02/2024

DEval DISCUSSION PAPER

ARE RURAL ENERGY ACCESS PROGRAMMES PRO-POOR INTERVENTIONS?

2024

Jörg Ankel-Peters
Gunther Bensch
Alexandra Köngeter
Mascha Rauschenbach
Maximiliane Sievert

DEval
GERMAN
INSTITUTE FOR
DEVELOPMENT
EVALUATION

IMPRINT

Published by

German Institute for Development
Evaluation (DEval)
Fritz-Schäffer-Straße 26
53113 Bonn, Germany

Phonel: +49 (0)228 33 69 07-0
E-Mail: info@DEval.org
www.DEval.org

Authors

Jörg Ankel-Peters[1,2]
Gunther Bensch[1]
Alexandra Köngeter[3]
Mascha Rauschenbach[3]
Maximiliane Sievert[1]

[1] *RWI – Leibniz Institute for Economic Research*
[2] *University of Passau*
[3] *German Institute for Development Evaluation*

Bibliographical reference

Ankel-Peters, J., G. Bensch, A. Köngeter, M. Rauschenbach and M. Sievert (2024), Are rural energy access programmes pro-poor interventions?, DEval Discussion Paper 2/2024, German Institute for Development Evaluation (DEval), Bonn.

ISBN 978-3-96126-213-7 (PDF)

The German Institute for Development Evaluation (DEval) is mandated by the German Federal Ministry for Economic Cooperation and Development (BMZ) to independently analyse and assess German development interventions.

DEval Discussion Papers present the results of the ongoing scientific study of evaluation and the effectiveness of development cooperation, thus contributing to relevant expert debates on evaluation, social science methods and development cooperation. The discussion papers are geared towards academics and practitioners in the field of evaluation, methodology research and development cooperation.

DEval Discussion Papers are written by DEval evaluators and external guest authors. In contrast to our evaluation reports, they do not contain any direct recommendations for German and international development organizations.

Although DEval Discussion Papers are internally peer-reviewed, the views expressed in them are only those of the authors and – unlike our evaluation reports – do not necessarily reflect those of DEval.

Abstract

This paper discusses whether energy access programmes in rural sub-Saharan Africa reach the poor. We examine on- and off-grid electrification as well as improved cooking. Pro-poor development requires that the programmes enable the poor to unlock their productive potential. We therefore focus on the productive use potentials triggered by energy access programmes, such as irrigation. Our review of the recent evaluation literature informed by our sector and evaluation experience on the topic also comprehensively cover other potential channels, including education and health. In doing so, we consider both direct economic benefits to the poor and whether indirect effects accrue to the unconnected via spillovers from among the connected. We conclude by emphasizing that energy access is beneficial for the poor if connections are made affordable through subsidization, but indirect effects from productive use and income generation are largely absent. From a pro-poor perspective, energy efficient biomass cookstoves offer the largest potential.

Acknowledgements

Corresponding author Jörg Ankel-Peters, *joerg.peters@rwi-essen.de*. Hohenzollernstr. 1-3, 45128 Essen, Germany. We are grateful for valuable comments and suggestions by Gerald Leppert and Sven Harten.

Contents

1. INTRODUCTION

It is consensus that access to electricity is a prerequisite to the provision of basic services and economic growth. Access to affordable and clean energy, which also includes access to improved cooking technologies, is therefore envisioned by the Sustainable Development Goals (SDGs) to improve livelihoods in low-income countries, not least in rural areas of sub-Saharan Africa (SSA) where energy-access deficits are most pronounced. But what does the recent experience tell us about whether energy-access programmes lead to pro-poor development?

In this perspectives article, we discuss the latest evidence from the energy-access literature on whether rural energy access programmes typically reach the poor. This discussion is crucially informed by our experience working in the energy sectors of different SSA countries and several impact evaluations we have conducted. We use our sector expertise to critically review the most relevant literature. We focus this analysis on the question whether energy access provides the poor with the opportunities to release their productive potential. Productive use potentials to promote capabilities are a key concern of the different understandings of "pro-poorness" (Kakwani and Pernia, 2000; Ravallion and Chen, 2003; Day et al., 2016), contributing to the distributional dimension of energy justice (Sovacool and Dworkin, 2014; Jenkins et al., 2016; Munro et al., 2017).

