there appears to be a lack of rigorous evidence on the specific nature and magnitude of electrification-induced benefits (Hamburger *et al.*, 2019; and Jiminez, 2017)[14]. However, the impacts between studies are highly variable, with some reporting null findings (ADB 2019 and 2020). To help fill this gap, and provide a comprehensive picture of the issue, ESCAP is conducting this systematic review with meta-analysis, which is further supported by a detailed assessment of heterogenous findings that explores gender and inequality in depth. This study ascertains the theorized impacts of electricity access with on-the-ground evidence. Complex linkages between electricity access and socio-economic development are assessed to help inform future energy access interventions and to better address on-the-ground needs. Through systemized methods, it substantiates the current evidence base, which can be used to inform the design and implementation of future programmes.

10 UNDP, 2018, "Energy access projects and SDG benefits", UNDP Discussion Paper. Bangkok.

11 ADB, 2019, "Impact Evaluation of Energy Interventions: A Review of the Evidence". Available at: https://www.adb.org/publications/impact-evaluation-energy-interventions; ADB, 2020, "Effects of Access to Electricity Interventions on Socioeconomic Outcomes in Low- and Middle- Income Countries", Independent Evaluation:SR-01 ; Independent Evaluation Group, 2015, "World Bank Group Support to Electricity Access, FY2000-2014, an Independent Evaluation". Available at: https://openknowledge.worldbank.org/handle/10986/22953; Jeuland and al., 2021, "Is energy the golden thread? A systematic review of the impacts of modern and traditional energy use in low-and middle-income countries", in Renewable and Sustainable Energy Reviews, vol. 135 ; Jimenez, R., 2017, "Development Effects of Rural Electrification", Inter-American Development Bank Policy Brief, No. DB-PB-261 ;

12 Bayer P. and al., 2020, "The need for impact evaluation in electricity access research", in Energy Policy, vol. 137. Available at: https://doi.org/10.1016/j.enpol.2019.111099

13 Gunnar Köhlin, Erin Sills, Subhrendu K. Pattanayak, Christopher Wilfong, 2011, "Energy, Gender and Development: What are the Linkages? Where is the Evidence?", World Bank Policy Research Working Paper

14 Hamburger and al., 2019 , "Shades of darkness or light? A systematic review of geographic bias in impact evaluations of electricity access", in Energy Research & Social Science, vol. 58. Available at: https://doi.org/10.1016/j.erss.2019.101236 and Jimenez, R., 2017, "Development Effects of Rural Electrification", Inter-American Development Bank Policy Brief, No. DB-PB-261.

4 Objectives

Following the methodology and guidelines of the Campbell Collaboration,[15] the systematic review will examine policies and programmes, identify what worked and what did not in different contexts, and quantify impacts. In addition, it will discuss trends and evidence of what particular elements of programmes and policies lead to success – not just in terms of achieving access, but in terms of ensuring that access leads to tangible and equitable socio-economic benefits.

The systematic review methodology, particularly when including meta-analysis is a very powerful tool in cumulating and summarizing the research across a field of knowledge.[16] Systematic reviews bring together and make comparable studies from different settings that would otherwise be difficult to compare. This makes it possible to overcome some of the limitations of a single individual study; for example, a single evaluation may be highly accurate for one particular programme or population, while meta-analysis can draw conclusions about the efficacy of a type of programme implemented across multiple settings. Because it consolidates quantitative impacts into one combined effect size, meta-analysis is one of the most comprehensive and least-biased approaches to examining an issue. Because evidence on electricity access is fragmented, attaining rigorous, high-quality evidence on what programme elements lead to transformational change will be a critical input to future programming. This review follows an additional systematic review that ESCAP conducted on the impacts of clean cooking interventions on adoption outcomes and long-term health impacts. ESCAP will use these studies to carry out capacity-building activities in various countries in Asia and the Pacific, in order to raise awareness of the energy access issues and to provide evidence-based recommendations to address it.

The objective of this study is to support evidence-based policy and decision-making in order to help collectively close the gap on electricity access. In pursuit of this objective, the current study strives to (a) systematically gather, summarize and analyse rigorous evidence on the impacts of electrification interventions; (b) improve evidence-based understanding on what works and what does not in order to achieve tangible, equitable and transformative impacts; and (c) identify remaining research gaps that may serve as topics for further investigation in future.

The research team intends to use this study to conduct capacity-building activities with stakeholders, including policymakers, donors, implementers and civil society, in order to enable evidence-based decision-making, strategy and implementation for future energy access programmes and policies.

15 The Campbell Collaboration is a non-profit that "promotes positive social and economic change through the production and use of systematic reviews and other evidence synthesis for evidence-based policy and practice". The collaboration provides a host of guiding tools on methodology for conducting a systematic review and meta-analysis that adheres to best practices in the field. https://campbellcollaboration.org/

16 Walker, E., A. Hernandez and M. Katta, 008, "Meta-analysis: It's strengths and limitations." Cleveland Clinic Journal of Medicine, vol. 75, No. 6.

4.1 Research questions

The guiding research questions aim to identify the causal linkages from an electricity intervention to short-term household benefits and, ultimately, to socio-economic impacts. The research team also investigated the distribution of impacts within the population in order to examine effects on inequality.

4.1.1 Main questions

1. To what degree do electrification interventions have an impact on income, education, employment and gender empowerment?

4.1.2 Supplemental questions

1. How do impacts vary, based on the type of electricity system, including national grid extension or installation of mini-, micro- or off-grid systems?[17]

2. How do results vary by geographic region?

3. What specific programme components lead to impact or the lack thereof?

4. What are the distributional impacts of electrification across income groups, gender and children?

17 Note that for the purpose of this study, off-grid systems are categorized as those with stand-alone, home-based systems – for example, PICO photovoltaic (PV) kits or solar home systems.

5 Methodology

In conducting this systematic review, the research team followed the guidelines advocated by the Campbell Collaboration for such reviews, as described in this section. The Campbell Collaboration is an international network with a mission to "promote positive social change by contributing to better-informed decisions and greater effectiveness for public and private services around the world". The group supports the development and dissemination of high-quality systematic reviews on the effectiveness of social programmes, policies and practices.[18] The current systematic review is not registered with the Campbell Collaboration, but it follows many of the organization's guidelines and guiding principles for conducting a systematic review.

In keeping with the Campbell Collaboration's recommendation to use a theory-based approach, the theory of change (ToC) described in figure 1 was the primary guide for the research framework. It informed the inclusion criteria, outcomes examined and data coded. ESCAP also conducted a descriptive qualitative analysis of papers in order to identify causal linkages as well as breakdowns in the ToC. The team examined income, education, employment and fertility through a meta-analysis. Wherever possible, the team also analysed qualitative findings on farm vs. non-farm income, firm performance and creation, gender and income equality, time allocation and childhood employment. This study uses meta-analysis to quantify impacts, and uses qualitative analysis to provide insights and details on pathways for achieving impacts. This section provides a brief summary, the overall methodology covering the selection criteria, search strategy, and data collection and analysis is laid out in Annexes 3 to 5.

18 Campbell Collaboration. "Campbell systematic reviews: Policies and guidelines". November 2019. Available at https://training.cochrane.org/handbook (accessed in January 2020).

5.1 Selection criteria for systematic review

To be eligible for inclusion in the review, the study had to meet the criteria listed in table 1.

The inclusion criteria employ the PICOS framework (outlined in table 1), which stands for population, intervention, comparator, outcomes and study designs. In sum, this study undertakes a global review of rural electrification interventions in low-middle income countries. It only includes studies in which there was an explicit programme or policy intervention that focused on electrification and a valid counterfactual using a control group, before-after design or quasi-experimental methods. Studies were included if socio-economic outcomes (listed in table 1) were assessed. Study designs included experimental and quasi-experimental designs – natural experiments, instrumental variables, Propensity Score Matching (PSM), before-after studies and cross-sectional studies that sufficiently accounted for confounding factors and enabled determination of the causal impact of the clean cooking component in the intervention.

Table_1 **PICOS framework summary**

Population	Low- and middle-income countries
Intervention	Electrification through national grid connection, mini-grids, micro-grids, off-grid systems.[19]
Comparator	Valid counterfactual using a control group, before-after design, or quasi-experimental methods.
Outcome(s)	Income – (i) income, (ii) consumption and expenditure. Education – (i) study time, (ii) years of schooling. Employment – (i) time spent working, (ii) employment status. Women's empowerment – (i) fertility.[20]
Study design	Experimental and quasi-experimental designs (natural experiments, instrumental variables, Propensity Score Matching (PSM), before-after studies, cross-sectional).

Due to resource constraints, this systematic review was conducted exclusively in English. Therefore, it only includes studies published in, or translated into English.

The team also initially attempted to identify the level of each intervention with regard to the tier of electricity access as identified by ESMAP's multi-tier framework on energy access. However, many studies do not provide this data. For that reason, this review includes all electrification technologies except the ones that focus on simply providing basic lighting.

5.2 Study search strategy

The team developed a comprehensive list of keywords (Annex 1) and conducted the PICOS search on 14 July 2020 in the electronic database SCOPUS. To minimize the possibility of publication bias, the research team also made efforts to search for both published and unpublished literature. Additional hand searches were conducted in Google, Google Scholar, SSRN, Researchgate, 3IE and various donor websites listed in Annex 2 to capture some of the gray literature that might not have been published in traditional journals. The team also reached out to the author of each eligible paper and inquired whether the author had written or knew of any published or unpublished studies that met the criteria for inclusion in the systematic review. All the results were systematically compiled into databases, cleaned of duplicates, and then screened. More information on the search process is provided in Annex 4.

5.3 Selection of studies: Screening process

To facilitate the screening and selection of studies, the team uploaded the titles, abstracts and metadata from the electronic search into Abstrackr,[21] a free open-source software recommended in the Campbell Search Strategy Guidelines, to facilitate review and screening

19 Some studies use a combination of interventions. In this case, authors identified the most dominant intervention and categorized it accordingly. In cases where there was more than one dominant interventios, both were added as a category.

20 The most common indicator used, and suitable for a meta-analysis was the number of children born in a given period.

21 Byron C. Wallace, Kevin Small, Carla E. Brodley, Joseph Lau and Thomas A. Trikalinos. Deploying an interactive machine learning system in an evidence-based practice center: abstrackr. In Proc. of the ACM International Health Informatics Symposium (IHI), p.819--824. 2012.

for systematic reviews. Once uploaded in Abstrackr, the team screened all titles and abstracts., In the pilot stage, the first 100 titles and abstracts were screened by all three screeners together with the team leader in order to ensure agreement across the team on what types of papers qualified. This pilot stage needed to achieve a kappa rate of at least 0.7 in order for the review to continue. If the rate of agreement was lower, the team would complete an additional pilot of 100 titles and abstracts before proceeding. In the case of a high level of agreement, screeners continued with single screening. In cases of uncertainty, abstracts were double coded by a second analyst.

In this stage, studies were screened based on the inclusion criteria outlined based on the subject matter and the PICOS framework outlined in table 1. However, because study design and comparison are not always explicit in the title and abstract of a study, wherever analysts were uncertain of these characteristics, studies were included for further review at the full-text screening stage. For the papers attained through hand search, an initial analyst first identified qualifying studies, after which a second analyst reviewed the selections as verification.

All studies that met the inclusion criteria based on title and abstract screening then underwent a full text screening. In that stage, analysts reviewed the full document based on the inclusion criteria, with particular emphasis on methodology and statistical design. Studies that met the inclusion criteria based on the full text screening went on to data collection. The resulting studies that qualified are presented in section 6.1.

5.4 Data collection and analysis

Analysing each of the qualifying studies, the analysts collected detailed data on population, intervention, comparison group, outcomes of interest and study design. They additionally extracted the effect sizes for the included outcomes and related statistical data needed to calculate standardized mean differences (SMDs), following the guidance of the Cochrane Handbook for systematic reviews of Interventions.[22] This included summary statistics such as averages, standard deviations, standard errors, and confidence intervals. The team additionally analyzed each paper to assess its risk of bias based on a modified version of the Risk of Bias in Non-randomized Studies (ROBINS) tool, a tool designed to assess the comparative effectiveness of interventions from studies that did not randomize assignment to treatment and control groups.[23, 24]

To provide a quantitative assessment of the summative findings, across studies, the authors conducted a meta-analysis. In order to be included in the meta-analysis a study had to meet the following additional criteria:

1. Include an effect size for one of the above-listed outcomes;

2. Include sufficient data about this effect size to enable calculation of a standardized mean difference;

22 Cochrane Training (2019). Cochrane Handbook for Systematic Reviews of Interventions (Version 6). Available at https://training.cochrane.org/handbook/current

23 Cochrane Methods. Robins-I Tool. Available at https://methods.cochrane.org/methods-cochrane/robins-i-tool

24 Sterne, Jonathan AC (2016). ROBINS-I: a tool for assessing risk of bias in non-randomized studies of interventions. BMJ 2011;343:d5928. Available at https://www.bmj.com/content/343/bmj.d5928#:~:text=The%20risk%20of%20bias%20tool%20covers%20six%20domains%20of%20bias,the%20domain%2C%20or%20different%20outcomes.

Box_1 **Interpretation of Hedges's G**

Hedges's g statistic is a standardized difference between means. A Hedges's g equal to ±1 indicates that the treatment and control group differ by 1 standard deviation, while ±2 or -2 indicates they differ by 2 standard deviations, and so on. The general interpretation is that a Hedges's g<0.2 indicates a small effect size while Hedges's g>0.8 indicates a large effect (Cohen, 1977). The equation for Hedges's G is further detailed in Annex 7.

3. Effect sizes included in meta-analysis must be independent (Annex 5).

For studies that did not provide sufficient data for inclusion in the meta-analysis, per the Cochrane Collaboration Guidance, analysts contacted authors to request the additional data needed.[25] After a period of two weeks, analysts reached out a second time to any authors that did not respond. If an author did not respond a second time and analysts could not find sufficient data, the study was excluded from the meta-analysis. Author's undertook additional analysis to ensure independence of findings of all results included in the meta-analysis. Further details on data collected and full list of outcomes are presented in Annex 5.

The authors conducted the meta-analysis, using Comprehensive Meta-Analysis (CMA) software.[26]

5.4.1 Measurement of treatment effects

Using the effect sizes and summary statistics indicated in each study the authors compiled and standardized treatment effects. The specific type of effect size used depended on the outcome measured. For all variables (income, consumption & expenditure, study time, years of schooling, time spent working, employment status and fertility), the effect size is expressed in Hedges's G.

In cases where data were insufficient to transform an effect size into the common standard for a meta-analysis, the outcome was excluded. After deriving the necessary statistics, the team inputted the data into Comprehensive Meta-Analysis (CMA) software to calculate the standardized mean differences (SMDs) and their confidence intervals. 27

In cases where data were missing, and the team was unable to procure the necessary data from the author, the team made several assumptions, including the following:

1. Where it was not specified how much of the sample was in the control group and how much was in the treatment group, the reviewers assumed that the total sample was divided equally between both groups.

2. Where standard deviation was only provided either before or after an intervention, the team assumed that standard deviation was similar at both points in time.

3. For dependent variables that were binary and were missing data on standard deviation, the authors calculated the SD using the formula, SD = p(1-p), where p stands for mean.

25 Cochrane, 2011,.Methods for obtaining unpublished data. Available at https://www.cochrane.org/MR000027/METHOD_methods-for-obtaining-unpublished-data

26 Comprehensive Meta-Analysis (Version 3) [Computer software]. (2020). Englewood, NJ: Biostat. Available at https://www.meta-analysis.com/

27 Ibid.

5.4.2 Data synthesis

After obtaining the SMDs, the team used CMA to calculate pooled effect sizes for each outcome. CMA calculates the pooled effect sizes as weighted averages of the SMDs, weighted based on inverse variance. Because there is a great deal of heterogeneity in the contexts, geographical locations, interventions and populations, the team used a random effects model to account for random differences between studies. The team then used CMA to produce forest plots with summative statistics, visually demonstrating the individual findings from different studies as well as conclusions about the pooled effect sizes. The team also presented these results by using moderators (subgroup analysis by region and intervention).

5.4.3 Additional analysis

In addition, the team examined publication bias, heterogeneity, and subgroup analysis based on moderators, the details of which are presented in Annex 6.

Publication bias occurs when the published literature on a topic is systematically different from the complete population of literature.[28] For example, studies demonstrating statistically significant findings may be more likely to get published than those that find null results, resulting in a bias in which the readily available publications suggest stronger findings than the complete body of research. Authors used various statistical techniques to investigate and minimize publication bias.

To further investigate trends in findings, the authors used two moderators for analysis: (a) type of intervention; and (b) geographic subregion. These moderators help to identify potential trends based on interventions and population subgroups.

5.4.4 Treatment of qualitative research

While the systematic review did not include studies that were purely qualitative, the team made efforts to incorporate and analyse some of the qualitative information in order to validate and further elaborate on quantitative findings. Campbell guidelines suggest that qualitative information can be valuable in terms of defining interventions in detail, providing insight into heterogeneous findings, and identifying some of the characteristics that led to success or the lack thereof.[29] Qualitative analysis was particularly used to inform heterogeneous findings as well as policy recommendations.

28 Publication Bias in Meta-Analysis - Prevention, Assessment and Adjustments Edited by H.R. Rothstein, A.J. Sutton and M. Borenstein © 2005 John Wiley & Sons, Ltd. https://www.meta-analysis.com/downloads/PBPreface.pdf

29 Campbell Collaboration, 2019, "Campbell systematic reviews: policies and guidelines". Available at https://training.cochrane.org/handbook

6 Results

6.1 Results of the search

6.1.1 Search and screening results

A total of 2,495 records were identified through electronic search in Scopus. The hand searches and snowballing identified an additional 152 records. Many of the relevant studies came from reference searches, particularly those among other systematic reviews. Other helpful resources were found using Google Scholar. Although the team made efforts to search various donor websites for evaluations that might not have been published in journals, the team found very few studies on these sites. In combining these search lists, the team identified 20 duplicate entries, leaving 2,627 records for the title and abstract screening stage.

6.1.1.1 Title and abstract screening results

A total of 2,627 titles and abstracts were each screened by at least one of the four analysts using Abstrackr.[30] In the pilot stage, the first 100 titles and abstracts were screened by all three screeners together with the team leader in order to ensure agreement across the team on what types of papers qualified. During the pilot stage, screeners attained an overall agreement rate of 94% and a marginal free kappa of 0.88 (0.82, 0.95). The team calculated the Kappa rate using the free online software tool, Online Kappa Calculator.[31] With this high level of agreement, screeners continued with single screening. In cases of uncertainty, abstracts were double coded by a second analyst. The screening process identified 209 titles and abstracts, which were shortlisted for a full text screening. A total of 2,418 papers were excluded; the reasons for exclusion are indicated in figure 3.

A total of 203 papers were screened out due to wrong subject matter i.e., unrelated to the topic of electricity access. An additional 1,355 papers were excluded because the study did not include a qualifying intervention. For example, papers that focused on the impact of feed-in-tariffs or auctions on electricity production or market prices were excluded.

A total of 148 papers were excluded because they did not examine the outcomes of interest. For example, papers that focused on the impact of electricity access interventions on energy consumption, public services efficiency and child health were excluded. An additional 14 papers were excluded based on study-design. These included studies for which the titles and abstracts indicated beyond reasonable doubt that the paper did not have a valid counterfactual or quantitative methodology. Some studies do not explicitly state the study design in the abstract; therefore, if the team was unsure of the study design the paper was included at this stage and further examined during the full text screening. An additional

30 Byron C. Wallace, Kevin Small, Carla E. Brodley, Joseph Lau and Thomas A. Trikalinos. 2012, Deploying an interactive machine learning system in an evidence-based practice center: abstrackr. In Proc. of the ACM International Health Informatics Symposium (IHI), p.819-824..