Pro-poor development effects can unfold by providing direct benefits to those gaining access to affordable and clean energy, who may still be poor despite typically being among the better-off in their communities. Alternatively, the pro-poor effects can unfold by indirect spillover effects from those who have received access to those who still lack energy access. For example, small enterprises or health centers that are newly connected to the electricity grid can generate externalities leading to more income or improved health status also among poor non-connected households.

We therefore first examine a key factor that determines which socio-economic strata obtain access in energy-access programmes: the typical cost burden of different energy access options. We then turn to our core discussion of the productive use of energy among enterprises and households in access programmes with no particular targeting, followed by a discussion of targeted productive use programmes and their impact potentials. Productive potentials among the poor can also be enhanced through educational and health impacts, through direct access or otherwise indirectly through schools and health infrastructure. Lastly, we describe those impact dimensions, for which there is most evidence on pro-poor impacts, namely savings in money and time.

In discussing these points, we distinguish between improved cooking technologies, more specifically energy-efficient biomass cookstoves (EEBCs) and clean fuels[1], as well as electrification in the form of the centralized grid, mini-grids, and stand-alone solar.

2. THE COST BURDEN OF DIFFERENT ENERGY-ACCESS OPTIONS

Two features of energy-access programmes determine the extent to which poorer strata are reached: a) the costs of the provided technology and b) the cost-sharing ambition of the program, that is, how much the end-users must contribute to acquisition costs via fees and prices.

For on-grid electrification programmes, the cost-sharing ambition is generally low, but fees are nevertheless often too high for considerable parts of the target population because of the extremely high costs. Therefore,

---

[1] In rural SSA, providing access to improved cooking technologies usually implies the dissemination of low-cost EEBCs. Liquefied Petroleum Gas (LPG) is hardly available in rural SSA and establishing supply chains is prohibitively expensive. Pilot projects for other clean stoves like gasifier stoves or biogas have largely failed (Carrión et al., 2021; Puzzolo et al., 2016; Rupf et al., 2015).

only the relatively better-off households get connected. Connection rates 'under the grid' across various countries are typically way below 100% (Golumbeanu and Barnes, 2013). Impact evaluations document connection rates in recently connected areas of 60% in Rwanda (Lenz et al., 2017), 39% in Ethiopia (Bernard and Torero, 2009), less than 30% in Tanzania (Chaplin et al., 2017), below 10% in Kenya (Lee et al., 2020a) and Burkina Faso (Schmidt and Moradi, 2023). To assess how responsive households are to connection fees, Lee et al. (2020a) randomized transformers across 150 communities in Kenya and, subsequently, randomized different subsidy levels for connection fees. They diagnose a sharp decrease in connection rates as fees increase: While almost all households connected if connection was for free, a subsidy equivalent to 57% or 29% increased connection rates by only 23 and 6 percentage points, respectively. Hence, considerable parts of the target population – and not least the poorer segments – do not directly benefit from grid extension programmes.

Programmes promoting stand-alone solar face lower technology costs than grid extension, yet most programmes follow a market-based paradigm requiring end-users to pay cost-covering prices. Programmes oftentimes only subsidize the marketing and perhaps the market expansion and after-sales infrastructure of a solar company. Since the demand for stand-alone solar is very sensitive to the price (see Grimm et al., 2020 and Meriggi et al., 2021), customers of such programmes are usually from better-off strata (see Barry and Creti, 2020, Bensch et al., 2018, and Mukoro et al., 2022).

Improved cookstove promotion programmes are also mostly implemented under the market-based paradigm, but costs of the technology are much lower, especially for EEBCs. At the same time, the price-responsiveness of improved cookstove demand is well established – including the diagnosis that many households in rural areas cannot afford the investment (Bensch and Peters, 2020; Beltramo et al., 2015; Munyehirwe et al., 2022; Pattanayak et al., 2019). Therefore, the cost-sharing approach screens out poorer households, especially in rural areas where the woodfuel is collected, not purchased so that no monetary savings can occur.