31 Randolph, J. J., 2008, Online Kappa Calculator [Computer software]. Available at http://justus.randolph.name/kappa

Figure_2 **Flow diagram of study inclusion**

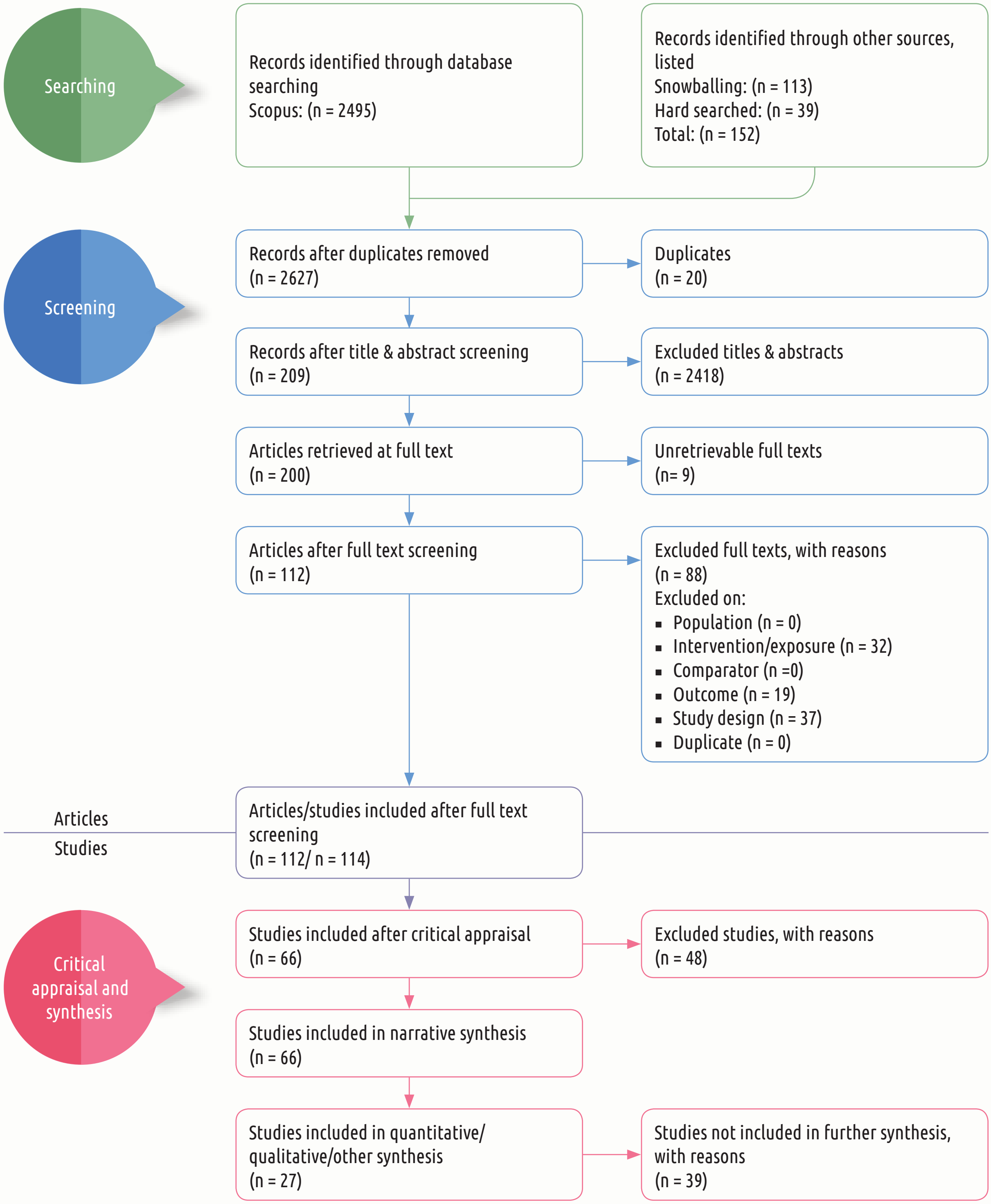
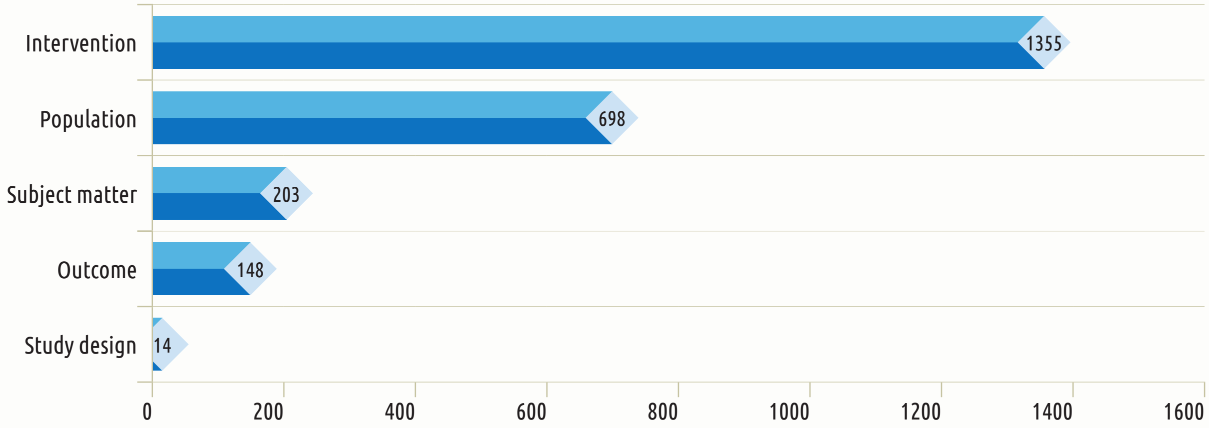


Figure_3 **Reasons for exclusion during title and abstract screening**



698 papers were excluded because they did not focus on low- to middle-income countries.

6.1.1.2 Full text screening results

Of the 209 remaining papers, one paper was written in Portuguese and eight papers were irretrievable, leaving 200 for full text screening. During this stage, 88 articles were excluded due to the reasons indicated in figure 4. As shown, 32 were excluded due to interventions that did not qualify. The majority of these studies did not include any explicit programme or policy to provide or improve electrification. An additional 37 studies were excluded due to non-qualifying study designs, and 19 due to non-qualifying outcome

6.1.1.3 Coding results

After the full-text screening, 112 papers were fully coded; they included 114 studies, as some of the papers contained more than one study. Of these studies, 48 were excluded at the coding stage due to the following reasons: (a) non-qualifying interventions; (b) non-qualifying study design (e.g., if only summary statistics were given without a hypotheses test); or (c) insufficient methodology. This left 66 studies that were included in the narrative synthesis

Figure_4 **Reasons for exclusion – full text screening**

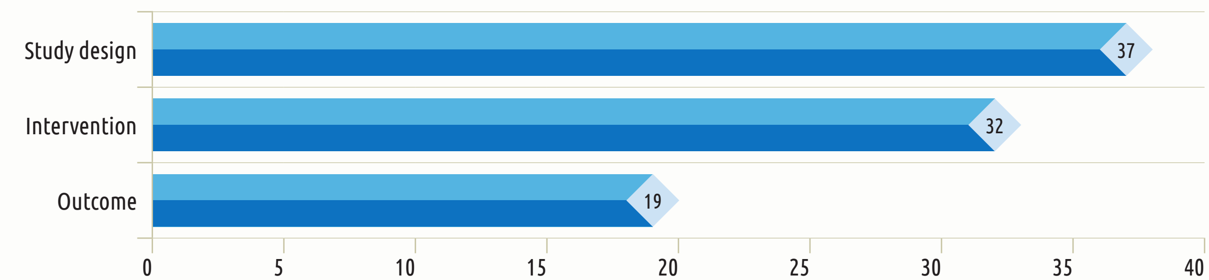
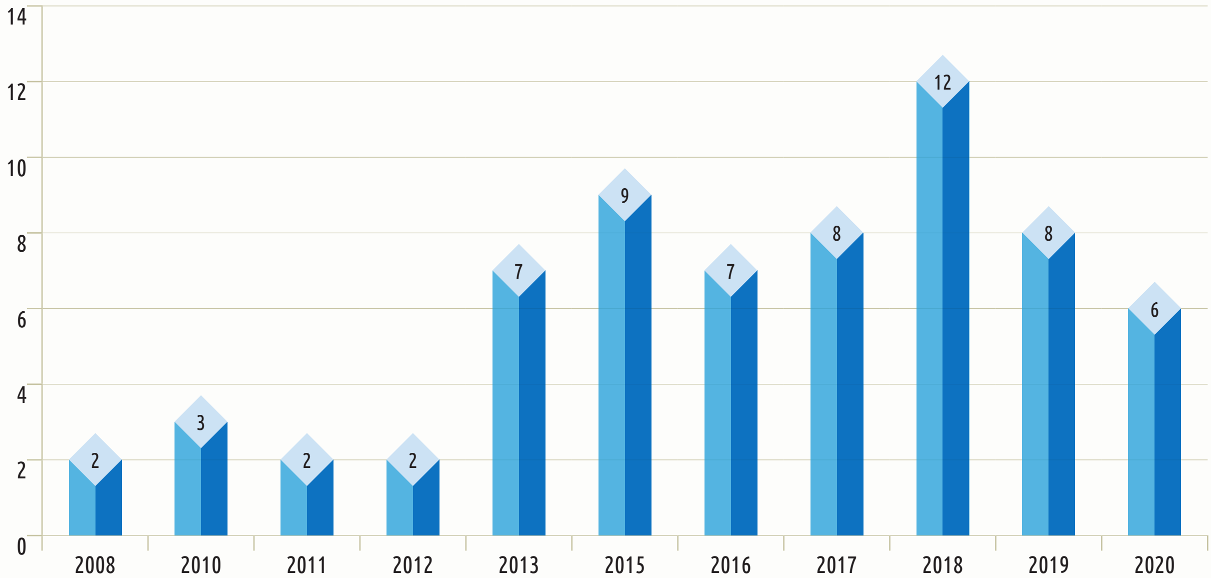


Figure_5 **Studies by year**



of the systematic review. Of these, 27 studies qualified for the meta-analysis. Studies were excluded from the meta-analysis if: (a) the data provided were insufficient to synthesize findings; (b) the outcome was reported in a measurement inconsistent with the effect size used; or (c) the studies violated the assumption of independence of findings. For example, the demographic surveys from the same country were used in several studies to estimate the impact of electricity access. To avoid counting the same individual several time in the meta-analysis, only one study had to be selected. Commonly, other studies were excluded because the sample size, the standard deviations or means of the outcome variable were not provided.

6.1.2 Description of included studies

The complete list of studies included in this systematic review is detailed in annex 5.

6.1.2.1 Studies by year

As shown in figure 5, the impact evaluation literature on electricity access has been increasing since 2013. Most of the studies that met the inclusion criteria were published after 2013 with a peak in 2018.

6.1.2.2 Studies by region and country

Figures 6 and 7 display the breakdown of papers by region and Asia-Pacific subregions, respectively. A total of 23 studies took place in Africa, 31 in Asia and the Pacific, and 12 in Latin America and the Caribbean. No studies that met the inclusion criteria were found in other regions. This is consistent with the fact that the majority of the remaining electricity access gap is in these regions.[32]

As figure 8 shows, the evaluation literature appears to cluster in a few specific countries. In

32 SE4All. Clean Cooking heat map. Accessed at: https://www.seforall.org/data-stories/clean-cooking

Figure_6 **Studies by region**

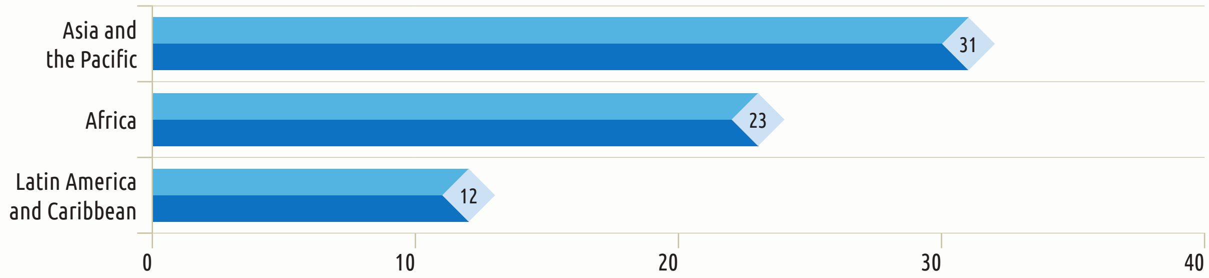
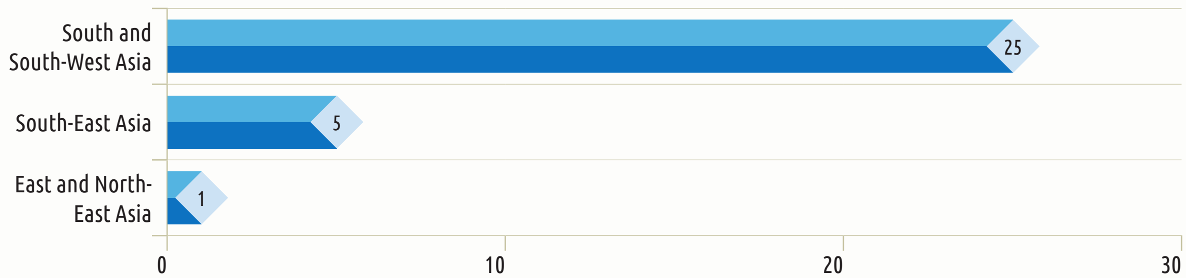


Figure_7 **Studies in Asia and the Pacific Region**



Africa, most evaluations took place in Kenya. In Asia, the main focus was on India, Bangladesh and Bhutan.

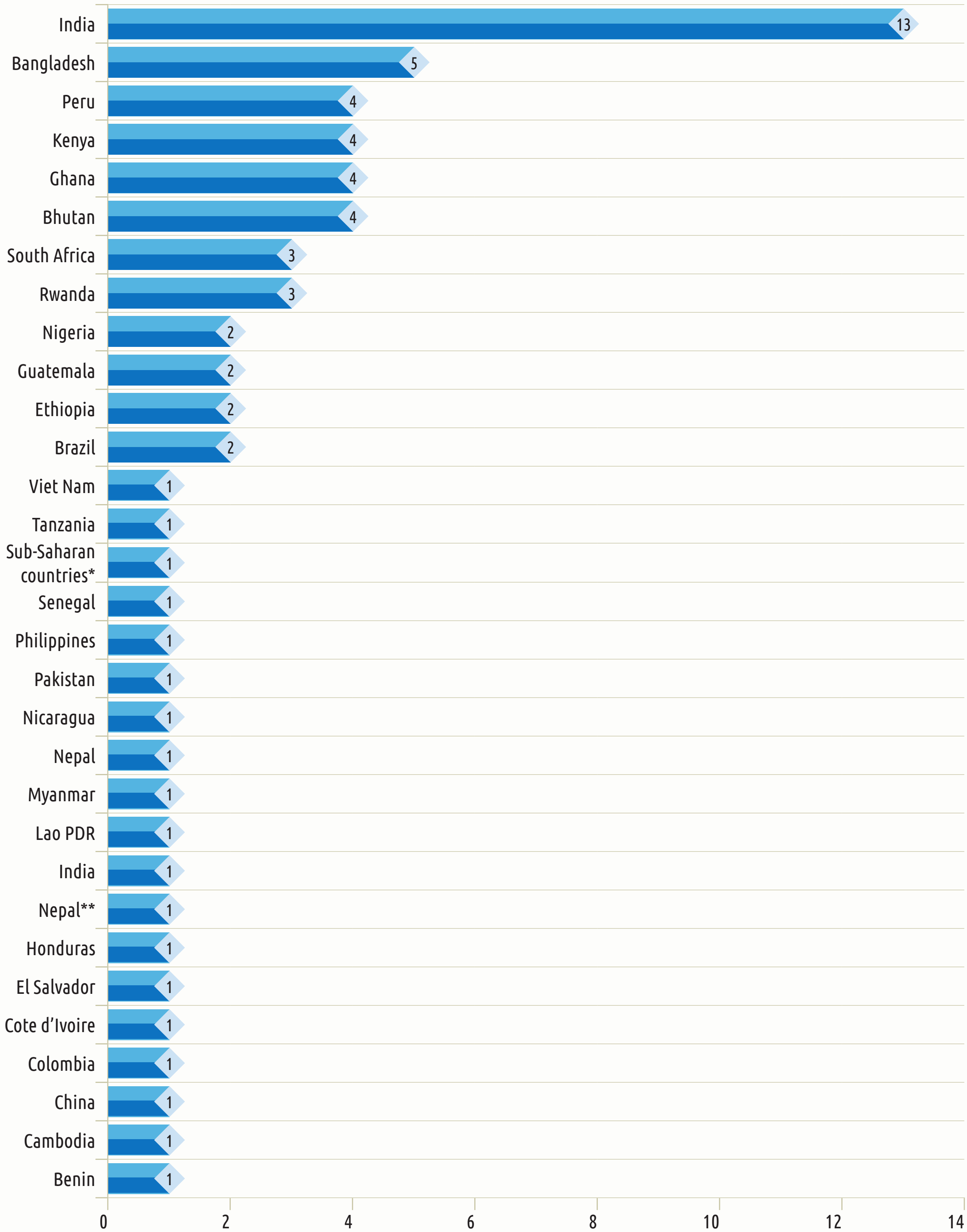
6.1.2.3 Studies by intervention

The interventions are mainly centred around national grid connections, followed by studies on mini-grid, micro-grid and off-grid connection (stand-alone systems).

6.1.2.4 Studies by outcomes

The papers included in the systematic review mainly investigated the impact of electrification on income, education and employment.

Figure_8 **Studies by country**



* The paper estimated the causal impact of electrification among the following 22 sub-Saharan countries: Benin, Burkina Faso, Cameroon, DRC Congo, Ethiopia, Ghana, Guinea, Kenya, Lesotho, Liberia, Malawi, Mali, Mozambique, Namibia, Niger, Nigeria, Rwanda, Senegal, Tanzania, Uganda, Zambia, Zimbabwe. As the causal impact of electrification was not studied separately for each country; the paper was not split into 22 studies.
** Similarly, the summary statistics were combined for India and Nepal.

Figure_9 **Studies, by intervention**

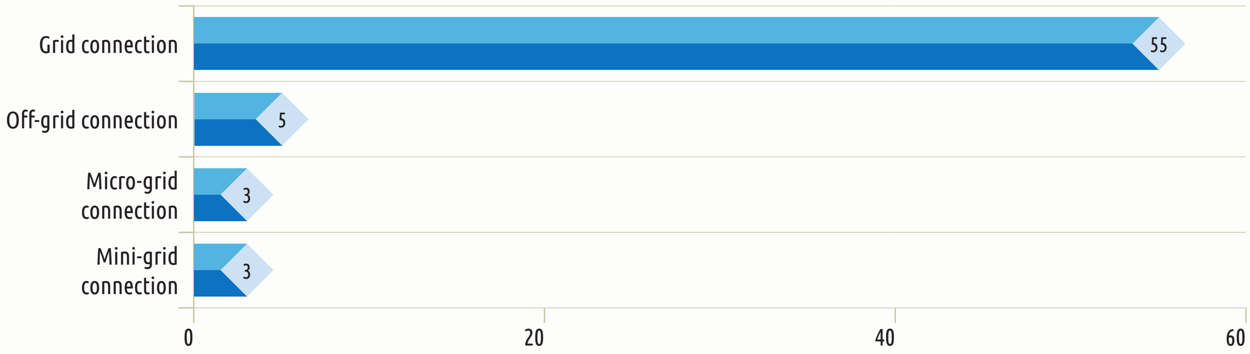
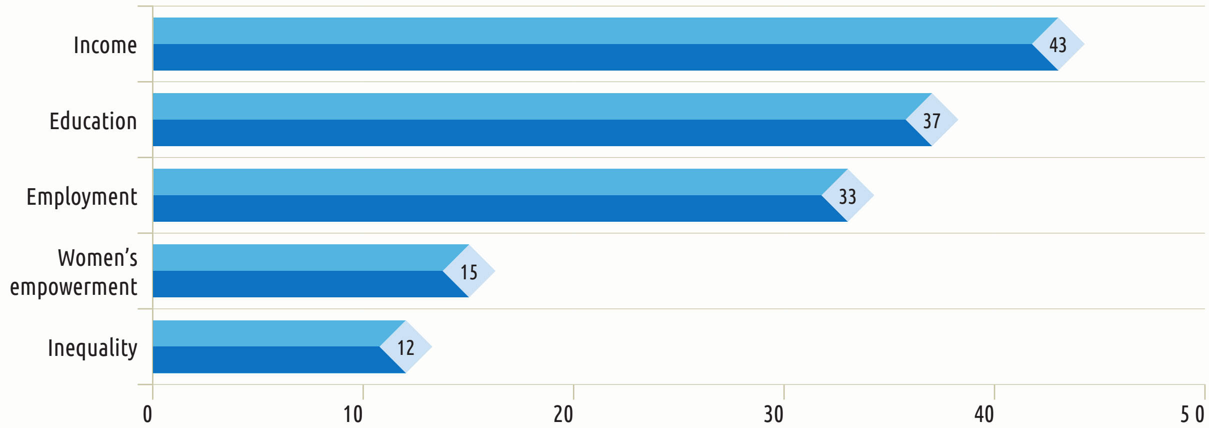


Figure_10 **Studies by outcome**



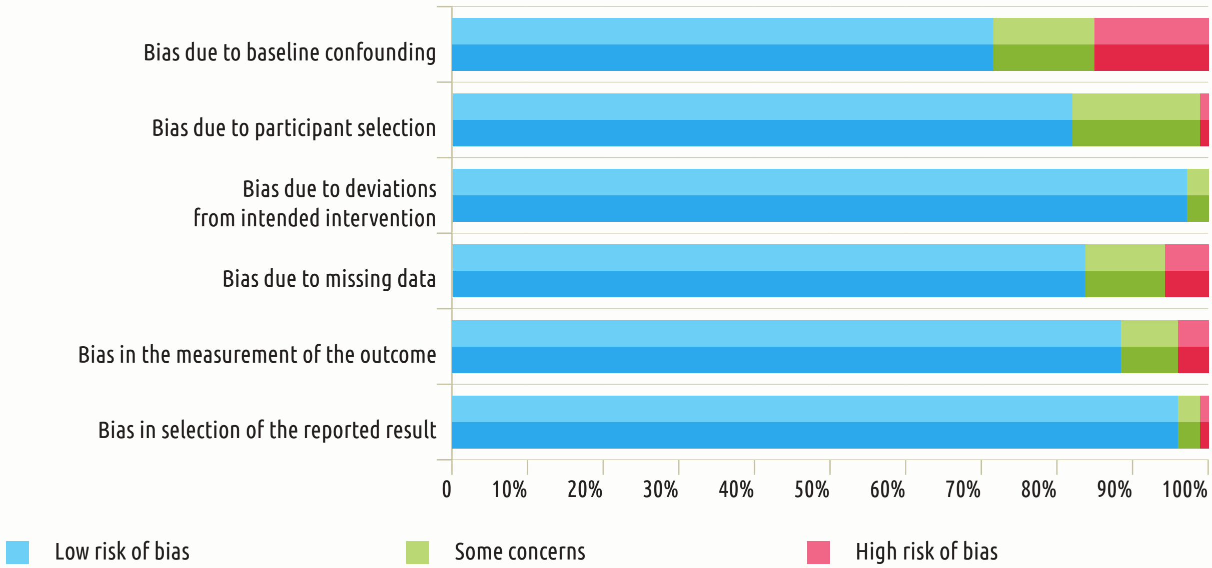
6.2 Risk of bias in included studies

The authors assessed the risk of bias within the individual studies by using a modified version of the Risk of Bias in Non-randomized Studies (ROBINS) tool.[33] This tool is specifically designed to assess the comparative effectiveness of interventions from studies that did not used randomized assignment for treatment and control groups.[34] As demonstrated in figure 11, all studies included in the systematic review were assessed across six domains of potential bias. Overall, the majority of studies included in this systematic review were assessed to be at low risk of bias, ranking in either the low or medium risk categories, but with some also ranking at high risk. Any studies that raised

33 Cochrane Methods. Robins-I Tool. Available at https://methods.cochrane.org/methods-cochrane/robins-i-tool

34 Sterne, Jonathan AC, 2016, ROBINS-I: a tool for assessing risk of bias in non-randomized studies of interventions. BMJ 2011;343:d5928. Available at https://www.bmj.com/content/343/bmj.d5928#:~:text=The%20risk%20of%20bias%20tool%20covers%20six%20domains%20of%20bias,the%20domain%2C%20or%20different%20outcomes.