3. PRODUCTIVE USE IN ENERGY-ACCESS INTERVENTIONS

Technically, the grid and sufficiently sized mini-grids provide powerful electricity that can be used for energy-intensive machinery and three-phase current. Productive use potentials for grid electrification hence constitute the upper bound of productive use potentials related to energy access. If productive use does not emerge in the wake of grid connection, it is unlikely to emerge when lower-powered stand-alone solar systems or smaller-scaled mini-grids are promoted.

Overall, recent impact evaluations suggest that the productive use of electricity in newly connected regions is very limited. Technical potentials are not exploited, and consumption remains on a very basic level. What is more, most enterprises in grid covered rural areas are shops, bars, tailors and hairdressers, and home businesses in households are rare. They use electricity for lighting and small appliances like electric shaver, entertainment devices and fridges, sometimes complemented by offering phone charging. Usage of grid electricity for irrigation is rare since pumps are mostly needed in plots that are too far away from the grid. Only few enterprises are typically found in rural areas that do use powerful electric machinery (in most cases welders, carpenters, and mills). All these enterprises have in common that they mostly serve local demand. Products are very rarely sold to regional or urban markets.

These patterns have been observed in several impact evaluations covering both enterprises and households in different countries. Chaplin et al. (2017) use a difference-in-differences (DiD) design to evaluate a large-scale grid extension program in Tanzania and observe very little productive take up in enterprises or through home businesses. In a different part of Tanzania but also using a DiD design, Bensch et al. (2019) confirm these findings. Lenz et al. (2017) evaluate a country-wide grid roll-out program in Rwanda, using a mixed-methods DiD identification strategy. They also observe very low consumption levels among enterprises and households, mostly for lighting, which is generally in line with literature reviews on commercial and domestic productive use potentials (see, for example, Terrapon-Pfaff et al., 2018, Kizilcec and Parikh, 2020 or Radley and Lehmann-Grube, 2022). Lee et al.'s (2020a) study as well do not find productive take-up among households in their sample in Kenya. Again for Kenya, Taneja (2018) documents another remarkable pattern: even when accounting for the time since grid connection, electricity consumption levels in newly grid-connected areas are drastically lower for households and also clearly lower for small businesses. This underpins that, with progressive electrification, poorer and more remote and poorer regions are gaining access to the centralized grid.

One valid concern about all these studies is the short-term evaluation horizon: they examine adoption and impacts 2 to 5 years after connection. Masselus et al. (2024) therefore provide a 10-year long-term evaluation of the Lenz et al. (2017) sample and find that the consumption and take-up patterns have not changed. Very modest productive take-up among enterprises was also documented in Benin, seven years after grid connection (Peters et al., 2011).

Contrary to these studies using primary, self-collected data, the literature based on secondary data diagnoses positive impacts of grid-extension electrification (see Lee et al., 2020b for a review). Ankel-Peters and Schmidt (2023) argue that the key difference is that secondary-data studies cannot use well-specified interventions but have to rely on proxy measures to identify where electrification happened; they additionally note a higher risk of publication bias in secondary-data studies, due to lower incentives to pursue towards publication with a null result than with primary-data studies given the high costs of data collection. Moreover, only few secondary-data studies examine countries or regions in SSA (Hamburger et al., 2019; Peters and Sievert, 2016). Regardless of the deeper reasons for the divide in findings between these two types of studies, we argue that the impact evaluation literature referred to above is more relevant for program evaluation purposes and project specific cost-benefit analysis in rural SSA.

The literature on stand-alone solar and micro-grids confirms our prior of modest productive use and impacts of programmes promoting these technologies (see Grimm et al., 2017, Bensch et al., 2018, Kizilec and Parikh, 2020, and Radley and Lehmann-Grube, 2022 for stand-alone solar and Aklin et al., 2017 for micro-grids).