Figure_11 **Assessment of bias**



critical concerns about bias were excluded from the systematic review.

Figure 11 shows that the domain with the highest risk of bias was baseline confounding. Bias in baseline confounding occurs when certain characteristics impact both the intervention someone receives and the outcomes. As some baseline differences between electrified and unelectrified households are inevitable, this type of bias was recorded when the methodology did not sufficiently account for these differences. Bias in participant selection most often stemmed from non-randomized assignment and/or sampling which may give rise to differences in observable and non-observable characteristics. With regard to bias in the measurement of outcomes, some studies relied on self-reported measurement of outcomes stated retroactively, which are subject to recall bias. Few studies displayed bias due to departure from intended interventions or reported results.

6.3 Synthesis of results

Because some of the studies in the systematic review could not be included in the meta-analysis, table 2 demonstrates the overall findings of the narrative synthesis. This consists of a simple count of how many studies found positive, negative, or null results on each of the respective outcomes. This is based purely on the conclusions of the authors of the individual studies. As shown, more than half of the studies of each outcome demonstrated a significant increase in consumption and expenditure, study time, years of schooling, school completion and grade attainment as a result of electrification; in addition, more than half of the studies examining fertility found that it decreased significantly as a result of electrification. There was substantial evidence of an increase in time spent working as well as income and earnings; however, with many null results, less than half of the studies of each of these outcomes had significant findings. Results for farm income, non-farm income, enrollment, literacy and employment rate

Table_2 **Overall findings from the narrative synthesis**

Outcome	General trend	Number of studies with significant increase	Number of studies with significant decrease	Number of studies with null findings	Total number of studies examining outcome
Study time	↑	12	1	8	21
Years of schooling	↑	7	1	3	11
Enrollment	?	2	1	7	9
Literacy	?	0	1	3	4
School completion	↑	2	0	1	3
Grade attainment	↑	2	0	1	3
Time spent working	↑	6	1	8	15
Employment rate	?	0	0	5	5
Income and earnings	↑	9	1	14	24
Consumption and expenditure	↑	9	0	4	13
Farm income	?	1	0	4	5
Non-farm income	↑	2	0	2	4
Fertility	↓	0	5	1	6

↑ More than half of the relevant studies showed a decrease ↑ Trend suggests increase ↓ More than half of the relevant studies showed a decrease ? No clear trend

Table_3 **Meta-analysis summary**

Category	Outcome	General trend	Number of studies with significant increase	Number of studies with significant decrease	Number of studies with null findings	Total number of studies examining outcome
Education	Study time	↑	8	1	5	14
	Years of schooling	↑	10	0	1	11
Employment	Time spent working	↑	3	0	6	9
	Employment status	?	6	1	3	10
Income	Income	↑	8	0	2	10
	Consumption	↑	6	0	2	8
Fertility	Number of children in a given period	↓	1	0	2	3

↑ Positive and statistically significant ↓ Negative and statistically significant ? Null finding were inconclusive, possibly due to the small number of studies on each of these outcomes. Consistent with the findings on income, however, several studies found significant increases in both farm- and non-farm incomes. The subsequent meta-analyses serve to further examine these findings.

Table 3 presents the results of the meta-analysis for each outcome of interest. On average, the impacts on education, employment, income and fertility were favourable. This is consistent with the findings of the narrative synthesis. Moderator analysis (analysis by different population subgroups e.g., intervention, region, gender) was conducted only for those outcomes where at least eight studies were available.

6.3.1 Effects of interventions on economic outcomes

6.3.1.1 Income

As shown in figure 12, of the 10 studies that analysed income, half found a significant positive impact. The other half found no significant impacts as a result of electrification. Overall, the meta-analysis of these findings demonstrated a moderate and statistically significant increase in income as a result of electrification with a Hedges's G of 1.1 (CI: .07, 2.2)

As shown in figure 13, nine of the 10 studies in the meta-analysis are based predominantly on national grid connection. Nine show a moderate and statistically significant increase with a Hedges's G of 1.2 (CI: 0.1, 2.3), while one study on micro-grid connections reports a null finding. Examining the impact by region in figure 14, both the Asia Pacific, and

Figure_12 **Income**

Study name	Subgroup within study	Statistics for each study		
		Hedges' g	Lower limit	Upper limit
Adu 2018		1.97	1.91	2.02
Chaplin 2017		0.12	0.06	0.18
Rao 2010		0.12	0.04	0.21
Rathi 2018(a)	Men	3.95	3.90	3.99
Rathi 2018(a)	Women	2.96	2.90	3.02
Rathi 2018(b)	Men	0.56	0.43	0.69
Rathi 2018(b)	Women	1.10	0.98	1.23
Samad 2016		0.11	0.08	0.14
Samad 2017		0.02	-0.03	0.07
Vernet 2019		0.04	-0.13	0.22
		1.10	0.07	2.12

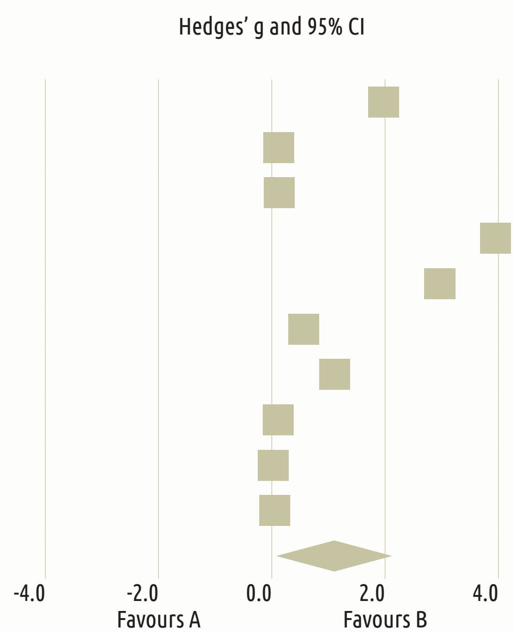
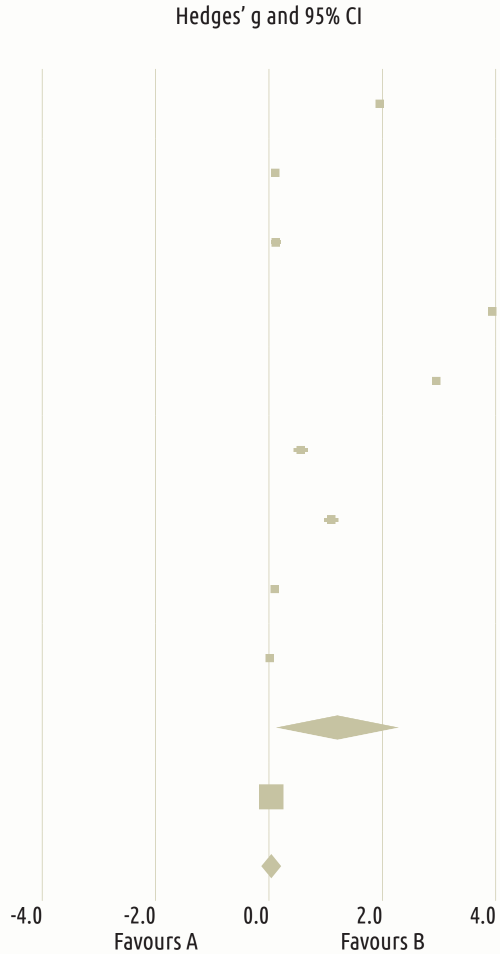


Figure_13 **Income, by intervention**

Group by intervention	Study name	Subgroup within study	Statistics for each study: Hedges' g	Lower limit	Upper limit
Grid connection	Adu 2018		1.966	1.912	2.020
Grid connection	Chaplin 2017		0.116	0.055	0.177
Grid connection	Rao 2010		0.124	0.037	0.212
Grid connection	Rathi 2018(a)	Men	3.946	3.900	3.992
Grid connection	Rathi 2018(a)	Women	2.961	2.903	3.019
Grid connection	Rathi 2018(b)	Men	0.561	0.432	0.690
Grid connection	Rathi 2018(b)	Women	1.102	0.978	1.226
Grid connection	Samad 2016		0.107	0.076	0.137
Grid connection	Samad 2017		0.022	-0.025	0.068
Grid connection			1.212	0.129	2.295
Micro-grid connection	Vernet 2019		0.043	-0.134	0.219
Micro-grid connection			0.043	-0.134	0.219



Africa region, record a large and moderate increase respectively but this is not statistically significant, possibly due to the small number of studies in each subgroup.

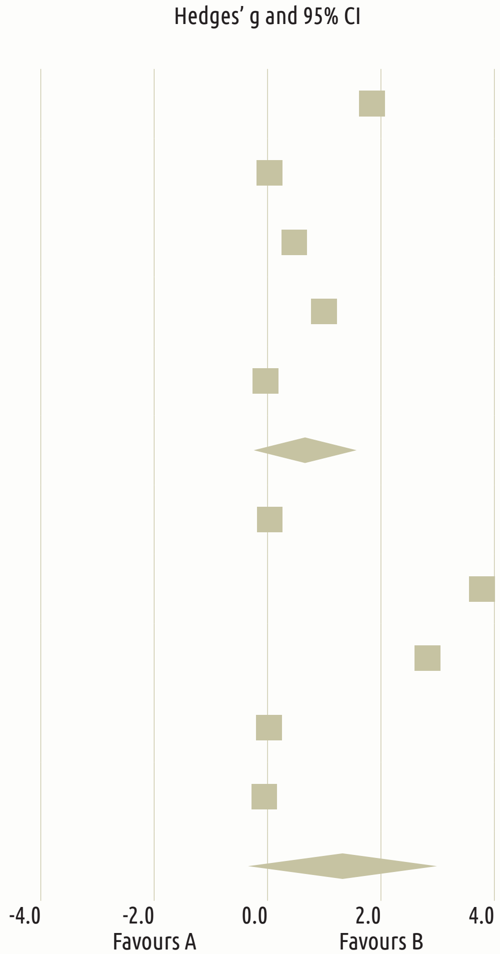
6.3.1.2 Consumption and expenditure

The meta-analyses of eight studies analyzed in figure 15 show that that electrification interventions led to a minor but statistically significant increase in consumption, with a Hedges's g of 0.16 (CI: .09, 0.23).

Examining the impact by moderators, figure 16 shows that the results from grid connections and off-grid connections are similar, with a Hedges's g of 0.17 (CI: 0.08, 0.25) and 0.11 (CI: 0.05, 0.18), respectively. However, the latter is based on only two studies, so additional research will be required to confirm these findings. By region, figure 17 shows that the impacts are significant, both in Asia and the Pacific 0.15 (CI: .07, .23) and Africa 0.20 (CI: 0.15, 0.26)

Figure_14 **Income, by region**

Group by region	Study name	Subgroup within study	Statistics for each study: Hedges' g	Lower limit	Upper limit
Africa	Adu 2018		1.97	1.91	2.02
Africa	Chaplin 2017		0.12	0.06	0.18
Africa	Rathi 2018(b)	Men	0.56	0.43	0.69
Africa	Rathi 2018(b)	Women	1.10	0.98	1.23
Africa	Vernet 2019		0.04	-0.13	0.22
Africa			0.76	-0.17	1.69
Asia and the Pacific	Rao 2010		0.12	0.04	0.21
Asia and the Pacific	Rathi 2018(a)	Men	3.95	3.90	3.99
Asia and the Pacific	Rathi 2018(a)	Women	2.96	2.90	3.02
Asia and the Pacific	Samad 2016		0.11	0.08	0.14
Asia and the Pacific	Samad 2017		0.02	-0.03	0.07
Asia and the Pacific			1.43	-0.27	3.13



6.3.1.3 Time spent working

As shown in figure 18, a statistically significant positive impact is observed on time spent working, with a Hedges's g of 0.59 [0.29, 0.89]. Overall, electrification appears to increase the working time slightly more than that of women. With the exception of Rathi's study in South Africa, all papers found limited difference between men and women.

As shown in figure 19, the moderator analysis by intervention highlights that electrification through the grid contributes to a moderate and significant increase in time spent working with a Hedges's g of 0.68 [0.35, 1.00]. Additional studies are required to confirm the findings on mini-grids with only one study reporting a negative but only a non-significant impact.

By region, figure 20 shows that no significant impact was detected in Asia and the Pacific, while a large and close-to-significant impact was recorded in Africa at 1.38 (-.01, 2.76).

Examining impacts by gender (figure 21, the summative statistic for men shows a large and

Figure_15 Consumption and expenditure

Study name	Subgroup within study	Statistics for each study		
		Hedges' g	Lower limit	Upper limit
Bridge 2016		0.21	0.13	0.29
Chaplin 2017		0.21	0.15	0.27
Grimm 2016		0.14	-0.09	0.36
Kumar 2020		0.00	-0.04	0.04
Saing 2017		0.40	0.30	0.51
Samad 2013		0.11	0.05	0.18
Samad 2016		0.10	0.07	0.13
Van de Walle 2015		0.13	0.08	0.19
		0.16	0.09	0.23

Hedges' g and 95% CI

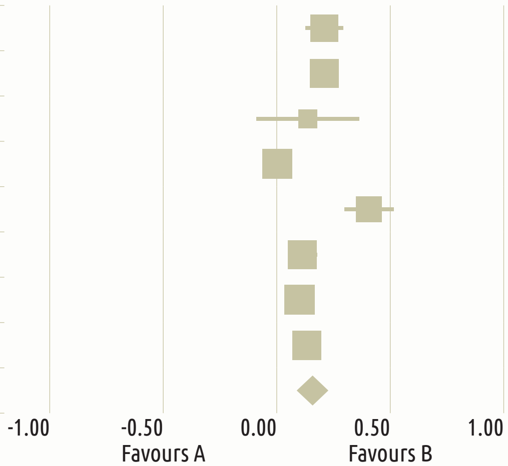


Figure_16 Consumption and expenditure, by intervention

Group by region	Study name	Subgroup within study	Statistics for each study		
			Hedges' g	Lower limit	Upper limit
Grid connection	Bridge 2016		0.21	0.13	0.29
Grid connection	Chaplin 2017		0.21	0.15	0.27
Grid connection	Kumar 2020		0.00	-0.04	0.04
Grid connection	Saing 2017		0.40	0.30	0.51
Grid connection	Samad 2016		0.10	0.07	0.13
Grid connection	Van de Walle 2015		0.13	0.08	0.25
Grid connection			0.17	0.08	0.25
Off-grid connection	Grimm 2016		0.14	-0.09	0.36
Off-grid connection	Samad 2013		0.11	0.05	0.18
Off-grid connection			0.11	0.05	0.18

Hedges' g and 95% CI

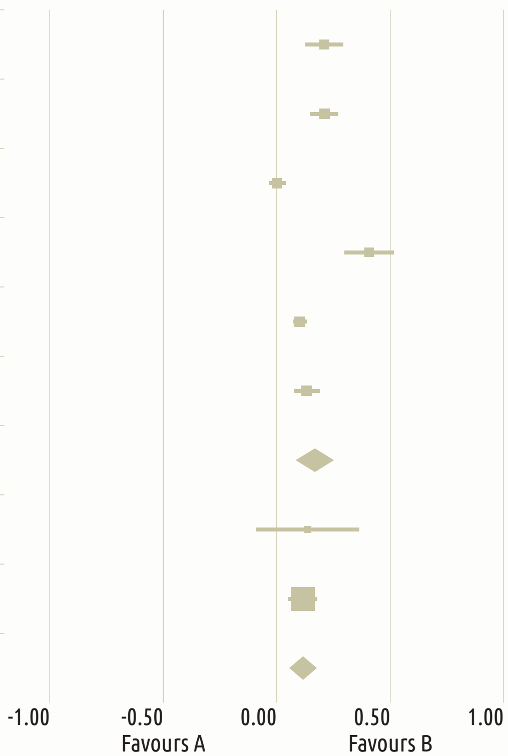


Figure_17 **Consumption and expenditure, by region**

Group by region	Study name	Subgroup within study	Statistics for each study		
			Hedges' g	Lower limit	Upper limit
Africa	Chaplin 2017		0.21	0.15	0.27
Africa	Grimm 2016		0.14	-0.09	0.36
Africa			0.20	0.15	0.26
Asia and the Pacific	Bridge 2016		0.21	0.13	0.29
Asia and the Pacific	Kumar 2020		0.00	-0.04	0.04
Asia and the Pacific	Saing 2017		0.40	0.30	0.51
Asia and the Pacific	Samad 2013		0.11	0.05	0.18
Asia and the Pacific	Samad 2016		0.10	0.07	0.13
Asia and the Pacific	Van de Walle 2015		0.13	0.08	0.19
Asia and the Pacific			0.15	0.07	0.23

Hedges' g and 95% CI

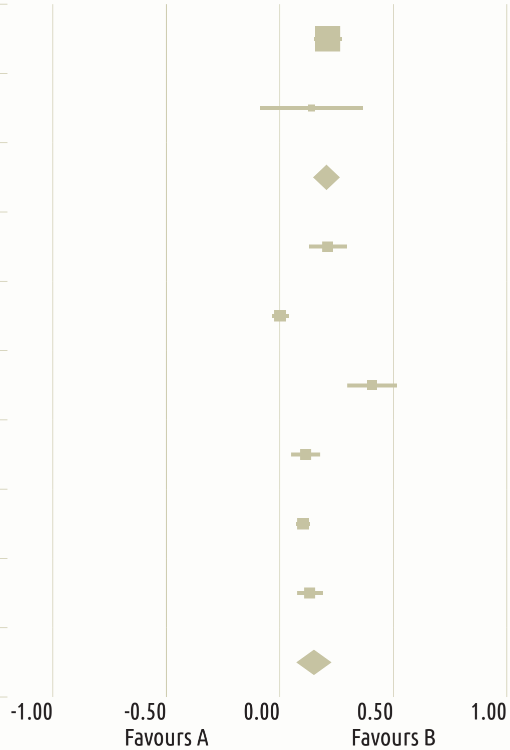


Figure_18 **Time spent working**

Study name	Subgroup within study	Statistics for each study		
		Hedges' g	Lower limit	Upper limit
Aklin 2017	Women	-0.103	-0.216	0.010
Rathi 2018	Men	4.547	4.321	4.773
Rathi 2018	Women	-0.288	-0.405	-0.171
Salmon 2016	Men	0.733	0.627	0.839
Salmon 2016	Women	0.537	0.422	0.652
Samad 2016	Men	0.000	-0.030	0.031
Samad 2016	Women	0.003	-0.027	0.034
Van de Walle 2015	Men	0.172	0.116	0.227
Van de Walle 2015	Women	-0.087	-0.143	-0.032
		0.589	0.291	0.888

Hedges' g and 95% CI

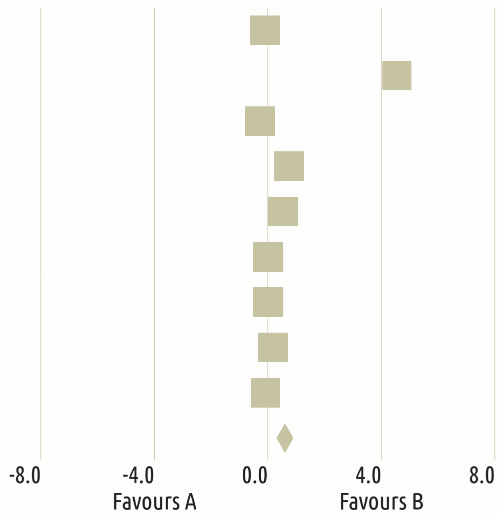


Figure_19 Time spent working, by intervention

Study name	Subgroup within study	Statistics for each study		
		Hedges' g	Lower limit	Upper limit
Aklin 2017	Women	-0.103	-0.216	0.010
Rathi 2018	Men	4.547	4.321	4.773
Rathi 2018	Women	-0.288	-0.405	-0.171
Salmon 2016	Men	0.733	0.627	0.839
Salmon 2016	Women	0.537	0.422	0.652
Samad 2016	Men	0.000	-0.030	0.031
Samad 2016	Women	0.003	-0.027	0.034
Van de Walle 2015	Men	0.172	0.116	0.227
Van de Walle 2015	Women	-0.087	-0.143	-0.032
		0.589	0.291	0.888

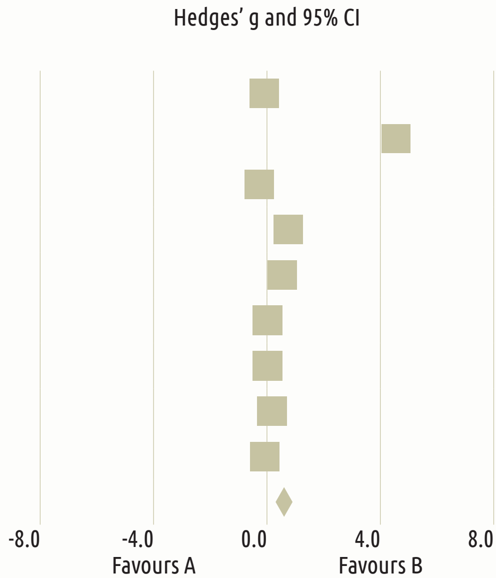


Figure_20 Time spent working, by region

Group by region	Study name	Subgroup within study	Statistics for each study		
			Hedges' g	Lower limit	Upper limit
Africa	Rathi 2018	Men	4.55	4.32	4.77
Africa	Rathi 2018	Women	-0.29	-0.41	-0.17
Africa	Salmon 2016	Men	0.73	0.63	0.84
Africa	Salmon 2016	Women	0.54	0.42	0.65
Africa			1.38	-0.01	2.76
Asia and the Pacific	Aklin 2017	Women	-0.10	-0.22	0.01
Asia and the Pacific	Samad 2016	Men	0.00	-0.03	0.03
Asia and the Pacific	Samad 2016	Women	0.00	-0.03	0.03
Asia and the Pacific	Van de Walle 2015	Men	0.17	0.12	0.23
Asia and the Pacific	Van de Walle 2015	Women	-0.09	-0.14	-0.03
Asia and the Pacific			0.00	-0.07	0.07

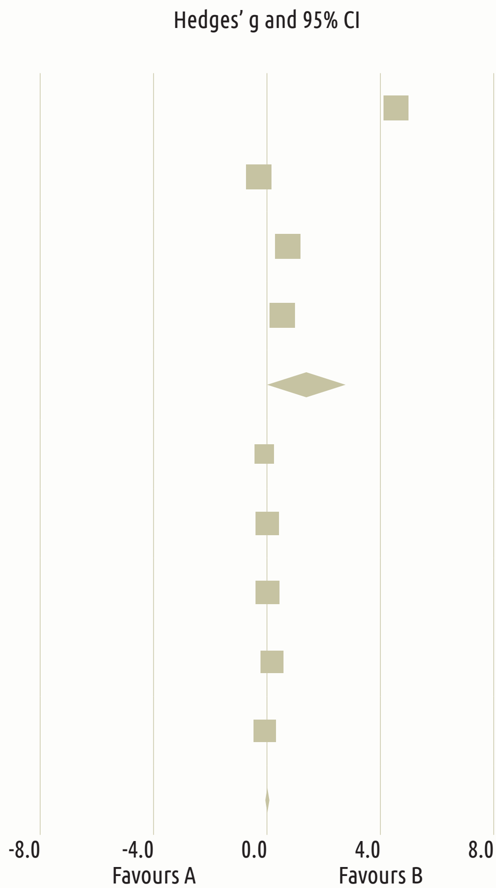


Figure_21 **Time spent working by gender**

Group by subgroup within study	Study name	Subgroup within study	Statistics for each study		
			Hedges' g	Lower limit	Upper limit
Men	Rathi 2018	Men	4.55	4.32	4.77
Men	Salmon 2016	Men	0.73	0.63	0.84
Men	Salmon 2016	Men	0.00	-0.03	0.03
Men	Van de Walle 2015	Men	0.17	0.12	0.23
Men			1.35	0.56	2.14
Women	Aklin 2017	Women	-0.10	-0.22	0.01
Women	Rathi 2018	Women	-0.29	-0.41	-0.17
Women	Salmon 2016	Women	0.54	0.42	0.65
Women	Samad 2016	Women	0.00	-0.03	0.03
Women	Van de Walle 2015	Women	-0.09	-0.14	-0.03
Women			0.01	-0.16	0.18

Hedges' g and 95% CI

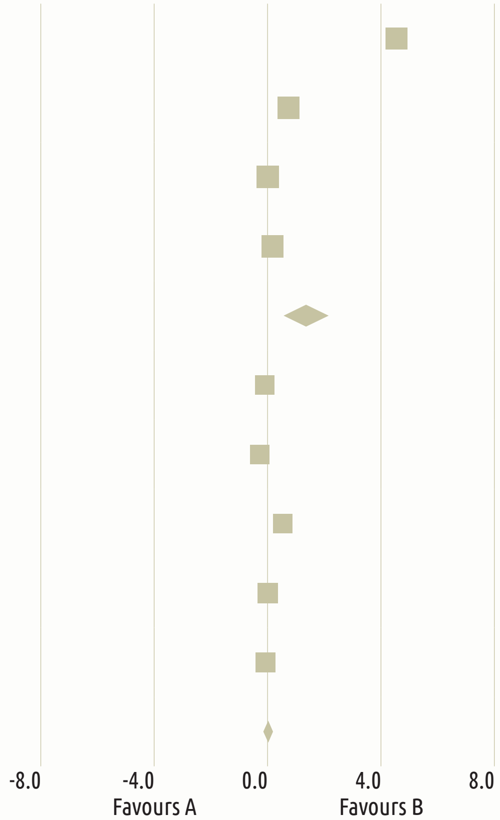


Figure_22 **Employment status**

Study name	Subgroup within study	Statistics for each study		
		Odds ratio	Lower limit	Upper limit
Barron 2019	Men	0.69	0.50	0.88
Barron 2019	Women	1.41	1.20	1.61
Grogan 2013	Men	-0.10	-0.16	-0.03
Grogan 2013	Women	1.19	1.11	1.26
Litzow 2019	Men	0.06	0.03	0.09
Litzow 2019	Women	0.08	0.05	0.11
Rathi 2018(a)	Men	-1.95	-1.98	-1.93
Rathi 2018(a)	Women	0.70	0.68	0.73
Rathi 2018(b)	Men	0.35	0.28	0.43
Rathi 2018(b)	Women	0.28	-0.42	0.97
		0.28	-0.42	0.97

Odds ratio and 95% CI

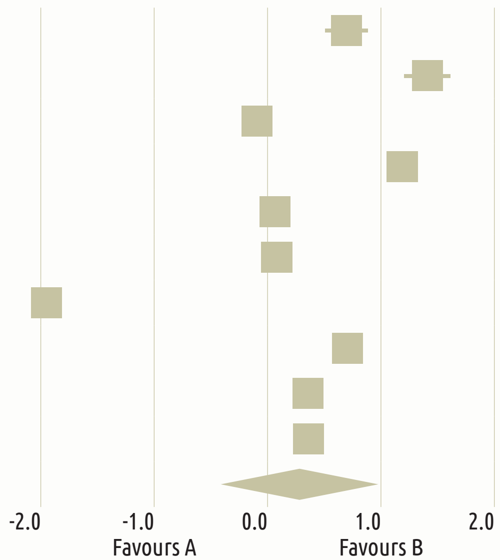
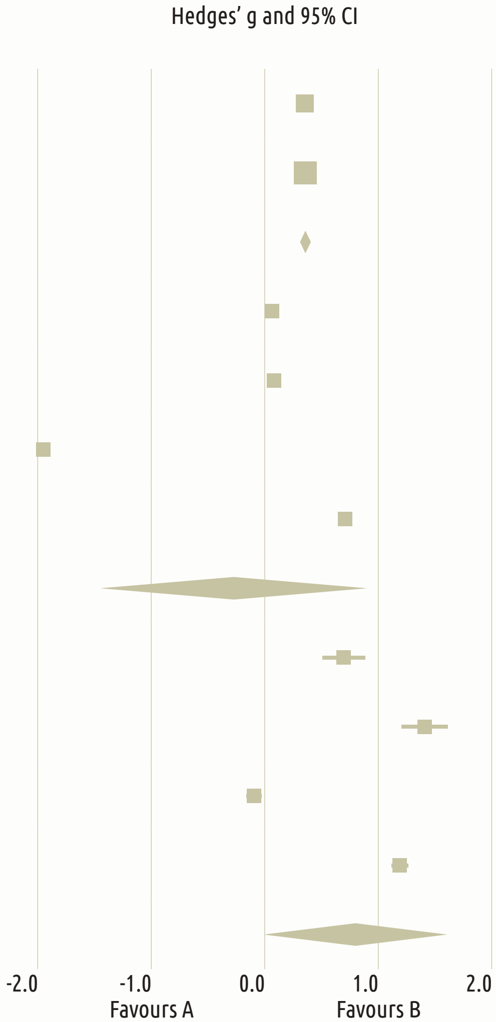


Figure_23 **Employment status, by region**

Group by region	Study name	Subgroup within study	Statistics for each study: Hedges' g	Lower limit	Upper limit
Africa	Rathi 2018(b)	Men	0.35	0.28	0.43
Africa	Rathi 2018(b)	Women	0.36	0.30	0.42
Africa			0.36	0.31	0.40
Asia and the Pacific	Litzow 2019	Men	0.06	0.03	0.09
Asia and the Pacific	Litzow 2019	Women	0.08	0.05	0.11
Asia and the Pacific	Rathi 2018(a)	Men	-1.95	-1.98	-1.93
Asia and the Pacific	Rathi 2018(a)	Women	0.70	0.68	0.73
Asia and the Pacific			-0.28	-1.45	0.90
Latin America and the Caribbean	Baron 2019	Men	0.69	0.50	0.88
Latin America and the Caribbean	Baron 2019	Women	1.41	1.20	1.61
Latin America and the Caribbean	Grogan 2013	Men	-0.10	-0.16	-0.03
Latin America and the Caribbean	Grogan 2013	Women	1.19	1.11	1.26
Latin America and the Caribbean			0.80	-0.01	1.61



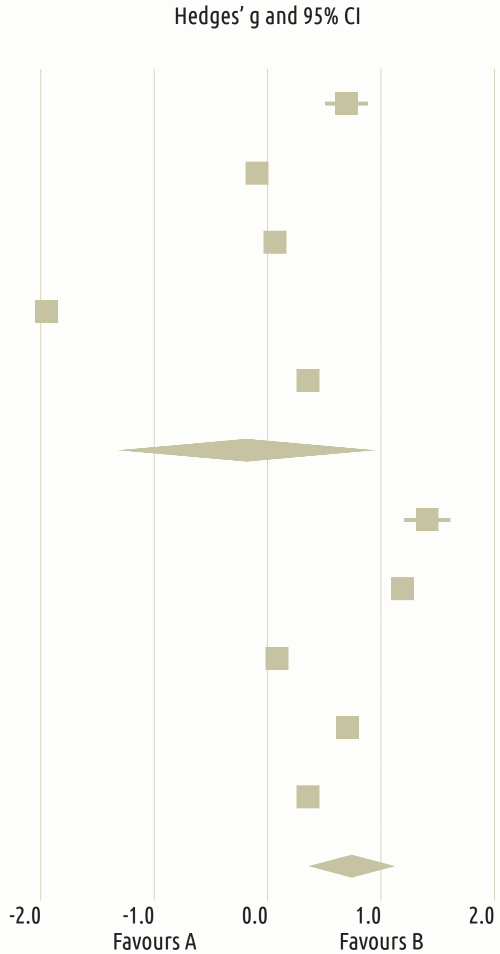
significant increase in time spent working with a Hedges's G of 1.35 (0.56, 2.14). The impact of electrification on women's time spent working was negligible with a Hedges's G of 0.01 (-0.16, 0.18). These differential impacts by gender are discussed in more detail in the heterogenous findings.

6.3.1.4 Employment status

As shown in figures 22 and 23, electrification had a small and non-significant impact on employment with a Hedges's g of 0.28 [-.42, 0.97]. The moderator analysis by gender in figure 24 shows that electrification had a positive and significant effect of 0.74 [.36, 1.12] on women's employment status, whereas men experienced a slightly negative non-significant effect with a Hedges's G of -0.19 (-1.33, 0.95. As there were only a few studies from each subregion, it was not possible to discern any region-specific impacts. All of these studies focused predominantly on national grid connections.

Figure_24 **Employment status, by gender**

Group by subgroup within study	Study name	Subgroup within study	Statistics for each study		
			Hedges' g	Lower limit	Upper limit
Men	Baron 2019	Men	0.69	0.50	0.88
Men	Grogan 2013	Men	-0.10	-0.16	-0.03
Men	Litzow 2019	Men	0.06	0.03	0.09
Men	Rathi 2018(a)	Men	-1.95	-1.98	-1.93
Men	Rathi 2018(b)	Men	0.35	0.28	0.43
Men			-0.19	-1.33	0.95
Women	Baron 2019	Women	1.41	1.20	1.61
Women	Grogan 2013	Women	1.19	1.11	1.26
Women	Litzow 2019	Women	0.08	0.05	0.11
Women	Rathi 2018(a)	Women	0.70	0.68	0.73
Women	Rathi 2018(b)	Women	0.36	0.30	0.42
Women			0.74	0.36	1.12



6.3.1.5 Heterogenous findings – economic outcomes

The meta-analysis finds that electrification led to a sizeable increase in the economic outcomes for beneficiaries. Qualitative findings, however can shed light on how progressive electrification interventions have been in terms of their distributional effects.

Distributional impacts of electricity access

Income equality

Empirical evidence suggests that groups with higher initial economic endowment often benefit more from electrification programmes. Many studies examined how equitable electrification programmes were in terms of whether they had differential impacts on richer and poorer households. While it was not possible to conduct a meta-analysis of these findings, this section explores these findings qualitatively. As shown in table 4, of the eight studies that examined inequality, Table_4 **Inequality in economic impacts of electrification**

Study	Country	Measure	Distributional impact
Khandker (2012)	Bangladesh	Income Expenditure	H – Households in the 85th percentile benefitted almost twice as much as those in the 15th percentile (23.9 per cent versus 12.4 per cent increase) H – Households in the 15th percentile appear not to benefit at all compared to households in all higher percentiles
Samad (2017)		Income Expenditure	H – No significant impact for households below the 60th percentile of the income distribution compared to the top 40% households H – households in the 80th percentile benefitted nearly three times more than households in the 20th percentile
Saing (2018)	Cambodia	Consumption	H – 75th percentile households experienced a 36% increase versus a 22% increase for households in the 25th percentile
Adu (2018)	Ghana	Income Expenditure	L – Over 50% increase for the lowest and middle quartile. No significant impact on richer households in the top quartile.
Khandker (2012)	India	Income Expenditure	H – Households in the 85th percentile benefited almost twice as much as those in the 15th percentile H – No significant impact on households in the 15th and 25th percentile. Households in the highest quantile benefited twice more than the middle quartile (30 per cent versus 16 per cent)
Samad (2016)		Expenditure	L – Low-income households benefited more than high-income households by 10% percentage points.
Chaplin (2017)	Tanzania	Consumption Share of households operating income-generating activity	Expenditures increased across all income quartiles. L – Share of households operating any income generating activity increased by 15 percentage points for households in the lowest income quartile, while no effect was observed among other income groups.
Khandker (2013)	Viet Nam	Income	H – No significant impact on households in the 15th income percentile as opposed to a 41% increase for households in 85th percentile

five found that electricity access benefited wealthier households more, while 3 found that it benefited poor households more[35,36]. All of these studies looked at grid-connections with a focus on efforts towards nation-wide electrification. Richer households benefitted more than poorer households in Bangladesh (Khandker, 2012; and Samad, 2017), Cambodia (Saing, 2018) and Viet Nam (Khandker, 2013). In the case of Ghana (Adu, 2018) returns to electrification are higher for the lowest and middle quartile.

Some evidence from India suggests that on average, rural electrification initiatives have been progressive. Based on a cross-sectional analysis in India, Khandker (2012) records a 26 per cent income increase for poorer households compared with a nearly 46 per cent rise for the richest households. However,

35 The results in table 4 are based on quintile regressions and thereby give a quantitative estimate of the impact across groups with different economic endowment. The quantitative estimates allow distinguishing whether richer households benefit more (indicated by 'R') or poorer households benefit more (indicated by 'P'), on average.

36 Studies are based on a subset of the population and may not accurately reflect national impacts of electrification overall. Findings should therefore not be interpreted as a generalization for the respective countries.

Samad (2016) conducted a similar analysis based on expenditure and found that low-income households had benefited more than high-income households. While both papers used similar data from the Indian Household Demographic Survey (IHDS), Samad's paper investigated these impacts over the long-term (2005-2012). Accounting for the difference in these two results, Samad (2016) proposed a plausible explanation that "over time, the rate of return from electrification declines among richer households, while poorer households catch up by diversifying their electricity use".

Examining the urban-rural divide, Kumar (2020) found that an "electricity connection" increased monthly per capita consumption for urban areas by 78% compared with only 56% for rural areas. This suggests that electrification results in greater economic benefit in urban areas, possibly due to higher baseline income or access to resources.

Farm and non-farm Income

Rural electrification usually increases non-farm income more than farm-income. Electrification can increase farm income by facilitating the automation of agricultural practices through adoption of technology, thereby increasing farm productivity. In addition, it can encourage households and/or individuals to seek new non-farm business opportunities (Rao, 2012).

Individual studies suggest that electrification usually increases non-farm income more than farm-income. Rao (2012) and Kumar (2018) observed that in Bhutan, non-farm income increased by 72% and 62%, respectively, while no significant impact was observed for farm income. Kumar (2018) noted that because non-farm income accounts for only a very small portion of total income among the study households, this change may be inconsequential.[37] Samad (2016) and Samad (2017) also detected significant increases in non-farm income in India and Bangladesh, suggesting that electrification led to further diversification of economic activity.

Changes in household routines

Electrification can alter households' daily routines through extended lighting hours, entertainment options and by freeing up time from household chores; however, more research is needed on how this translates to economic benefits. In Rwanda, 3.5 years after the rollout of a national electrification programme. Lenz (2017) found that although there was some uptake of new appliances (mainly lighting, radios, TV sets and electronic irons), these were mostly used for non-productive purposes. As a result, people in electrified communities spent 50 minutes longer awake, on average, compared with people in non-electrified communities mainly due to extended lighting hours and entertainment. Evidence of impacts on income and other poverty indicators was weak with only a slight increase in local micro-enterprises. In Tanzania, the impact of grid electrification on time spent on income-generating activities was inconclusive. However, both adults and children spent less time collecting fuel and water,[38] while men spent less time preparing food.[39] There was a marked increase in the time spent by adults and children watching television and socializing (by 1.15-1.45 hours).

Firm outcomes

Overall, the results show no impact on financial performance, but demonstrate that in some cases electrification led to creation of more

37 Focus group discussions suggested that local micro-enterprise experienced a boost in terms of new firm creation and financial performance. The lack of an impact on farm-income makes sense as the majority of agriculture is subsistence-based. in addition to the mountainous terrain and small-farm size ownership in Bhutan (Kumar, 2018).

38 men = -0.26 hours and women =- 0.09 hours

39 0.08 hours

local businesses. Peters (2011) analysed the profits of firms in Ghana and found no significant impact as a result of grid connection. Pueyo (2018) studied the effect of solar mini grids on financial performance and new firm creation, and found that two years after the intervention neither had improved. Businesses did extend their operational hours, but this did not translate into higher profits. In contrast to these results, a study by Peters (2011) in northern Benin did find a positive effect on firm creation, but no effect on financial performance of existing businesses. Vernet (2019) similarly assessed the impact of a solar micro-grid at a local trading center in Kenya and found that this led to an increase in firm creation.

Access quality and reliability

Studies overwhelmingly show that unreliable or limited access to electricity – for example, due to frequent power shortages – restricts the full realization of benefits. Some studies quantitatively define access quality as the duration or capacity (e.g., Kwh) of the supply or the estimated impact in the absence of power outages. Samad (2016) estimated that while a grid connection resulted in a 9.6 per cent increase in income, the impact on those with 24-hour-per-day power was nearly double. Defining quality as the number of hours of supply per day, Chakravorty (2014) found similar results – a grid connection increased non-agricultural income by 9 per cent while quality access resulted in a 28 per cent increase.[40] Ganguly (2020) measured the impact of longer access duration on micro-enterprises and reported an increase in operating hours and customer footfall, although no increase in revenue was detected. In view of this, Akpandjar (2017) suggested that unreliable access may even have a negative impact on financial performance as businesses divert resources towards backup capacity or revert to traditional fuels to cope with service interruptions. Khandker (2012) also noted that in addition to productivity losses, power outages may even damage machinery.

In addition, Aklin (2017) observed no causal effects of a low-capacity solar microgrid on time spent working in India. The connection enabled only basic lighting and phone charging – the level of electricity supply was inconsequential for productivity enhancement. Similarly, Grimm (2016) did not find a significant impact of low-cost Pico-photovoltaic kits on people's time dedicated to income generating activities in Rwanda.

Complementary drivers for rural electrification

Barron (2014) suggested that access to electricity may increase household income, depending on local economic dynamism and the extent to which income-generating activities were not being exploited beforehand. A favourable economic environment and access to non-farm employment appear essential to realizing the greater benefits from electrification. Ganguly (2020), Kumar (2018) and Samad (2017) further pointed out that additional measures, such as market linkages, business development and access to capital services, should be combined with electricity access interventions to bolster income-generating activities and to deploy non-farm employment opportunities. Peters (2011) similarly suggested that limited market access undermined the productive use of electricity. When a region does not have the market potential to take in the expanded production, the development impacts of interventions would be optimized when accompanied by technical, information and financial assistance. Adu (2018) also recommended that rural electrification projects should be complemented with non-farm economic ventures to expand the

40 Samad (2016) noted an 37% increase in farm income when controlled for power outages as opposed to the 15% increase otherwise.

productive use of electricity. Accordingly, Fetter (2020) found that electricity access had greater impacts in north-western India, where complementary economic opportunities were available, in comparison to other Indian regions. Future research should study further the complementary drivers that maximize the success of rural electrification programmes.

Comparing grid connections with decentralized technologies

Effect sizes for decentralized technologies must be interpreted with regard to local context and systematic differences in the populations being studied. The meta-analyses demonstrate that electrification, whether from grid extension or mini-grids, resulted in significant benefits; however, comparing the results of decentralized technologies (mini-grids, micro-grids and off-grid stand-alone systems) to national grid connections, shows that the impacts in some cases are smaller in magnitude. This trend should be interpreted with caution because the areas in which these technologies are deployed may be systematically different to areas where the national grid is present. Areas receiving decentralized solutions are likely to be much more remote and less economically developed than areas eligible for grid extension. As a result, impacts may be smaller, primarily due to the differences in geography and local context.