Most improved cooking programmes target households, not enterprises (see Grimm and Peters, 2015 for an efficient cookstove intervention targeting local beer breweries in urban Burkina Faso). One widespread productive application of improved cookstoves is in restaurants. Here, they likely lead to higher productivity, but probably not in a transformative way – also since, as discussed above, these enterprises mainly cater to local demand.

4. TARGETED PRODUCTIVE USE INTERVENTIONS

The previous section showed that programmes providing energy access to the broader population of households and enterprises in SSA yield no significant impacts on productive uses. We now turn to energy-access interventions that specifically target certain users with high productive potential (see Lukuyu and Taneja, 2023). For example, a mini-grid intervention could select only villages that host a so-called anchor customer. In practice, however, this proves difficult, as such anchor customers in remote areas are rare and identifying them often fails (see Duthie et al., 2023 for a large program pursuing this approach in Indonesia; see as well Peters et al., 2019). Mini-grid placement according to irrigation potentials is another option (Wamalwa et al., 2023). Lukuyu et al. (2022) propose a technique to detect such potentials based on existing diesel-fed irrigation pumps using remote sensing data.

Another approach is to target potential productive users with stand-alone solar-powered machinery. Their portability makes solar-powered water pumps particularly interesting. Increasing agricultural productivity via irrigation additionally circumvents the barrier to many other productive uses in rural areas, which is a lack of market access. Most parts of rural SSA are well integrated into markets for agricultural products. Expanding agricultural production is hence more straightforward than for artisanal or manufactured products (Peters and Sievert, 2016). While proof-of-concept evidence for solar-powered irrigation exists (Burney et al., 2010), a broader view on the thin literature suggests that promotion at scale encounters various problems: groundwater depletion, operational problems ranging from maintenance problems to lack of power on cloudy days (see Closas and Rap, 2017) and unresolved regulatory questions like land-tenure (Chokkakula and Giordano, 2013). Solar-powered water pumps also compete with diesel, which under many circumstances is the more economically viable energy source from the farmers' perspective (see Smith and Urpelainen, 2016 and Xie et al., 2021).

In general, diesel is the most important hazard to the impact potentials of this targeting approach because potentials for standard productive uses such as milling and pumping are typically already exploited in regions not covered by the grid, by using diesel-powered generators, pumps or mills. Less obvious productive potentials are much harder to identify. As a consequence, targeting programmes must either increase the risk they take and aim at not-so-obvious productive potential hitherto untapped by diesel-driven appliances. If the program otherwise supports the conversion of existing productive uses from diesel to solar or other sources of electricity, impact potentials are limited to potential fuel cost reductions (if the electricity is cheaper than diesel) and environmental benefits.

In sum, reliable evidence on targeted energy-access programmes is very scarce. Development practitioners' priors on such programmes are often shaped by experience and anecdotes from small-scale pilot projects. Tacit knowledge like this is not irrelevant, but it needs to be considered that small-scale pilot projects often are successful because they are small-scale and pilot. That is, the level of care the project receives from implementers typically cannot be replicated at scale, and once at scale, the increased supply of the supported production (e.g. irrigated vegetables) may find it harder to find sufficient demand. Nevertheless, productive use impact prospects for a program featuring a well-crafted targeting are certainly higher than for the typical non-targeted electrification program. In case they prove successful, a pro-poor effect is also plausible via external effects on local employment and income. In any case, also targeted approaches will require subsidization to overcome the limited purchasing power and liquidity constrains in the high-risk investment setting that rural entrepreneurs typically face.

5. HEALTH AND EDUCATION

Energy access may not only reach the poor through economic development in the narrow sense, but also by improving their health and educational status. This might happen through immediate effects on households with energy access or indirectly via improved educational and health services in public institutions.