Impact by gender

The distributional impact of electrification on labour market mechanisms pose a complex picture and are highly dependent on socio-political structures, local gender norms and labour market characteristics. Economic impacts by gender were highly heterogenous – some studies demonstrate that electrification had a larger effect on men (Dasso, 2015; Rathi, 2018; Salmon, 2016; and van de Walle, 2015) and others on women (Barron, 2019; Grogan, 2018; Khandker, 2012; Samad, 2016; and Samad, 2018). While the meta-analysis finds a negligible impact overall on women's working time, more women were brought into the fold of employment as a result of electrification. Inversely, men were working longer hours even though the impact on overall employment status attributable to electrification is negligible. Individual studies add to the complexity:

- Rathi (2018) found that in India, the working hours of men declined while women experienced a rise. A simultaneous increase in earnings occurred in both groups;41

- In South Africa, Rathi (2018) found that working hours of men increased while for women they did not. Interestingly, women experienced a much more significant rise in earnings.[42] One possible reason is that electrification relieved women of unpaid and physically intensive household chores, allowing them to perform labour market activities more productively;

- In El Salvador, Barron (2019) observed that four years after an electrification programme, gains in women's employment exceeded those for men. Women increasingly engaged in home-based businesses and non-farm employment. This was accompanied with an annual income increase of US$ 450 for women, which was more than twice that of men (from an average value of around US$1,500 in the control group);[43]

- Dasso (2013) found that Peru's nationwide rural electrification projects between 1993

41 It is important to note that these results are highly sensitive to the model used. For example, PSM results showed that men's employment hours actually rose significantly.

42 It should be noted that this effect was limited to women who could find jobs or were already employed. It does not necessarily imply that more women were brought into the fold of employment

43 0.5 Standard Deviations

and 2012 significantly increased women's probability of becoming employed or starting businesses, ultimately leading to a 35% increase in income among women. Electrification's impact on men's earnings was near-negligible despite working an additional 2.5 hours per week. Dasso stated that electrification may have also positively contributed to the gender wage gap;

- Grogan (2008) found that in Guatemala, younger women benefitted more from community level electrification in terms of increased labour force participation. On the whole, adults became less likely to work in agriculture as they could diversify their income sources.

6.3.2 Effects of interventions on education outcomes

6.3.2.1 Study time

As shown in figure 25, there were 14 studies that analysed study time. The meta-analysis of these findings demonstrated a small but statistically significant increase in study time as a result of electrification with a Hedges's G of 0.22 (CI: .15, .29). Only one study demonstrated a significant negative impact, while the remaining results were consistent.

The moderator analysis by intervention shown in figure 26 suggests that grid connections and off-grid connections both led to a significant

Figure_25 **Study time**

Study name	Subgroup within study	Statistics for each study		
		Hedges' g	Lower limit	Upper limit
Bensch 2013	Children	0.49	0.23	0.74
Chaplin 2017	Children 15-24	0.18	0.12	0.24
Chaplin 2017	Children 5-14	0.26	0.20	0.32
Grimm 2016	Boys 12-17	0.39	-0.20	0.81
Grimm 2016	Boys 6-11	0.31	-0.08	0.70
Grimm 2016	Girls 12-17	0.21	-0.19	0.62
Grimm 2016	Girls 6-11	0.17	-0.23	0.58
Samad 2016	Boys 5-18	0.16	0.12	0.19
Samad 2016	Girls 5-18	0.10	0.07	0.14
Aguirre 2017	Children 5-15	0.95	0.76	1.13
Karumba 2017	Children	-0.43	-0.70	-0.17
Kumar 2018	Children 7-18	0.21	0.12	0.30
Samad 2013	Boys 5-18	0.14	0.07	0.20
Samad 2013	Girls 5-18	0.16	0.10	0.23
		0.22	0.15	0.29

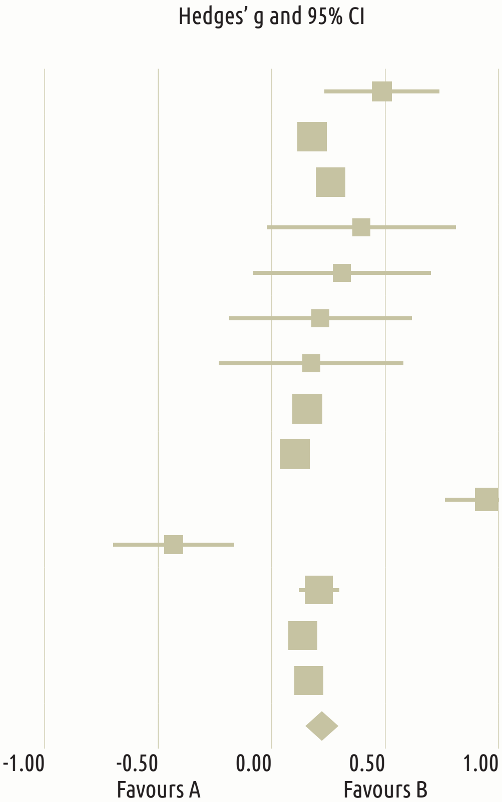
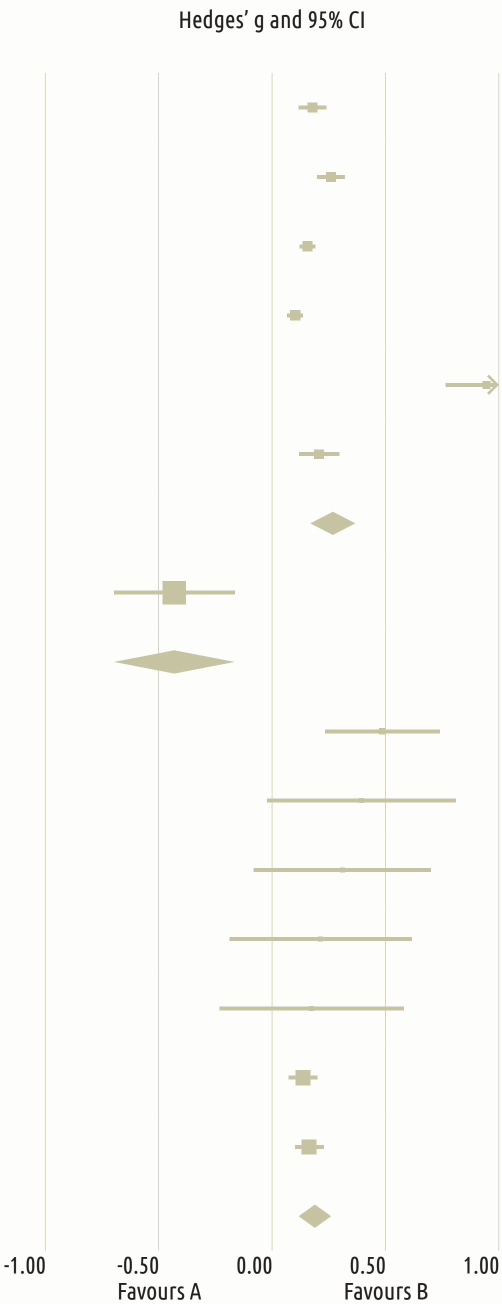


Figure_26 **Study time, by intervention**

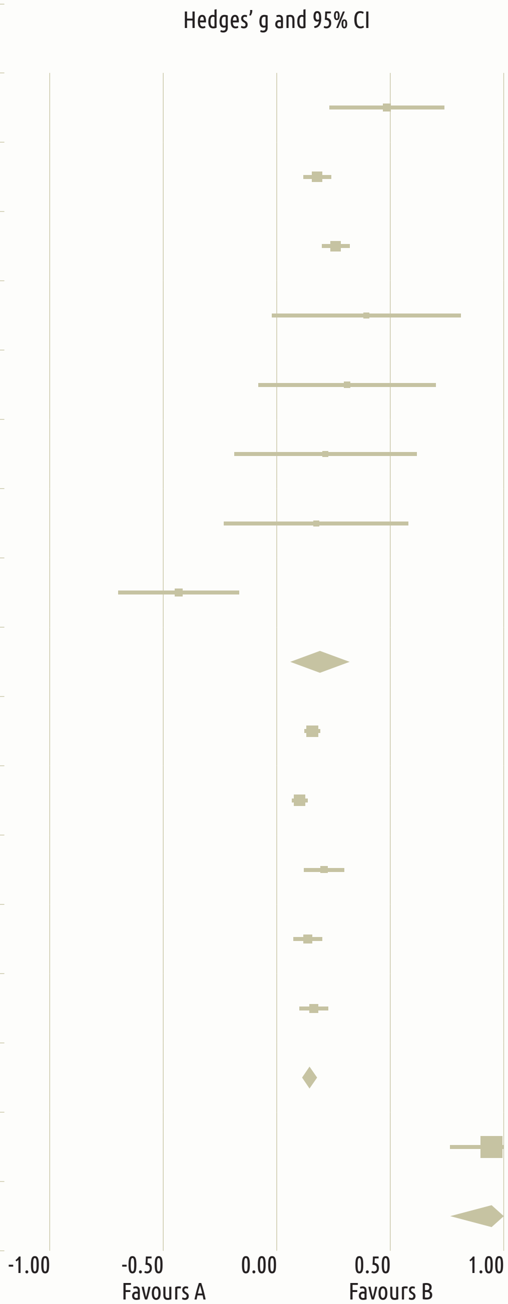
Group by intervention	Study name	Subgroup within study	Statistics for each study: Hedges' g	Lower limit	Upper limit
Grid connection	Chaplin 2017	Children 15-24	0.178	0.117	0.240
Grid connection	Chaplin 2017	Children 5-14	0.260	0.199	0.321
Grid connection	Samad 2016	Boys 5-18	0.156	0.122	0.190
Grid connection	Samad 2016	Girls 5-18	0.101	0.066	0.136
Grid connection	Aguirre 2017	Children 5-15	0.947	0.764	1.129
Grid connection	Kumar 2018	Children 7-18	0.207	0.119	0.296
Grid connection			0.268	0.169	0.367
Micro-grid connection	Karumba 2017	Children	-0.432	-0.696	-0.165
Micro-grid connection			-0.432	0.696	-0.165
Off-grid connection	Bensch 2013	Children	0.486	0.232	0.739
Off-grid connection	Grimm 2016	Boys 12-17	0.394	-0.022	0.810
Off-grid connection	Grimm 2016	Boys 6-11	0.310	-0.082	0.701
Off-grid connection	Grimm 2016	Girls 12-17	0.214	-0.188	0.617
Off-grid connection	Grimm 2016	Girls 6-11	0.174	-0.232	0.580
Off-grid connection	Samad 2013	Boys 5-18	0.137	0.074	0.200
Off-grid connection	Samad 2013	Girls 5-18	0.164	0.101	0.227
Off-grid connection			0.189	0.117	0.260



increase in study time. The impact was slightly larger for grid connections with a Hedges's g of 0.27 [0.17, 0.37], compared with a Hedges's g of 0.189 [0.117,0.260] for off-grid connections. For both technologies, all studies demonstrated positive results, although more of the off-grid connection interventions were statistically significant. Only one study examined micro-

Figure_27 **Study time, by region**

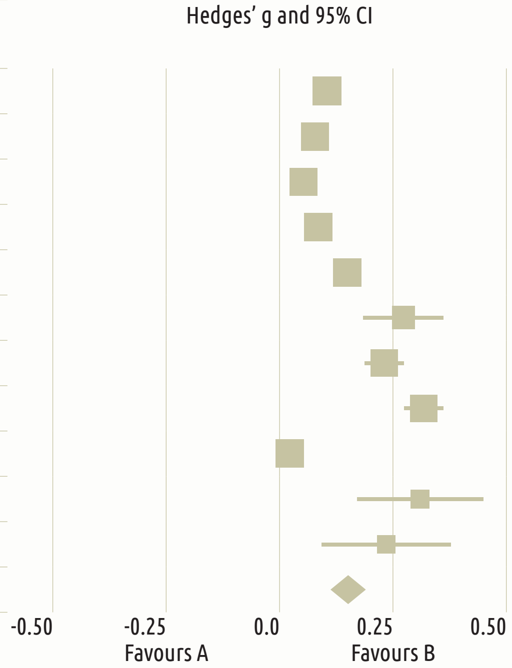
Group by region	Study name	Subgroup within study	Statistics for each study		
			Hedges' g	Lower limit	Upper limit
Africa	Bensch 2013	Children	0.49	0.23	0.74
Africa	Chaplin 2017	Children 15-24	0.18	0.12	0.24
Africa	Chaplin 2017	Children 5-14	0.26	0.20	0.32
Africa	Grimm 2016	Boys 12-17	0.39	-0.02	0.81
Africa	Grimm 2016	Boys 6-11	0.31	-0.08	0.70
Africa	Grimm 2016	Girls 12-17	0.21	-0.19	0.62
Africa	Grimm 2016	Girls 6-11	0.17	-0.23	0.58
Africa	Karumba 2017	Children	-0.43	-0.70	-0.17
Africa			-0.18	-0.39	0.02
Asia and the Pacific	Samad 2016	Boys 5-18	0.16	0.12	0.19
Asia and the Pacific	Samad 2016	Girls 5-18	0.10	0.07	0.14
Asia and the Pacific	Kumar 2018	Children 7-18	0.21	0.12	0.30
Asia and the Pacific	Samad 2013	Boys 50-18	0.14	0.07	0.20
Asia and the Pacific	Samad 2013	Girls 5-18	0.16	0.10	0.23
Asia and the Pacific			0.14	0.11	0.18
Latin America and Caribbean	Aguirre 2017	Children 5-15	0.95	0.76	1.13
Latin America and Caribbean			0.95	0.76	1.13



grids, which surprisingly reported a negative impact on study time. More studies on micro-grids will be needed to determine whether this finding is an anomaly. The impact by region, as shown in figure 27, is positive for both Africa, and Asia and the Pacific, although the estimate is higher for the latter.

Figure_28 **Years of schooling**

Study name	Subgroup within study	Statistics for each study: Hedges' g	Lower limit	Upper limit
Akpandjar 2017	Children (urban and rural)	0.10	0.10	0.11
Khandler 2012(a)	Boys	0.08	0.05	0.11
Khandler 2012(a)	Girls	0.05	0.02	0.08
Khandler 2012(b)	Boys	0.09	0.06	0.11
Khandler 2012(b)	Girls	0.15	0.12	0.18
Kumar 2018	Children 7-18	0.27	0.18	0.36
Litzow 2019	Boys	0.23	0.19	0.27
Litzow	Girls	0.32	0.27	0.36
Lopez 2018	Adults 19+	0.02	-0.00	0.05
Saing 2017	Boys	0.31	0.17	0.45
Saing 2017	Girls	0.24	0.09	0.38
		0.15	0.11	0.19



6.3.2.1 Years of schooling

As shown in figure 28, electrification had a small but significant positive impact on years of schooling with a Hedges's g of 0.15 [0.11, 0.19]. The results are largely consistent, with most studies reporting significant positive impacts; only one study reported a null finding. All of these studies focused on connections to the national grid.

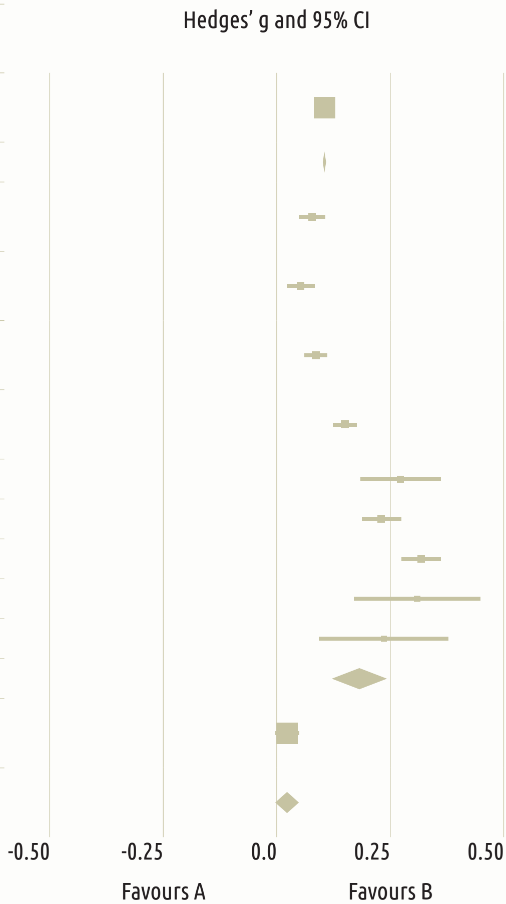
The moderator analysis by region (figure 29) shows that the majority of these studies took place in the Asia-Pacific region, demonstrating a significant positive impact with a Hedges's g of 0.18 [0.12, 0.24]. There were not enough studies in Africa, Latin America and the Caribbean region to allow conducting an analysis for those regions.

6.3.2.2 Heterogenous findings: Education

Overall, providing households with an electric connection had a positive impact on educational outcomes. In Peru, Aguirre (2017) observed that rural electrification efforts launched since 2006 led children to study an extra 94- 37 minutes at home per day, on average. Samad (2013) found that adoption of solar home systems in Bangladesh led to an increase of 7-8 minutes among children. Similarly, children living in households with solar home systems in Senegal spent 30 more minutes on studying than children living in non-electrified households (Bensch, 2013). Finally, Karumba's findings (2017) on the impact of a micro-grid connection stand in stark contrast as children in electrified households were found to be devoting 43 minutes less to evening studies than children in unelectrified households. The author states that this may

Figure_29 **Years of schooling, by region**

Group by region	Study name	Subgroup within study	Statistics for each study: Hedges' g	Lower limit	Upper limit
Africa	Akpandjar 2017	Children (urban and rural)	0.10	0.10	0.11
Africa			0.10	0.10	0.11
Asia and the Pacific	Khandker 2012(a)	Boys	0.08	0.05	0.11
Asia and the Pacific	Khandker 2012(a)	Girls	0.05	0.02	0.08
Asia and the Pacific	Khandker 2012(b)	Boys	0.09	0.06	0.11
Asia and the Pacific	Khandker 2012(b)	Girls	0.15	0.12	0.18
Asia and the Pacific	Kumar 2018	Children 7-18	0.27	0.18	0.36
Asia and the Pacific	Litzow 2019	Boys	0.23	0.19	0.27
Asia and the Pacific	Litzow 2019	Girls	0.32	0.27	0.36
Asia and the Pacific	Saing 2017	Boys	0.31	0.17	0.45
Asia and the Pacific	Saing 2017	Girls	0.24	0.09	0.38
Asia and the Pacific			0.18	0.12	0.24
Latin America and Caribbean	Lopez 2018	Adults 19+	0.02	-0.00	0.05
Latin America and Caribbean			0.02	-0.00	0.05



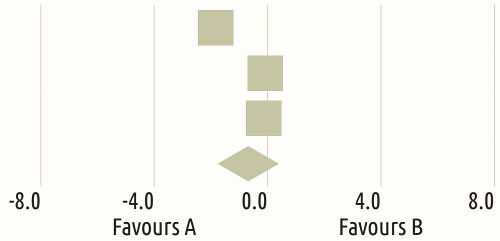
be due to children spending more time on other activities such as watching television or listening to a radio.

While access to electrification is associated with increased years of schooling and time spent studying for all children, there is no clear trend of who benefits the most. Litzow (2019) found that grid electrification in Bhutan had a greater effect for girls as years of schooling increased by 1.12 years, compared to 0.68 years for boys. This is because access to electricity reduced the time spent on fuel collection and preparation, a task usually undertaken by girls. On the contrary, an evaluation of rural electrification in Cambodia increased the likelihood of primary school enrollment for boys by 9.7%, but not for girls. In addition, the years of schooling for boys increased by 0.85 and by 0.62 for girls (Saing, 2017).

In order to enhance the benefits of electrification on education outcomes, Cajiao (2018) suggested that electricity access should come together with other public policy strategies that inform households of the best opportunities to harness all the advantages that electricity can bring.

Figure_30 **Fertility (number of children)**

Study name	Subgroup within study	Statistics for each study: Hedges' g	Lower limit	Upper limit
Akpandjar 2017		-1.83	-1.92	-1.74
Rao 2010		-0.09	-0.17	0.00
Fujii 2019		-0.14	-0.214	-0.06
		-0.68	-1.76	0.40



Three papers analysed the effects on child employment, either as a mechanism that undermined the results of schooling or as an outcome itself. Squires (2015) found that school drop-out rates in Honduras rose after electrification. One of the factors that contributed to this was an increase in childhood labour of 2.38 percentage points. Lopez (2018) found that in Brazil electrification resulted in lower childhood employment rates in poorer municipalities but higher rates in richer municipalities; however, those results were not significant. However, in comparison to poorer areas, richer municipalities with relatively mature labour markets may create more jobs and better incentives for working as opposed to studying. In other words, the opportunity cost of studying may have been higher in richer municipalities, leading to an increase in child employment.

Akpandjar (2017) noted that as a result of electrification, the fraction of children working fell by 4.18 percentage points in Ghana. Electrification may also affect education via migration, particularly if it entails an influx of migrants from neighboring unelectrified villages (Dinkelman, 2000). Population growth may result in higher enrollment, but it also means larger classrooms with a smaller student-teacher ratio. This suggests that an increase in enrollment alone does not provide an accurate picture of educational quality. Moreover, Governments should consider providing electrification in conjunction with broader sustainable development initiatives that target education and local commerce. Outmigrants may be richer and more educated than those who remain behind Dinkelman pointed out.

Last, while electrification has the potential to improve schools by offering lighting, attracting better teachers, and improving school services, none of the included studies examined school quality in particular.

6.3.3 Effects of interventions on gender empowerment

6.3.3.1 Fertility

As shown in figure 30, there were three studies that analysed fertility. However, individual studies varied in their definition of fertility.[44] The meta-analysis of these findings

44 Akpandjar (2018) defines fertility as the no. of children ever borne by woman while measuring the impact 13 years after the intervention. In contrast, Rao (2010) defines fertility as a binary variable if any children were born 3 years before the follow-up survey took place – treatment households had electricity for an average of 4 years. Finally, Fujii (2019) defines it as the number of children born over 5 years since the baseline survey.

demonstrated a negative but not a statistically significant decrease in fertility as a result of electrification. The analysis shows a Hedges's G of -0.53 (-1.19, .13).