Positive health effects on the household level are possible if dirty kerosene lamps are replaced by electric lighting (Barron and Torero, 2017). However, the LED lighting transition that rural SSA has experienced over the past 15 years changed the baseline situation. That is, kerosene is rarely used anymore in rural SSA and is replaced by LED torches and small solar lamps (Bensch et al., 2017). Household-level health effects are most widely discussed for improved cooking technologies. Simple EEBCs do not reduce smoke emissions to a level that is sufficient to prevent significant health hazards according to guidelines of the World Health Organization. While there is some suggestive evidence that positive health effects might nevertheless materialize (La Fave et al., 2021), for example because of a reduced cooking time and hence less smoke exposure (see Bensch and Peters, 2015), it seems more prudent not to expect substantive positive health effects in EEBC dissemination projects (Bensch et al., 2023). The alternative option of disseminating clean stoves like LPG or gasifier stoves has proven to be very difficult in rural SSA. Even in efficacy studies where the clean stoves (or fuels) were delivered free of charge to households, no health improvements could be observed, because many households continued to use dirty fuels for at least part of their food preparations (Jack et al., 2021; Mortimer et al., 2017).

Educational effects on the household level are most likely to materialize because of improved lighting conditions for studying at home. This has indeed been observed in Rwanda (Grimm et al., 2017), for example, but could not be confirmed in Malawi (Stojanowski et al., 2021). In sum, while positive educational and health effects might materialize on the household level under certain circumstance, it is unlikely that they will be very pronounced among poorer strata – also because adoption rates are low.

On the institutional level, it has often been claimed that the lack of electricity in rural health facilities and schools is a barrier for service provision (see for example Moner-Girona, 2021; IEG, 2008). In our experience (see Lenz et al., 2017, for example), though, even grid-connected schools hardly use electricity for educational purposes. Schools only operate during day-time hours and computers are not used in class. Teachers – often civil servants from urban areas – benefit and anecdotes suggest they tend to stay longer in a village if the grid is available. Rural health centers in regions beyond the reach of the grid mostly use a solar panel to fuel basic appliances like a fridge, a sterilizer and lighting. Fridges are otherwise also run on kerosene or gas. Electricity hence facilitates services (and lowers costs), but it is not key. Both health services and education are incredibly important for empowering the poor to develop out of poverty. Yet, both services are mainly hampered by the combination of other bottlenecks instead of the lack of access to electricity alone, including limited budgets, lack of skilled staff and equipment.

6. MAIN IMPACTS ON THE POOR: SAVINGS IN TIME AND MONEY

We have outlined in the previous sections that in most programmes, the poorer households in the respective target population do not obtain access, largely for affordability reasons, and that main transformative development effects on income, health, and education are limited. We now discuss other pro-poor effects can be identified at least for those with direct access to energy. For electricity, most important direct effects are on quality of life and convenience rather than dimensions with transformative potential. Electricity access can lead to monetary savings if electricity is indeed cheaper per kWh than what was used at baseline. Even then, the net savings effect on the household budget is either negligible or even negative, since new and often consumptive (not productive) energy services are used, such as television. Savings potentials are also limited for households who only consume lighting, because people use cheap LED torches or non-branded solar products to meet their basic lighting needs in the absence of electricity access (Bensch et al., 2017; Grimm and Peters, 2016; Groenewoudt et al., 2020).

The most accentuated impacts with some transformative potential occur for households who gain access to an EEBC. Here, the ratio between what can be expected in terms of monetary or time savings and the costs of an EEBC is clearly higher than for electrification. Firewood savings in rural areas for appropriate EEBCs that are also regularly used are between 15 and 40% (see Bensch and Peters, 2015; Munyehirwe et al., 2022, Mekonnen et al., 2022, and Usmani et al., 2017). Since firewood collection time, especially in biomass-scarce regions, is often in the ballpark of 8 to 12 hours per week, it is easy to see that such firewood savings rates have noteworthy impacts on people’s time constraints (see, e.g., Krishnapriya et al., 2021). Purchasing firewood is much rarer in rural SSA, but for those who purchase the savings are considerable and in the order of the abovementioned firewood savings.