6.3.3.2 Heterogenous findings: Women's empowerment

Fertility

Although further research is needed, results suggests that electrification may be associated with a reduction in fertility. In Ghana, Akpandjar (2018) evaluated the national rural electrification program from 1992-2005 and found that after 13 years, women from electrified households had, on average, three fewer children than women from non-electrified households.45 Other studies measured the impact of electrification on fertility over relatively shorter periods but also reported a decline. For example, impact evaluations from Bangladesh and Bhutan show that in three to five years of receiving a grid connection, electricity connection resulted in women having fewer children (Rao 2010; and Fujii 2019).

In contrast, Arraiz (2015) assessed the impact of an off-grid solar powered home system on a number of socio-economic outcomes in rural Peru. The connection mainly provided basic lighting with the extended possibility to support low-power requirement appliances such as mobile phone charging, radio and TV. Majority of the adopters used the system for lighting and three years after the intervention, there were positive results on children's schooling and women's daily routines who now spent more time awake and growing their home-based businesses. However, the impact on fertility was not significant.

45 Note that Akpandjar (2018) defined fertility as the total number of births during the past 13 years, while other studies looked at the number of children born during the past 3-5 years.

Gender empowerment

Preliminary qualitative evidence suggests electrification not only increases women's involvement in productive activities but may enable systemic changes in gender norms and roles within the household, that can empower women. According to Samad (2019), several pathways emerge through which electrification may increase women's empowerment. Electrification can increase women's participation in the labour market and allow them to generate their own income (a result consistent with the findings of this report's review). These women are likely to have greater financial freedom and intra-household bargaining power. Improved access to information through education as well as consumption of electronic media (TV, radio), may enhance exposure to potential opportunities that lead to empowerment. For example, women may have a stronger agency to engage in economic, social and political affairs, which can further balance gender roles. Increased education for girls also has a positive impact on almost all aspects of women's empowerment.

Samad (2019) measured the effect of rural electrification in India on empowerment, using proxies such as women's decision-making ability, mobility, financial autonomy, reproductive freedom, and social participation. His analysis shows that electrification advances all measures of women empowerment, specifically through enhanced participation in the labour market. Access to electricity was associated with a 4.6 percentage point increase for decision-making (including women's ability to make independent decisions about their own work or medical treatment), a 10 percentage point increase for mobility, 6.9 percentage point increase for financial autonomy, 2.7 percentage point increase for reproductive freedom, and 8 percentage point increase for social participation (measured by membership in local organizations). Greater exposure to media was associated with greater financial and reproductive freedom. Higher educational attainment among girls, as a result of electrification, also had a positive impact on all dimensions.

Similarly, Samad (2017) found that women living in households with grid electricity were more likely to make independent decisions over children's health and self-earned income. In Bhutan, Rao (2010) found that women's decision-making on issues related to health care and education improved by 5% after rural electrification, whereas the decisions related to investment, expenditure and income-generating activities remained in the hands of men. In Bangladesh, Samad (2013) assessed the impact of solar home systems on women's empowerment. Women with solar home systems spent 9% less hours per day on fuel collection. In addition, lower kerosene consumption was found to improve the health of women and children. They also had greater decision-making ability however, this was observed only for households with televisions. In contrast, in Ethiopia rural electrification did not increase women's participation in household decision-making, public affairs and control over household resources (Nguissie, 2015).

Access to electricity may further enhance women's safety and security. Sievert (2015) conducted a study on 22 Sub-Saharan countries to estimate the impact of electrification on domestic violence against women. The study found that the access and higher exposure to information via electronic media, especially TV, was significantly associated with lower acceptance of intimate partner violence. On the contrary, Aklin (2017), whose study assessed the impact of low-capacity solar microgrids on the perception of domestic violence and harassment against women, found no improvements in women's safety from domestic violence. 46 This may be due to the fact that this intervention only provided enough power to support basic necessities such as lights and mobile phone charging.

6.4 Publication bias

Publication bias arises when there is a systematic difference between the literature that is published on a certain topic compared with the literature that is not ultimately published on that topic. For example, studies with statistically significant findings may be more likely to get published than studies with non-significant findings. This would result in a bias in which the research that is readily available demonstrates stronger results than the broader literature on a topic. To address this concern, the authors examined the risk of publication bias for all meta-analyses that included at least eight results.

To investigate publication bias, the review team used CMA to create funnel plots, demonstrating the observed results from the included studies together with imputed results for possible studies that might not have been published. In addition, the team employed Duvall and Tweedie's trim and fill function to estimate the adjusted values of the summary statistics with both the actual and imputed studies to investigate whether the findings were likely to have been influenced by publication bias.47 The detailed findings and funnel plots are discussed in Annex 8.

As shown in Annex 8, income, consumption, time spent working, study time and fertility

46 The low-capacity solar micro-grid connection provided only basic lighting and mobile phone charging.

47 Shi, Linyu, 2019. The trim-and-fill method for publication bias: practical guidelines and recommendations based on a large database of meta-analyses. Available at https://www.ncbi.nlm.nih.gov/pmc/articles/PMC6571372/

were at low risk of publication bias. Applying Duval and Tweedie's trim-and-fill, the team found the results were all robust to the possibility of publication bias. Accordingly, the authors concluded that rural electrification interventions led to a moderate and significant increase in the mentioned outcomes.

The findings for years of schooling and employment status may have been subject to publication bias. The meta-analysis found that electrification led to a small, but significant increase in years of schooling (SMD = 0.15; CI: 0.11, 0.19). Adjustment for publication bias based on trim-and-fill suggests that these findings remain positive and significant in the wider range of the literature, but may be overstated in this study. With imputed studies demonstrated in figure 31, the trim-and-fill analysis suggests an SMD of 0.11 (CI: 0.07, 0.15). As the difference is small, the risk of publication bias is still relatively low and does not have an impact on the interpretation of the findings on education.

As shown in figure 32, findings on employment status were also subject to publication bias, suggesting that results in the wider population of literature may be smaller. In the meta-analysis, employment status was found to not have had a significant impact. With the additional risk of publication bias on these findings, this review cannot deduce a detectable impact on employment status on average.

Figure_31 **Years of schooling funnel plot**

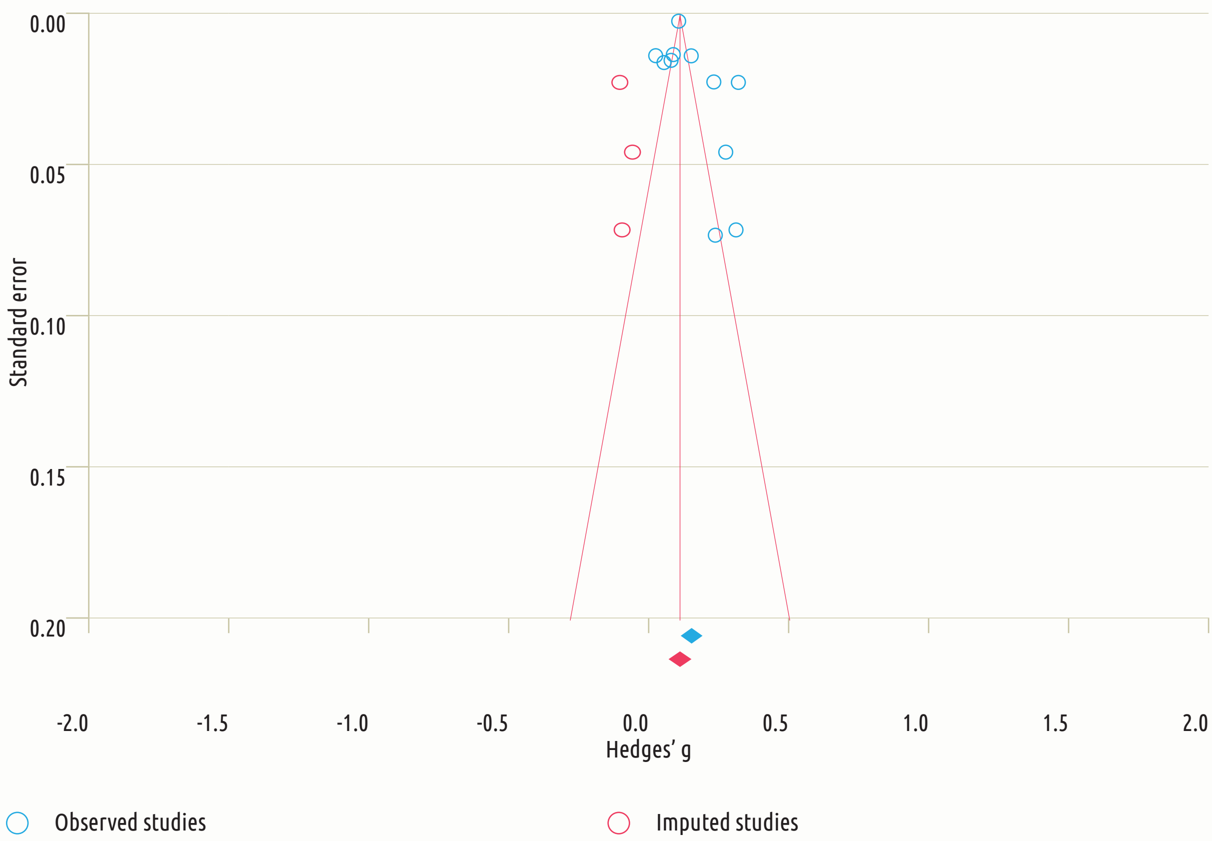
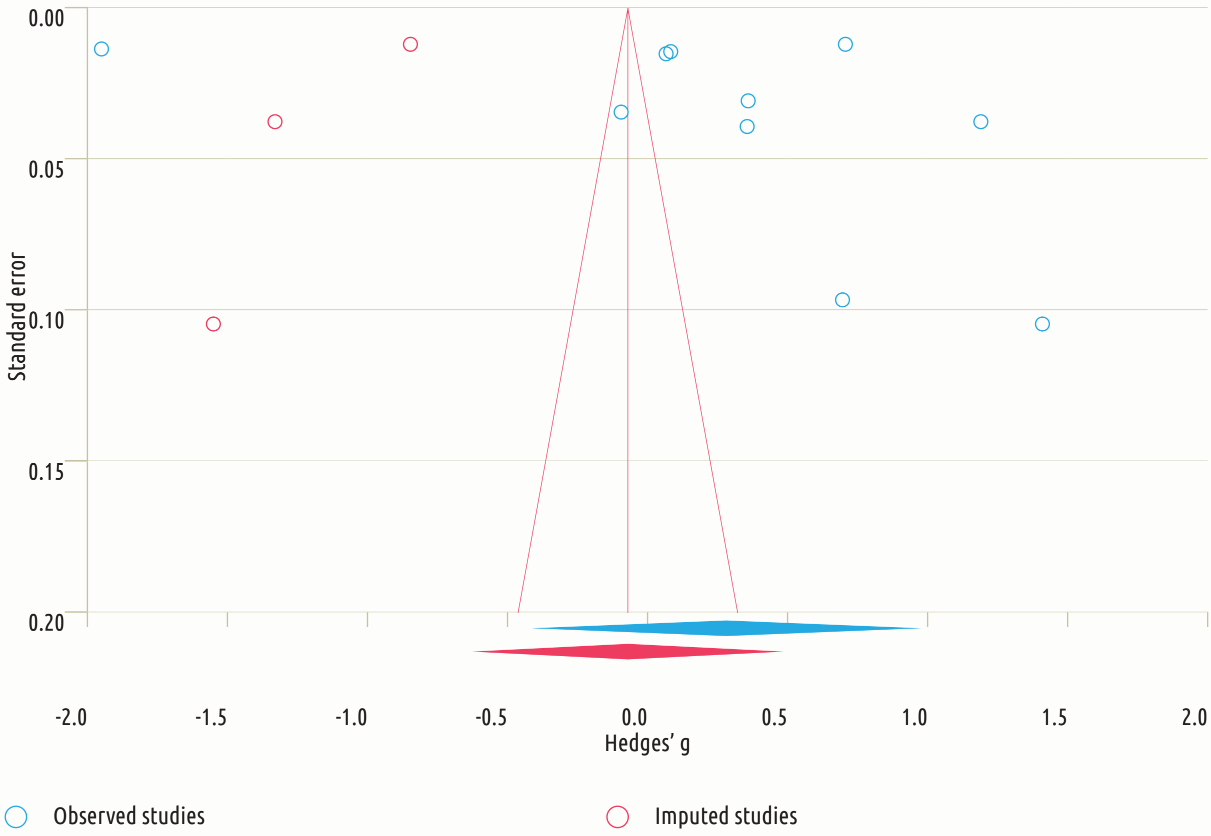


Figure_32 **Employment status funnel plot**



7 Discussion

7.1 Summary of main results

In sum, this systematic review finds that on average, electricity access interventions increased income, consumption and expenditure, and working time. These results are consistent and significant for all economic indicators examined, suggesting that electrification can play a very valuable role in economic development. These benefits were largely attributed to (a) increased hours of productivity due to lights, (b) greater exposure to information, which enables access to opportunities and resources, and (c) increased productivity due to use of appliances for both housework and income-generating activities. In terms of who benefits the most, qualitative analysis suggests that benefits accrue across all income groups; however, in most cases, richer households benefit more, possibly because they can afford more electricity and more productivity-boosting appliances. However, these impacts vary based on local context. Preliminary evidence also suggests that while electrification led to significantly more employment for women, no significant impact was seen for men. Differential impacts by gender may vary as they are highly dependent on local gender norms and labour market characteristics.

The review found that electricity access interventions led to positive educational outcomes for children, including an increase in study time and total years of schooling. These benefits were largely attributed to (a) lighting, which enabled study in the evenings, and (b) productivity increases, which freed up time for children who might otherwise have been helping parents with housework or other activities. The effects were stronger for studies in which beneficiary communities were electrified for longer, suggesting that educational benefits increase further over time.

Based on both quantitative and qualitative findings, electrification also demonstrates positive impacts on gender empowerment. Study authors suggested that electrification can improve women's decision-making ability, financial autonomy, reproductive freedom and social participation, often due to increased labour market participation. Several studies found that electrification reduced women's time spent on housework, such as gathering and preparing fuel. Preliminary evidence also suggests that it can reduce acceptability of intimate partner violence due to greater media exposure. This systematic review found that, on average, electrification may have led to a reduction in fertility, as measured by the total number of children; however, this result was not significant. Only a few studies examined electrification's impacts on gender empowerment and fertility. Additional studies could help shed light on this important pathway for change.

7.2 Quality of evidence

The majority of the studies included in this systematic review were assessed to be at low risk of bias, ranking in either the low or medium risk categories based on the ROBINS-I tool.

However, three types of bias were particularly common among the studies. A total of 28% of the studies were at moderate or high risk of bias due to baseline confounding, while18% presented moderate-to-high risks of participant selection, and 17% presented risks due to missing data. These factors compromise the quality of available evidence on this subject.

In addition, there was quite a bit of heterogeneity between the studies. While this is to be expected, given the diversity of countries and contexts in the study, it may limit the generalizability of findings.

7.3 Limitations and potential bias in the review process

There are no major bias concerns in the searching and screening process of this systematic review; however, limiting the review to English may present a language bias. The selection of electronic databases, i.e., Scopus, is likely to capture much of the relevant literature on the topic without bias. The process of screening resulted in a high rate of internal agreement, which also indicates a low likelihood of bias. The additional search for gray literature and unpublished literature by using hand searches and contacting authors was designed to further reduce the risk of bias. While some studies were excluded from the meta-analysis, due to missing data or inconsistency in effect sizes reported, it is unlikely that these results were systematically different from those included.

Due to resource constraints, this review only included studies in English; while the authors do not expect that this is likely to raise large bias concerns, it may have resulted in the exclusion of valuable literature, particularly from China. The authors conducted a very preliminary search for relevant papers in the Chinese, French, Russian and Spanish languages. This process consisted of a basic Google search using a modified version of the search terms to get a sense of whether there was relevant literature in any of those languages. The research team did not find any qualifying papers in French, Russian or Spanish, but they did two in Chinese. These papers were not included in the analysis as the review methodology did not account for foreign language searches. However, the team concluded that there may be relevant literature in Chinese that could help inform future programming.

One limitation of this review is that it does not include a comparative analysis based on the duration of the intervention or the length of time between the intervention and the final endline survey. Future research could help to shed light on how electricity impacts change over time.

7.4 Agreements and disagreements with other studies and research

The results of this systematic review strongly align with a wider body of academic and development literature. The Asian Development Bank's (ADB) Systematic Review on the Impact of Access to Electricity on Household Welfare also conducts a meta-analysis on the quantitative impact of electrification. In addition, Jiminez (2017) conducted a comprehensive literature review on electricity access impact evaluations. Overall, the results of this study are consistent with the broader literature.

The ADB's systematic review reports a positive impact on household welfare. Both studies detect an increase in study time, years of schooling and income. Although this study does not conduct a meta-analysis on farm vs non-farm income, this study's qualitative results are congruent with the meta-analysis conducted by ADB. In addition, Jiminez (2017) conducted an extensive literature review examining electricity access impact evaluations; this study also noted an increase in employment and income. Consistent with findings in this study, Jiminez also did not find any conclusive evidence on the impact of electrification on fertility. The current study finds a negative but statistically insignificant impact on fertility. Since this analysis is based on only three studies, additional research would be needed to find conclusive evidence of this relationship.

All studies find considerable heterogeneity in the evaluation literature, suggesting that the impacts of rural electrification are highly dependent on the policy, programme and local context in which it is implemented.

7.5 Implications for policy and practice

Electrification is a powerful tool for advancing economic development; countries stand to benefit from setting unified goals and targets for universal electrification as well as continuing to enhance the quality of access through more reliable and affordable connections. This systematic review, consistent with the wider body of literature, finds that electricity improves economic standing across a wide range of different indicators. Many studies suggest that electricity is a necessary precondition for business operations. However, electricity is often treated as a binary variable, when in reality the quality of access varies widely. Studies suggest that a lack of reliability in the form of power outages drastically reduces potential economic benefits, in some cases by as much as half (Samad, 2016; and Chakravorty 2014). For this reason, measures to improve electricity infrastructure, such as generation capacity, transmission lines, grid extension and energy efficiency, are excellent pathways to boosting economic growth. Furthermore, even when electricity is technically available, it may be too expensive for poorer households to use it regularly. To address the cost element of accessibility, policymakers may institute initiatives such as subsidizing electricity for the poor or providing energy-efficient appliances that could help boost productivity, while reducing household costs. In this regard, the World Bank's Multi-Tier Framework (MTF) is a useful tool for helping to monitor and assess local electricity quality.

While electrification programmes generally benefit everyone, studies demonstrate differential impacts for different subpopulations, particularly based on wealth status, gender and geography; by instituting targeted policies to help benefit marginalized groups, policy makers can further enhance the benefits of electrification, while ensuring that no-one is left behind. This review found that wealthier households often benefit from electrification more than poor households because they can afford more electricity and productivity-boosting appliances. To rectify this inequality and support pro-poor growth, policymakers may couple electrification programmes with specific benefits for poor communities, such as subsidized services or other public amenities. With regard to gender, various studies found that men, women, boys and girls benefited more from electrification, depending on the local context.

Many studies, however, agree that electrification has the potential to improve gender equity, particularly through media, and economic opportunities for women. To fully realize this opportunity, policy makers may utilize tools such as media campaigns promoting gender equity or entrepreneurship training programmes to improve women's household status. For children, policymakers may consider providing specific incentives for families to keep daughters in school. Last, remote villages generally gain less from electrification compared with urban or peri-urban areas that are eligible for grid extension. This is largely attributed to the lack of economic activity and opportunities available in rural areas. Long-term planning for rural development in the form of infrastructure, job creation and capacity-building can help to create pathways for growth.

Electricity access is only as beneficial as the amenities it supports. Bundling electrification services with other benefits, such as increased access to finance, provision of telecommunications and information technology, investment in human capital and development of complementary infrastructure (Ganguly, 2020), can help to unleash the full potential of electrification, particularly in remote rural areas. While electricity is critical to the operation of schools and hospitals, providing electrification does not guarantee that education and health care will improve. Aligning electrification efforts with other SDGs, including those on poverty, health, education and gender equality, would magnify impacts. For example, while this review found that electrification significantly increased children's study time and years of schooling, coupling electrification with school improvements and recruitment of strong teachers could further accelerate educational outcomes. Similarly, information and communication technologies have the potential to be highly beneficial, depending on how they are used.

Many studies have noted that media exposure through television and radio improved perspectives on gender equality and helped to connect people with economic opportunities. Conversely, however, one study suggested that watching too much television reduced children's study time. Providing communities with resources and education could help maximize benefits achieved through electrification and minimize potential adverse effects. Last, while this review found that electrification improved economic development across a number of indicators, the impact could be magnified by enabling economic activities. For example, roads may provide farmers or entrepreneurs access to new markets, subsidies on high-power appliances to increase productivity could enable business expansion, and provisions for access to credit could enable business investments for future gains. These provisions are particularly valuable for remote rural areas where there are few economic opportunities, even with the added benefits of electrification.

Both grid-extension and off-grid solutions show evidence of benefits, and policymakers may best choose among these options based on local contextual needs; where grid extension is not financially feasible, mini-grid and off-grid solutions based on renewable energy provide some of the most cost-effective and sustainable solutions. Continuous technological improvement can further enhance these benefits. While this review finds limited evaluation literature on decentralized solutions in particular, the positive impacts of electrification in general are clear. As countries successfully close the gap in electricity access, many of the remaining areas are too remote to be eligible for grid extension. To reach the "last mile," many Governments deploy decentralized solutions based on renewable energy, particularly because these technologies and accompanying end-use appliances have experienced a significant decline in costs and improvements in efficiency. Between 2010 and 2016, the cost of LED lights and lithium-ion batteries dropped by 80% and 73%, respectively – the two main components used in standalone solar home systems – dropped by 80% and 73%, respectively.48 Low-capacity electrification solutions can offer some intermediate benefits in terms of replacing kerosene for lighting and allowing to charge mobile phones etc. But as local business and household needs grow, communities will demand more from such technologies. Given this anticipated rise in demand, a low supply of electricity may minimize the potential socio-economic benefits (Akpandjar, 2017). Preventing this will require continuous improvements in the technology and expansion of decentralized systems and more importantly, the provision of such technologies at affordable prices to ensure that no one is left behind.