7. CONCLUSION

Energy access is important for a decent living and providing everybody with electricity and proper cooking opportunities is a first-order policy priority, as it is reflected in the Sustainable Development Goals (SDG 7). Yet, rural energy access alone does probably not lead to transformative impacts in terms of economic development – even if the conventional wisdom also holds true in that electricity is required to enable endogenous growth. Most programmes also require the target group to share parts of the costs through connection fees or even cost-covering market prices, which excludes significant shares of the population from the service. Even for EEBC programmes, where the disseminated technology comes at much lower costs than for stand-alone solar or grid extension programmes, the poorer strata mostly abstain from making the investment. If these bottom-of-the-pyramid groups are to be reached, significant subsidies are necessary to bring down end-user prices to affordable levels. The interest of poorer households in improved energy services has been widely documented. It is affordability that hampers them from adoption. Subsidies targeted to potential productive users are probably also required if productive take-up should reach levels that might trigger transformational economic impacts. Simply replacing existing diesel applications (for example for irrigation pumps) may be a worthwhile undertaking, for grid planning and environmental reasons, but also to develop the market for such solar appliances. However, in order to have a noticeable impact, targeting procedures need to identify productive potentials that had not been profitable enough with diesel machinery. The extent to which such income-generation activities then reach the poor or otherwise spill over to poorer strata is yet another open question. In fact, from a pro-poor perspective, affordable and hence subsidized EEBCs offer the highest potentials.

8. REFERENCES

Aklin, M., P. Bayer, S.P. Harish and J. Urpelainen (2017), "Does Basic Energy Access Generate Socioeconomic Benefits? A Field Experiment with Off-grid Solar Power in India", *Science advances*, 3(5), e1602153, *doi.org/10.1126/sciadv.1602153*.

Ankel-Peters, J. and C. M. Schmidt (2023), "Rural Electrification, the Credibility Revolution, and the Limits of Evidence-based Policy", *USAEE Working Paper Series* No. 23-608.

Barron, M. and M. Torero (2017), "Household Electrification and Indoor Air Pollution", *Journal of Environmental Economics and Management*, 86, pp.81-92, *doi.org/10.1016/j.jeem.2017.07.007.*

Barry, M.S. and A. Creti (2020), "*Pay*-as-you-go Contracts for Electricity Access: Bridging the "Last Mile" Gap? A case study in Benin", *Energy economics*, 90, 104843, *doi.org/10.1016/j.eneco.2020.104843*.

Beltramo, T., G. Blalock, D. I. Levine and A. M. Simons (2015), "The Effect of Marketing Messages and Payment Over Time on Willingness to Pay for Fuel-efficient Cookstoves", *Journal of Economic Behavior & Organization*, 118, pp. 333−345, *doi.org/10.1016/j.jebo.2015.04.025.*

Bensch, G., W. Cornelissen, J. Peters, N. Wagner, J. Reichert and V. Stepanikova (2019), *Electrifying Rural Tanzania. A Grid Extension and Reliability Improvement Intervention*, Impact Report commissioned by the Netherlands Enterprise Agency, Ministry of Foreign Affairs of the Netherlands, The Hague.

Bensch, G., M. Grimm, M. Huppertz, J. Langbein and J. Peters (2018), "Are Promotion Programs Needed to Establish Off-grid Solar Energy Markets? Evidence from Rural Burkina Faso", *Renewable and Sustainable Energy Reviews*, 90, pp. 1060–1068, *doi.org/10.1016/j.rser.2017.11.003*.

Bensch, G., M. Jeuland, L. Lenz and O. Ndiaye (2023), "A Bridge to Clean Cooking? The Cost-Effectiveness of Energy-Efficient Biomass Stoves in Rural Senegal", *Ruhr Economic Papers*, No. 1057, *doi.org/10.4419/96973227.*

Bensch, G. and J. Peters (2015), "The Intensive Margin of Technology Adoption – Experimental Evidence on Improved Cooking Stoves in Rural Senegal", *Journal of Health Economics*, 42, pp. 44–63, *doi.org/10.1016/j.jhealeco.2015.03.006.*

Bensch, G. and J. Peters (2020), "One-Off Subsidies and Long-Run Adoption—Experimental Evidence on Improved Cooking Stoves in Senegal", *American Journal of Agricultural Economics*, 102(1), pp. 72–90, *doi.org/10.1093/ajae/aaz023*.