As shown by the COVID-19 pandemic, electricity access will be critical to the distribution of vaccines, providing medical services as well as achieving economic recovery. As Governments issue recovery packages, directing some of these funds and initiatives towards electricity access in low-income communities could help to create jobs quickly, while building towards much-needed long-term economic growth. The pandemic has highlighted the critical need for electricity access to support the provision of basic necessities including health care and hospitals. Allocating recovery funds to expanding electricity access could help to accelerate eradication of COVID-19, while providing remote communities with the means to advance their economies.

7.6 Implications for research

Developing a deeper understanding of the impact of electrification on education, income, employment and fertility has also brought to the forefront a number of issues including but not limited to gender, inequality, children's education and a need for an integrated approach to infrastructure development. This can help to inform and adjust the policy formulation approach for electrification projects.

Several research pathways have been highlighted across the review. Disaggregated data by gender and age can further help to uncover the distributional impacts of electricity access. Further research is required on the impacts on farm vs non-farm income and employment, gender and age. There is also a need to better quantify impacts on overall quality of life through issues such as domestic violence and time devoted to leisure. These are among some of the non-market fruits that electrification bears, and they have been highlighted in the heterogenous findings. Additional studies may also assess explore outcomes such as life expectancy at birth, crime rate and overall safety in communities.

Additional research is also required on firm performance for which a handful of studies exist and which do not report any impact. For example, the impact of electricity access on the creation of new businesses as well as their financial performance can help to provide a better understanding of how electrification gives rise to local commerce. Peters (2011) stressed that future impact evaluations should also disentangle the separate effects of electricity access on new and existing businesses, and in particular investigate the degree of crowding-out among the latter. Ganguly (2020) noted that future studies may assess the impact of electrification on the extent of business diversification. In addition, as highlighted by Dinkelman (2015), future studies should show how public infrastructure investment, in particular electricity, may affect migration patterns and, as a result, the impact on socio-economic outcomes. Finally, to enhance our understanding of the

48 IRENA (2019). "Off-grid renewable energy solutions to expand electricity access: An opportunity not to be missed".

affordability barrier of access, future studies may also look at the “willingness-to-pay” for electricity access (Bensch 2011). Van de Walle (2015) also emphasized that non-connected households may also benefit from electricity-powered television and fans of neighbours, and from the lighting from village streets. This is an interesting topic for future work. Finally, future research should further study the complementary drivers that maximize the success of rural electrification programmes.

Conducting more granular research will require detailed data collection. The World Bank’s data collection efforts, using the Multi-tier Framework (MTF), on energy access can be utilized by researchers. These can additionally be used to evaluate further how the quality of access has an impact on electrification. The need for future study to examine the period it takes for the impact to become realized has also been underlined by several studies (Burlig, 2016; Fuji, 2020; Khandker, 2012; and Vernet, 2019). Finally, there is a call to estimate the long-term impact of electricity access based on randomly assigned intervention (Ganguly, 2020; Peters, 2011; and Thomas, 2020).

Last, the COVID-19 pandemic clearly shows that the field could benefit from additional research into the health benefits of electrification through improved health-care facilities as well as better access to clean cooking fuels and technologies.

Annexes

Annex 1. Key words used for PICO search

TITLE-ABS-KEY(electricity OR electrification) AND TITLE-ABS-KEY(access OR *connect* OR "*grid*" OR power OR solar* OR photovoltaic OR wind OR hydro OR Subsidy OR voucher OR demand OR supply OR capacity OR renewable OR diesel OR extension OR expan* OR reliability OR rural OR "energy poverty") AND TITLE-ABS-KEY(Control* OR Treatment OR Compar* OR Counterfactual OR Evaluat* OR Impact* OR Random OR Placebo OR Intervention OR Before OR After) AND TITLE-ABS-KEY(income* OR expenditure OR consumption OR revenue OR profit OR produc* OR econom* OR capital OR assets OR employ* OR job* OR labor OR labour OR work* OR educat* OR school* OR attendance OR inequality OR poor OR rich OR low*income OR high*income OR poverty OR gender OR empowerment OR fertility OR women OR woman* OR girl* OR sex) and TITLE-ABS-KEY "Randomized Controlled Trial" OR RCT OR "Difference*in*difference" OR "Propensity score matching" OR PSM OR "Instrumental variable" OR "Regression discontinuity" OR Regression OR "P value" OR econometric* OR "statistical* significan*" OR "panel data" OR "impact evaluation")

Annex 2. List of databases

Table_5 **List of databases used in hand search for gray literature**

Database / Website		
3ie impact	GIZ	Journal of Development Effectiveness
Google	Independent Evaluation Group (World Bank)	Journal of Development Studies
Google Scholar	Inter-American Development Bank	Journal of International Development
ResearchGate	Millennium Challenge Corporation	National Bureau of Economic Research
African Development Bank	USAID Development Experience Clearinghouse	Science Direct
Asian Development Bank	World Bank	World Development
Australian Agency for International Development	Economic Development and Cultural Change	
Department for International Development (United Kingdom)	Journal of Development Economics	
Canadian International Development Agency	IPA	
Danish International Development Agency	JPAL	

Annex 3. Selection criteria for systematic review

The selection criteria for this review follows the PICOS format, detailing population, intervention, comparison, outcomes, and study designs. To be eligible for inclusion in the review, the study had to meet the following criteria.

Subject

- Electricity access

Population

- Low- and middle- income countries
- Populations that received electrification

Type of intervention

Given its focus on informing policies, this review only includes studies in which there was an explicit programme or policy intervention. Included in this systematic review was any electricity access intervention including the following:

- Grid connection (national)
- Mini-grids
- Micro-grids
- Off-grids (Stand-alone systems, e.g., solar home systems)
- Subsidy programmes to subsidize any of the listed fuels and/or technologies

Comparison

- Valid counterfactual using either control group, before-after design, or quasi-experimental methods

Outcomes defined

In accordance with the theory of change detailed in figure 1, this systematic review included studies that examined any of the following outcomes related to income, education, employment and gender empowerment.

Income

- Income and earnings
- Consumption and expenditure

Education

- Study time
- Years of schooling

Employment

- Time spent working
- Employment status

Gender empowerment

- Fertility

Of note, the team did attempt to gather evidence of which tier of access each intervention corresponds to; however, very few studies examined these outcomes quantitatively.

The team also initially attempted to identify contextual details, including policy landscape and regulatory environment during the implementation of electrification programmes, but the studies that were included do not always elaborate on this topic

Study design

This systematic review included only studies with a valid counterfactual using any of the study designs listed below. In all cases, studies needed to conduct a balance test to demonstrate that baseline characteristics were balanced and used appropriate statistical methods to control for characteristics in which balance was not achieved. The study designs that were included are listed below:

- Randomized control trials in which individuals or groups were randomly assigned to treatment and control groups;
- Quasi-experimental designs in which the investigator used statistical methods to control for confounding factors. Methods may include statistical matching (e.g., propensity score matching or covariate matching), difference-in-difference design, instrumental variables, or multivariate regression to control for selection bias, baseline characteristics and other confounding factors. Quasi-experimental designs may include:

- Natural experiments in which treatment and control were assigned based on non-random factors, but in which authors used one of the above-mentioned methods to control for possible bias;
- Before-after studies;
- Cross-sectional studies in which balance was established and appropriate statistical methods were used to address confounding factors;
- Regression discontinuity design.

Other criteria

Language

- Due to resource constraints, this systematic review was conducted exclusively in English. Therefore, it only included studies published in or translated into English.

Annex 4. Study search strategy

Electronic searches

In searching for qualifying studies, the research team employed a PICOS search format, as detailed in the selection criteria section, in several databases. The PICOS search terms, as detailed in Annex 1, were selected based on the specific goals of the current study, with consideration for the search term selection of prior systematic reviews. The team conducted the PICOS search in the electronic database Scopus on 14 July 2020. Scopus is an abstract and citations database that includes thousands of journals and results from scientific web pages. literature. For all hits from the research team downloaded titles, abstracts, and relevant reference information. These were then compiled into Excel. Duplicates were removed.

Hand searches

To help identify gray literature, recent papers, and other studies that might not have been published in traditional journals, the team supplemented the electronic search with hand searches in various databases, as well as "snowball searches". These hand searches were completed during August 2020. It is estimated that more than half of the studies reported in conference abstracts are not ultimately published, and those that are published are systematically different.49 Hand searches help to capture some of this gray literature. The hand searches were conducted using a modified version of the search terms in Annex 1 to search in Google, Google Scholar, and various donor websites listed in Annex 2. In addition, depending on the formats of the websites or search engines, the research team adjusted search terms for the search filters as needed. The authors found few qualifying studies this way. The hand searches additionally consisted of "snowballing", an iterative process of searching the references of relevant papers in order to identify other relevant studies. This process continued until the team could find no additional qualifying papers that were not already in the list.

Based on the Campbell Search Strategy Guidelines, other systematic reviews present some of the best sources of references for potentially relevant studies. Accordingly, the team did a snowball search of each of the relevant systematic reviews identified in table 6. This search yielded many relevant studies. The team additionally conducted snowball searches after the initial round of screening to search the references of the studies identified for inclusion in the systematic review. The team found the snowballing methodology to be highly beneficial in terms of rendering relevant papers. All papers found through hand searches were downloaded in PDF form into a folder. Key data including author, title, year of publication, country of study, and link to paper, were recorded in an excel spreadsheet.

Search for unpublished studies

To minimize the possibility of publication bias, the research team made efforts to search for both published and unpublished literature. In addition to the hand searches to look for gray literature, the team also reached out to the author of each eligible paper and inquired whether the author had

49 Scherer, R.W., P. Langenberg and von Elm E. (2007) (2).Full publication of results initially presented in abstracts. The Cochrane database of systematic reviews. Mr000005.

written or knew of any published or unpublished studies that met the criteria for inclusion in the systematic review.

Studies in other languages

Early in developing the study design, the team discussed the possibility of searching for papers in several languages, particularly in all official United Nations languages. Unfortunately, due to resource constraints it was not possible to conduct a complete search in languages other than English. The team did, however, conduct some preliminary research to assess whether there were likely to be many relevant studies in any particular language. In this process, a single analyst, used a modified version of the search terms in google to try to get a sense of whether there was relevant literature in that language.

The purpose of this exercise was not to identify papers for the current review, but rather to identify areas for future research. Preliminary searches were conducted in Chinese, French, Russian and Spanish. Due to resource constraints, the team was unable to search for papers in Arabic.

Selection of studies

Title and abstract screening

To facilitate the screening and selection of studies, the team uploaded the spreadsheet containing titles, abstracts, and reference information from the electronic search into Abstrackr,50 a free open-source software, developed by researchers at Brown University. This software, recommended in the Campbell Search Strategy Guidelines, facilitates review and screening of titles and abstracts for systematic review by using text mining functionality and machine learning to identify papers that are likely to qualify and present these papers first. This function helped pre-screen relevant papers. Once uploaded in Abstrackr, a team of three analysts double-screened all titles and abstracts. In a pilot stage, the first 100 titles and abstracts were screened by all three screeners along with the team leader in order to ensure agreement across the team on what types of papers qualified. This pilot needed to achieve a kappa rate of at least 0.7 in order for the review to continue. If the rate of agreement were lower, the team would complete an additional pilot of 100 titles and abstracts before proceeding to double-coding.

After the initial pilot, three analysts independently screened each title and abstract, and recorded reasons for exclusion where relevant. In cases of disagreement, the full team reviewed the title and abstract to come to consensus. In this stage, studies were screened based on the inclusion criteria pertaining to population, intervention, comparison, outcomes, and study design. However, because study design and comparison are not always explicit in the title and abstract of a study, where analysts were uncertain of these characteristics, studies were included for further review at the full-text screening stage. For the papers attained through hand search, after an initial analyst identified qualifying studies, a second analyst reviewed the selections to verify.

50 Byron C. W., K. Small, C. E. Brodley, J. Lau and T. A. Trikalinos (2012). Deploying an interactive machine learning system in an evidence-based practice centre: abstrackr. In Proc. of the ACM International Health Informatics Symposium (IHI), pp.819-824.

Full text screening

After identifying qualifying titles and abstracts, the team downloaded all qualifying studies and noting if any were unavailable. The team then conducted a full text screening to ensure that the identified papers qualified, particularly on the basis of study methodologies which are often not explicitly stated in the abstract. During the full-text screening phase, each paper was reviewed by one of the analysts on the team, and reasons for exclusion were recorded where relevant. All studies identified for inclusion at the full-text review stage were then coded and analyzed.

Annex 5. Data collection and analysis

Data extraction and management

Two analysts independently reviewed each qualifying study, extracting all relevant data to ensure that data and outcomes were correctly interpreted and extracted. The two analysts then compared findings to resolve any disagreements or differences in interpretation. For any matters for which analysts could not reach agreement, a third analyst reviewed the study to provide input and reach consensus. The team leader additionally reviewed a random selection of studies to assure accuracy of data included. Data extracted included:

Metadata

- Author
- Author contact information
- Title
- Study dates

Population

- Country
- Geographic region
- Sample size
- Proportion of sample that is female
- Subgroup of analysis (if any)
- Method of sampling
- Programme duration

Intervention

- Type of treatment (technology/connection type)
- Details of treatment (including any supplemental programme components)

Comparison

- Method and unit of assignment to treatment and control (where applicable)
- Assessment of balance

Outcomes

- List of outcomes
- Effect size for included outcomes
- Supplemental data to standardize effect sizes (pooled standard deviation, standard error, confidence interval, T statistic, P value, number of observations, etc.)

Study design

- Study design

The data were later used in both the meta-analysis and the narrative synthesis. The systematic review included meta-analyses of the following outcomes:

Income

- Income and earnings
- Consumption and expenditure
- Education Study time
- Years of schooling

Employment

- Time spent working
- Employment status

Women's empowerment

Fertility

In order to be included in the meta-analysis a study had to meet the following additional criteria:

- Include an effect size for one of the above-listed outcomes;
- Include sufficient data about this effect size to enable calculation of a standardized mean difference;
- Effect sizes included in meta-analysis must be independent.

For studies that did not provide sufficient data for inclusion in the meta-analysis, per the Cochrane Collaboration Guidance, analysts contacted authors to request the additional data needed.51 After a period of one week, analysts reached out a second time to any authors that did not respond. If an author did not respond a second time and analysts could not find sufficient data, the study was excluded from the meta-analysis.

Assessment of the risk of bias in included studies

For each included study, the research team analysed the potential for any bias or confounding factors that could impact the accuracy of results. The team analysed potential for bias using a modified version of the Risk of Bias in Non-randomized Studies (ROBINS) tool.52 This tool is specifically designed to assess the comparative effectiveness of interventions from studies that did not used randomized assignment to treatment and control groups.53 The types of bias assessed included:

1. Bias due to participant selection:
   - Was selection randomized, or was there bias due to self-selection, selection based on pre-specified characteristics or other bias?
   - Were the treatment and control groups adequately comparable?
2. Bias due to baseline confounding:
   - Did the study account for potential confounding factors by including appropriate controls?
   - Were there any major confounding factors such as simultaneous implementation with an additional programme?
3. Bias due to missing data:
   - Did the study have a high level of attrition or missing data that could bias results?
   - Did the study adequately address missing data or missing observations?

51 Cochrane (2011). Methods for obtaining unpublished data. Available at https://www.cochrane.org/MR000027/METHOD_methods-for-obtaining-unpublished-data
52 Cochrane Methods. Robins-I Tool. Accessed at: https://methods.cochrane.org/methods-cochrane/robins-i-tool
53 Sterne, Jn AC (2016). ROBINS-I: A tool for assessing risk of bias in non-randomized studies of interventions. BMJ 2011;343:d5928. Available at https://www.bmj.com/content/343/bmj.d5928#:~:text=The%20risk%20of%20bias%20tool%20covers%20six%20domains%20of%20bias,the%20domain%2C%20or%20different%20outcomes.

4. Bias due to departures from the intended interventions:

    - Were there major changes in the intervention during implementation that could bias results?
    - Was the programme implemented inconsistently in a way that may bias results?
    - Measurement bias in key outcomes
    - Are there any issues in the measurement of outcomes that could lead to measurement bias?
    - Were the methods of measurement of outcomes comparable across interventions/studies?

The research team considered each of these questions in assessing potential bias concerns. In cases of potential bias, the team further identified what statistical methods were used to mitigate bias and rated the risk of bias as low, moderate, or high. Any studies that raised major bias concerns were excluded. Given the challenges of implementing randomized control trials, some amount of bias was expected in quasi-experimental methodologies, particularly in the assignment to treatment and control groups; quasi-experimental studies that adequately addressed these potential bias concerns using statistical techniques qualified for the systematic review.

Criteria for determination of independent findings

In order to ensure independence of findings in the meta-analysis, the research team used the following guidelines:

1. **Each meta-analysis only included one result per sample.**

    - In most cases, this effectively meant that only one effect size per study was included in a meta-analysis. For example, if a study measured study time in terms of minutes/week as well as minutes/day, the meta-analysis for study time would only include one of these two variables. In these cases, the research team selected the outcome based on:
        - Outcome prioritized by the author (if any)
        - Consistency of the indicators used in other studies.
    - In cases in which the author examined outcomes for different subgroups of the sample, multiple effect sizes were included in the same meta-analysis as long as the samples were not overlapping. For example, study time effect sizes for both boys and girls could be included, but not in conjunction with the study time effect size for all children, as that would constitute overlapping samples. In such cases, the review team included each of the subgroups to allow for more granular analysis of the effect sizes in the specific subsamples.
    - Several papers included studies in same countries comprising of the same population group e.g., if there were two studies in a particular country and both used data from a

nationally representative survey, there will be overlaps which could violate the independence assumption. In this case, the authors chose the study based on:

- Most up-to-date data and methodology;
- Availability of relevant summary statistics needed to calculate effect size:

- Several papers included multiple studies in different countries or different regions of the same country, for which the sample was completely different and non-overlapping. In these cases, each study was considered independent, and accordingly, one effect size from each of the studies could be included in the same meta-analysis. However, some studies were conducted on the same sample of data and examined the same outcomes. In this case, the authors selected the outcome based on (i) availability of data, (ii) later date of publication, and (iii) methodological considerations.

2. **If an author included multiple outcomes of interest that were eligible for different meta-analyses, one could be included in each meta-analysis.** For example, if one study examined both income and years of schooling, because these outcomes fall into separate meta-analyses, both were analysed. The study's inclusion in two separate meta-analyses does not violate independence, as long as the same study (of the same sample) does not appear more than once in the same meta-analysis.

3. **For authors who had written multiple studies based on the same sample, only one was included in a meta-analysis.** Because many authors produce multiple papers based on the same data, to retain independence, each meta-analysis only included an outcome from one of these studies. If an author had multiple papers that were updated versions of the same or very similar content, the research team selected the most recent paper provided the methodology was similar if not better. If the content of the papers was significantly different, the research team selected the most relevant study.

Additional statistical analysis

Using Comprehensive Meta-Analysis (CMA) software,54 the authors conducted the meta-analysis, the details of which are included below.

Assessment of publication bias

Publication bias occurs when the published literature on a topic is systematically different from the complete population of literature.55 For example, studies demonstrating statistically significant findings may be more likely to get published than those that find null results. This results in a bias in which the publications that are readily available suggest stronger findings than the complete body of

54 Comprehensive Meta-Analysis (Version 3) [Computer software]. (2020). Englewood, N.J. Biostat. Available at https://www.meta-analysis.com/

55 Publication Bias in Meta-Analysis – Prevention, Assessment and Adjustments H.R. Rothstein, A.J. Sutton and M. Borenstein (eds.). ©2005 John Wiley & Sons, Ltd. https://www.meta-analysis.com/downloads/PBPreface.pdf

research would have suggested. To investigate publication bias, the review team used CMA to create funnel plots, demonstrating the observed results from the included studies together with imputed results for possible studies that might not have been published. The team additionally employed Duvall and Tweedie's trim and fill function to estimate the adjusted value and confidence interval of the summary statistics with the imputed studies to investigate whether the findings were likely to have been influenced by publication bias.56

Assessment of heterogeneity

To assess heterogeneity among studies, the team used CMA to calculate and report on the I2 statistic for each meta-analysis. Generally, an I2 statistic of above 50% is considered moderate-to-high. The Cochrane Handbook recommends the following more specific guidance on interpretingI2:

1. 0% to 40%: might not be important;

2. 30% to 60%: may represent moderate heterogeneity;

3. 50% to 90%: may represent substantial heterogeneity;

4. 75% to 100%: considerable heterogeneity.

Because of the global nature of the current review, and the wide variation in contexts and interventions, the team expected a certain degree of heterogeneity, and used random effects models to address this issue.

Subgroup analysis using moderators

The team used two moderators to examine how impacts varied based on different factors:

1. The first moderator was type of intervention, including connections using National grid, micro-grid, mini-grids, off-grid systems and multipronged intervention. Multi-pronged interventions include at least two or more of the mentioned connection types.

2. The second moderator was geographic region based on the United Nations categories, including Africa, Asia and the Pacific, Western Asia, Europe, and Latin America and the Caribbean.

For any meta-analyses including at least 8 results, the research team used CMA to group results by these two moderators in order to assess whether the summary statistics varied by intervention type or region.

56 Shi, Linyu (2019). The trim-and-fill method for publication bias: practical guidelines and recommendations based on a large database of meta-analyses. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC6571372/

Treatment of qualitative research

While the systematic review did not include studies that were purely qualitative, the team made efforts to incorporate and analyse some of the qualitative information in order to validate and further elaborate on quantitative findings. Campbell guidelines suggest that qualitative information can be valuable in terms of:57

1. Defining interventions more specifically;
2. Providing insights into heterogeneous findings across studies;
3. Addressing some of the factors that obstruct or facilitate intervention effectiveness; and
4. Highlighting characteristics of successful implementation, as well as reasons for poor implementation.

Because the impact of electrification varies widely, it is difficult to capture intervention characteristics through quantitative data alone. For example, two programmes might use similar technology, but have very different results in terms of reliability, quality and affordability. Monitoring and follow-up plans might differ considerably. In addition, programmes might be run under a very different policy and regulatory environment. To better capture these factors, the authors included a subsection on heterogeneous findings on each of the analysed results. This section discusses some of the qualitative characteristics that may have affected programme success or the lack thereof. The authors additionally discuss the implementation, external validity, and costs of the various interventions and studies. This qualitative information helped to inform the implications for policy and practice as well.

57 Campbell Collaboration. "Campbell systematic reviews: policies and guidelines". November 2019. Available at https://training.cochrane.org/handbook in January 2020.

Annex 6. List of studies included in the review

Primary author	Intervention	Region	Country	Study design	Sample size	Education	Income	Inequality	Employment	Women Empowerment
Adu	Grid connection	Sub-Saharan Africa	Ghana	DiD	7,931	✓	✓	✓	✓	
Aguirre	Grid connection	Latin American and the Caribbean	Peru	IV	987	✓				
Aklin	Mini-grid connection	South and South-West Asia	India	RCT	1,597	✓	✓		✓	✓
Akpandjar	Grid connection	Sub-Saharan Africa	Ghana	IV	3,288 women					✓
Akpandjar	Grid connection	Sub-Saharan Africa	Ghana	Two periods cross-sectional	444,837	✓			✓	✓
Alam	Grid connection	South and South-West Asia	Bangladesh	PSM	51,895	✓				
Ali	Grid connection	South and South-West Asia	Pakistan	PSM	500		✓		✓	
Argawal	Off-grid connection	South and South-West Asia	India, Nepal	PSM	859		✓			✓
Arraiz	Off-Grid connection	Latin American and the Caribbean	Peru	PSM	1,320	✓	✓			✓
Bahaj	Mini-grid connection	Sub-Saharan Africa	Kenya	DiD	1,069		✓			
Barron	Grid connection	Latin American and the Caribbean	El Salvador	IV	500	✓	✓		✓	
Bensch	Mini-grid connection	Sub-Saharan Africa	Rwanda	PSM	537	✓	✓			

Primary author	Intervention	Region	Country	Study design	Sample size	Education	Income	Inequality	Employment	Women Empowerment
Bensch	Mini- and Off-grid connection	Sub-Saharan Africa	Senegal	PSM	218	✓				
Bernard	Grid connection	Sub-Saharan Africa	Ethiopia	RCT	566	✓			✓	
Bhandari	Grid connection	South and South-West Asia	Bhutan	Cross-sectional	240	✓	✓	✓	✓	
Bridge	Grid connection	South and South-West Asia	Nepal	IV	5,988		✓			
Burlig	Grid connection	South and South-West Asia	India	Panel, RD	30,000 villages	✓	✓		✓	
Chakravorty	Grid connection	South and South-West Asia	India	IV, Panel	4,613		✓			
Chakravorty	Grid connection	South-East Asia	Philippines	RD	209 villages		✓			
Chaplin	Grid connection	Sub-Saharan Africa	Tanzania	DiD	8,897	✓	✓	✓	✓	✓
Chauvet	Grid connection	South-East Asia	Myanmar	IV	497 firms		✓			
Dasso	Grid connection	Latin American and the Caribbean	Peru	Panel	12,964 individuals		✓		✓	
Dasso	Grid connection	Latin American and the Caribbean	Peru	Panel	2,400 individuals	✓				
Diallo	Off-grid connection	Sub-Saharan Africa	Côte d'Ivoire	IV	12,899	✓	✓			
Ding	Subsidies	East and North-East Asia	China	DiD, PSM	2,459 villages		✓		✓	
Dinkelman	Grid connection	Sub-Saharan Africa	South Africa	IV	1,816 communities	✓			✓	

Primary author	Intervention	Region	Country	Study design	Sample size	Education	Income	Inequality	Employment	Women Empowerment
Dinkelman	Grid connection	Sub-Saharan Africa	South Africa	IV	1,1816 communities	✓	✓			
Fetter	Grid connection	South and South-West Asia	India	RD	7,649				✓	
Fujii	Grid connection	South and South-West Asia	Bangladesh	IV	2,542					✓
Ganguly	Mini-grid connection	South and South-West Asia	India	Before-and-After	284 firms		✓			
Grimm	Off-grid connection	Sub-Saharan Africa	Rwanda	RCT	300	✓	✓		✓	
Grogan	Grid connection	Latin American and the Caribbean	Guatemala	IV	6,378 individuals		✓		✓	
Grogan	Grid connection	Latin American and the Caribbean	Colombia	IV	1,929	✓			✓	✓
Grogan	Grid connection	Latin American and the Caribbean	Guatemala	IV	12,473 individuals				✓	
Grogan	Grid connection	Latin American and the Caribbean	Nicaragua	IV	6,729 individuals				✓	
Karumba	Mini-grid connection	Sub-Saharan Africa	Kenya	PSM	267	✓				
Khandker	Grid connection	South-East Asia	Vietnam	IV	1,262	✓	✓	✓		
Khandker	Grid connection	South and South-West Asia	Bangladesh	IV	20,900	✓	✓	✓		
Khandker	Grid connection	South and South-West Asia	India	IV	41,554	✓	✓	✓	✓	

Primary author	Intervention	Region	Country	Study design	Sample size	Education	Income	Inequality	Employment	Women Empowerment
Kumar	Grid connection	South and South-West Asia	India	IV, Panel	29,112		✓	✓		
Kumar	Grid connection	South and South-West Asia	Bhutan	PSM	2,098	✓	✓			
Lenz	Grid connection	Sub-Saharan Africa	Rwanda	DiD, PSM	974	✓	✓		✓	
Litzow	Grid connection	South and South-West Asia	Bhutan	PSM	12,893	✓			✓	
Lopez	Grid connection	Latin American and the Caribbean	Brazil	RD	24,982 individuals	✓		✓		
Mejdalani	Grid connection	Latin American and the Caribbean	Brazil	DiD, Panel	13,404 schools	✓				
Nigussie	Grid connection	Sub-Saharan Africa	Ethiopia	PSM	110	✓				✓
Peters	Grid connection	Sub-Saharan Africa	Ghana	IV	232 firms		✓			
Peters	Grid connection	Sub-Saharan Africa	Benin	PSM	56,071 children		✓			
Pueyo	Mini-grid connection	Sub-Saharan Africa	Kenya	DiD, PSM	384 firms		✓			
Rao	Grid connection	South and South-West Asia	Bhutan	PSM	2,098	✓	✓			✓
Rao	Grid connection	South and South-West Asia	India	Cross-sectional	8,125		✓			
Rathi	Grid connection	South and South-West Asia	India	Panel	41,554		✓		✓	
Rathi	Grid connection	Sub-Saharan Africa	South Africa	Panel	7,305		✓		✓	

Primary author	Intervention	Region	Country	Study design	Sample size	Education	Income	Inequality	Employment	Women Empowerment
Saing	Grid connection	South-East Asia	Cambodia	DiD	137 villages	✓	✓	✓		
Salmon	Grid connection	Sub-Saharan Africa	Nigeria	IV	4,878				✓	
Samad	Grid connection	South-East Asia	Lao People's Democratic Republic	PSM	3,500	✓	✓		✓	
Samad	Grid connection	South and South-West Asia	India	PSM	21,896 women	✓	✓	✓	✓	
Samad	Grid connection	South and South-West Asia	Bangladesh	IV	7,018	✓	✓	✓	✓	✓
Samad	Off-grid connection	South and South-West Asia	Bangladesh	PSM	4,000	✓	✓			✓
Samad	Grid connection	South and South-West Asia	India	PSM	28,446	✓			✓	✓
Sievert	Grid connection	Sub-Saharan Africa	Sub-Saharan Africa	Panel	369,400				✓	✓
Squires	Grid connection	Latin American and the Caribbean	Honduras	IV	22,923	✓			✓	
Tagliapietra	Grid connection	Sub-Saharan Africa	Nigeria	IV, Panel	5,000			✓	✓	
Thomas	Grid connection	South and South-West Asia	India	RD	686		✓		✓	
Van de Walle	Grid connection	South and South-West Asia	India	IV	6,008		✓		✓	
Vernet	Mini-grid connection	Sub-Saharan Africa	Kenya	DiD	1,067		✓			✓

Annex 7. Effect size equations and transformations

The Hedges's g formula is:

$$\text{Hedges's g} = \frac{M_1 - M_2}{SD^*pooled}$$

Where M_1-M_2 is the difference in means between the treatment and control group, and SD*pooled is the weighted and pooled standardized deviation.

In calculating Standardized Mean Differences (SMDs), the team applied the guidance of Cochrane Handbook.[58]

Continuous variables

For continuous variables, the team used the following formula to calculate SMDs:

$$\text{SMD} = \frac{\text{Difference in mean outcome between groups}}{\text{Standard deviation of outcome among participants}}$$

This formula was used for all continuous variables with effect sizes reported in regression coefficient. The pooled standard deviation was calculated as follows:

$$S_{pooled} = \sqrt{\frac{S_T^2 (n - 1) + S_C^2 (n_C - 1)}{n_r + n_C - 2}}$$

where s_T and s_T are the standard deviations in the treatment and control group, respectively; *nT* and *nC* are the sample size of the population from which the groups were drawn out.

For any studies that did not report sufficient data for the team to calculate SD, the team contacted the author to further inquire about the data.

In cases where SD was only reported either post- or pre-, it was assumed that the SD was similar in both periods. Similarly, for any studies that did not report the distribution of sample size between treatment and control groups, it was assumed that these groups were of equal size. In addition, the team performed basic transformations as needed, such as converting confidence intervals to SD.

58 https://training.cochrane.org/handbook/current/chapter-06#_Ref421277795

Binary variables

Among the binary variables, pneumonia and severe pneumonia were measured in relative risk the equation for which is as follows:

$$\text{Rate ratio} = \frac{\text{Incidence rate in experimental group}}{\text{Incidence rate in comparator group}}$$

All studies included in these meta-analyses provided effect sizes in relative risk.

COPD and hypertension were measured in odds ratio, the equation for which is:

$$\text{Odds ratio} = \frac{\text{Odds of event in experimental group}}{\text{Odds of event in comparator group}}$$

For a couple of studies, the team converted risk ratio to odds ratio using the 2x2 table of two group randomized trial with dichotomous outcome as detailed in the Cochrane guidelines.

Annex 8. Publication bias

Risk of publication bias in effects of electricity access on economic outcomes

Figure_33 **Income funnel plot**

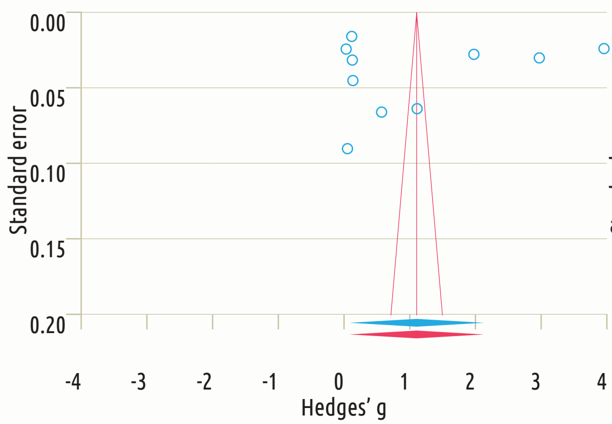
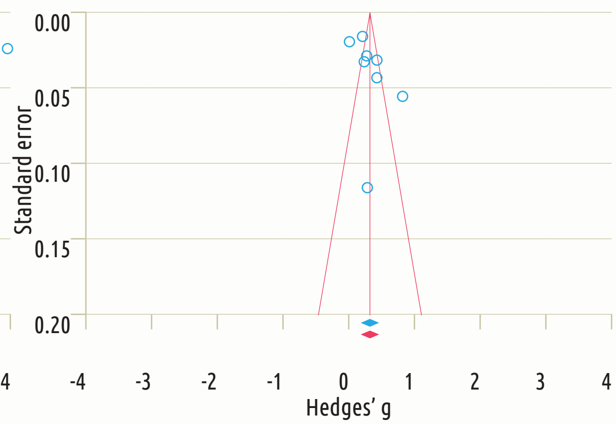
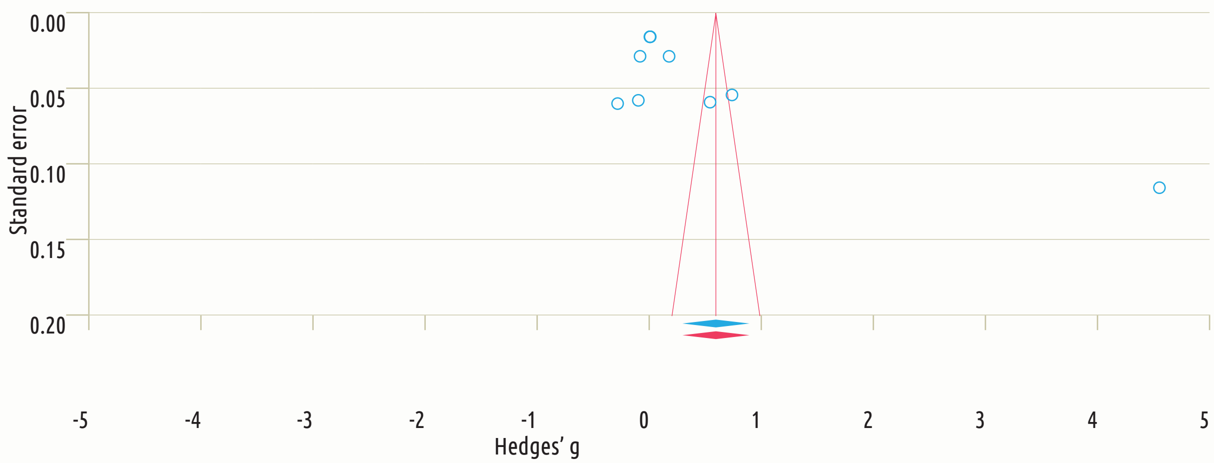


Figure_34 **Consumption and expenditure funnel plot**



Observed studies Imputed studies

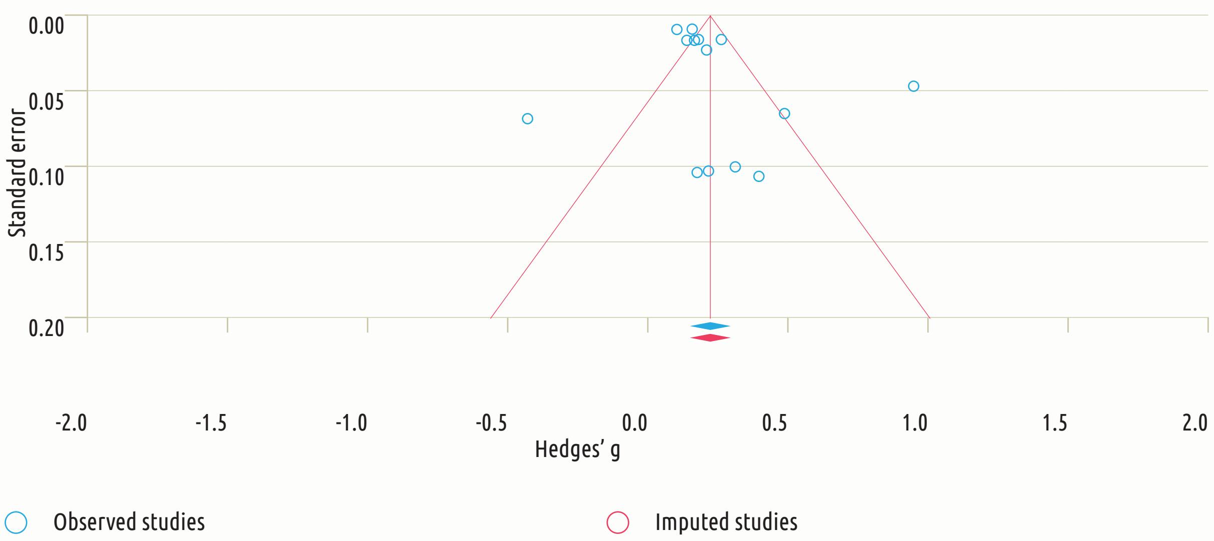
Figure_35 **Time spent working funnel plot**



Observed studies Imputed studies

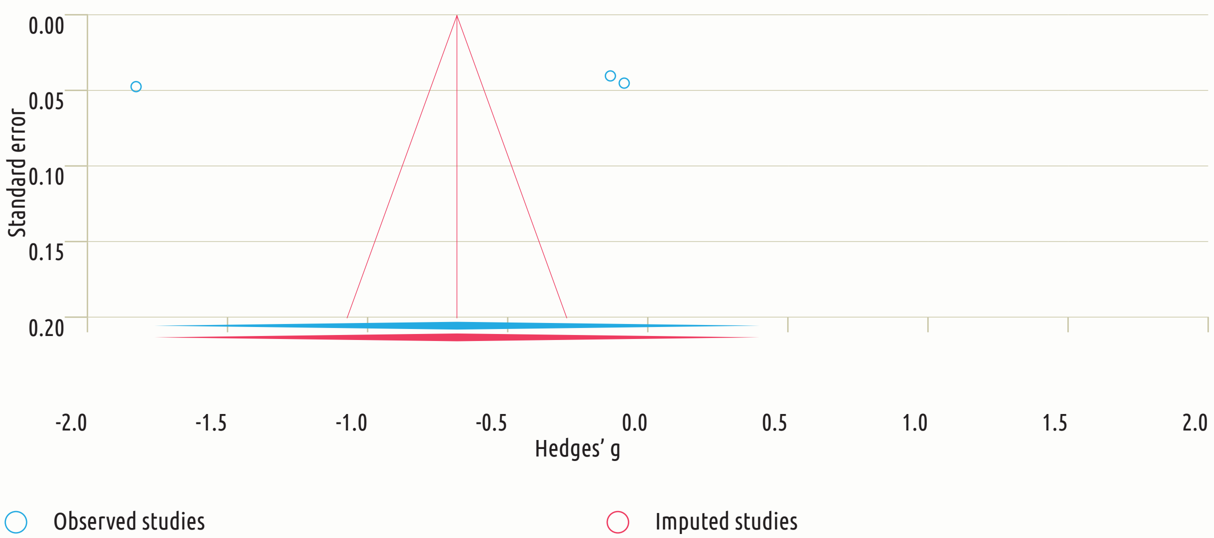
Risk of publication bias in effects of electricity access on education outcomes

Figure_36 **Study time funnel plot**



Risk of publication bias in effects of electricity access on women's empowerment

Figure_37 **Fertility funnel plot**



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Annex 10. Summary of existing literature

Table_6 **Previous systematic and non-systematic reviews on the impact of electricity**

Author and year	Topic	Key findings
Asian Development Bank, 2020[3]	**The systematic review with meta-analysis evaluates the impact of electricity interventions on socio-economic outcomes in low- and middle- income countries.**	**On average, electrification interventions have small but positive effects on education, socio-economic welfare, health, and environmental outcomes. These effects were associated with considerable heterogeneity across the studies.**
Asian Development Bank, 2019[4]	Summary of impact evaluations on energy supply interventions (mainly including electrification, energy efficiency programmes and electricity sector reforms) in developing countries.	The literature review found significant effects of electricity access on energy use, income, consumption, education, gender disparities, health, and fertility. The variation among findings requires further research.
Bayer and al., 2020[5]	Impact of household electrification on business creation, education, energy expenditure, household income/expenditure, and household savings in the developing world.	The systematic review found that the impacts on business creation, education, income and expenditure and household savings were positive for 48 papers and neutral for 16 papers. Only one paper noticed a negative impact following electrification, with reduced female labour market participation.
Jeuland and al., 2021[6]	A systematic review of the impacts of modern and traditional energy use in low- and middle-income countries (LMICs)	Positive impacts on income, consumption, education, gender empowerment, time allocation and firm productivity. Individual studies demonstrate considerable heterogeneity with many studies reporting null findings.
Dutch Ministry of Foreign Affairs, 2013[7]	Impact of renewable energy interventions (improved cooking stoves, biogas digesters, solar home systems, hydro powered mini-grids) on the livelihoods of end-users (individuals, households, public facilities and small enterprises) in rural areas and the urban periphery in developing and middle-income countries.	This systematic review found that renewable energy interventions have a positive impact on health and uncertain impacts on time savings. The impact on the environment is at best modest. The review also noted a two-way causality between income and energy use.
Hamburger *et al.*, 2019[8]	Impact of electricity access on socio-economic indicators in the developing world, with a focus on the geographical distribution of the evaluations.	Electricity access interventions were associated with greater benefits in South Asia than in sub-Saharan Africa, which calls for greater attention to geographical bias in future impact evaluations

Author and year	Topic	Key findings
Independent Evaluation Group, 20159	Impact of electricity access on health, education, and welfare in low- and middle-income countries.	Electricity access enhanced children education, total income and non-farm income. The evidence is mixed with regard to women's empowerment. No overall impact on the number of hours worked was observed. The evidence on health outcomes and micro-enterprise profit is weak.
Jimenez, 201710	Literature review on the impact of access to and improvements in electricity services on education, labour, and income.	Access to reliable electricity has a positive impact on school enrollment, employment and incomes. Greater effects were observed for poorer households, women, and smaller firms.
Köhlin *et al.*, 201511	Systematic review on advanced energy services (rural electrification and other renewable technologies) and biomass improved cooking stoves on air pollution, health, fuelwood and income.	Advanced energy services deliver health and income benefits.
Köhlin *et al.*, 201112	Literature review of the impact of household electrification on welfare and gender.	Electrification was associated with longer working days, better access to information, better and safer lighting, greater efficiency in domestic and caring responsibilities and expanded opportunities for income generation. In addition, electricity provision was found to potentially promote gender equality and women's empowerment.

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