Bensch, G., J. Peters and M. Sievert (2017), "The Lighting Transition in Rural Africa—From Kerosene to Battery-powered LED and the Emerging Disposal Problem", *Energy for Sustainable Development*, 39, pp. 13−20, *doi.org/10.1016/j.esd.2017.03.004*.

Bernard, T. and M. Torero (2009), *Welfare Impact of Rural Electrification: 'Short-Term' Evidence from Ethiopia: A Report for the Ethiopian Electric Power Corporation and the World Bank*, International Food Policy Research Institute*,* Washington.

Burney, J., L. Woltering, M. Burke, R. Naylor and D. Pasternak (2010), "Solar-powered Drip Irrigation Enhances Food Security in the Sudano–Sahel". *Proceedings of the National Academy of Sciences*, 107(5), pp. 1848–1853, *doi.org/10.1073/pnas.0909678107.*

Carrión, D., R. Prah, T. Tawiah, O. Agyei, M. Twumasi, M. Mujtaba, D. Jack and K. P. Asante (2021), "Enhancing LPG Adoption in Ghana (ELAG): A Trial Testing Policy-Relevant Interventions to Increase Sustained Use of Clean Fuels", Sustainability, 13(4), 2213, *doi.org/10.3390/su13042213.*

Chaplin, D., A. Mamun, A. Protik, J. Schurrer, D. Vohra, K. Bos, H. Burak, L. Meyer, A. Dumitrescu, C. Ksoll and T. Cook (2017), Grid Electricity Expansion in Tanzania by MCC: Findings from a Rigorous Impact Evaluation, *Report submitted to the Millennium Challenge Corporation*, *Mathematica Policy Research*, Washington.

Chokkakula, S. and M. Giordano (2013), "Do Policy and Institutional Factors Explain the Low Levels of Smallholder Groundwater Use in Sub-Saharan Africa?" *Water international*, 38(6), pp. 790−808, *doi.org/10.1080/02508060.2013.843842*.

Closas, A. and E. Rap (2017), "Solar-based Groundwater Pumping for Irrigation: Sustainability, Policies, and Limitations", *Energy Policy*, 104, pp. 33–37, *doi.org/10.1016/j.enpol.2017.01.035*.

Day, R., G. Walker and N. Simcock (2016), "Conceptualising Energy Use and Energy Poverty Using a Capabilities Framework", *Energy Policy*, 93, pp. 255−264, *doi.org/10.1016/j.enpol.2016.03.019.*

Duthie, M., J. Ankel-Peters, C. Mphasa and R. Bhat, (2023), "The elusive quest for sustainable off-grid electrification: New evidence from Indonesia", *USAEE Working Paper Series*, No. 23-609.

Golumbeanu, R. and D. F. Barnes (2013), *Connection Charges and Electricity Access in Sub-Saharan Africa*, Policy Research Working Paper 6511, World Bank, Washington.

Grimm, M., L. Lenz, J. Peters and M. Sievert (2020), "Demand for Off-grid Solar Electricity: Experimental Evidence from Rwanda", *Journal of the Association of Environmental and Resource Economists*, 7(3), pp. 417−454, *doi.org/10.1086/707384.*

Grimm, M., A. Munyehirwe, J. Peters and M. Sievert (2017), "A First Step up the Energy Ladder? Low-cost Solar Kits and Household's Welfare in Rural Rwanda", *The World Bank Economic Review*, 31(3), pp. 631−649, *doi.org/10.4419/86788635*.

Grimm, M. and J. Peters (2015), "Beer, Wood, and Welfare – The Impact of Improved Stove Use Among Dolo-Beer Breweries", *PLOS ONE*, 10(8), e0132603, *doi.org/10.1371/journal.pone.0132603.*

Grimm, M. and J. Peters (2016), "Solar Off-Grid Markets in Africa. Recent Dynamics and the Role of Branded Products", *The Journal of Field Actions,* Special Issue 15, pp. 160−163.

Groenewoudt, A. C., H. A. Romijn and F. Alkemade (2020), "From Fake Solar to Full Service: An Empirical Analysis of the Solar Home Systems Market in Uganda", *Energy for Sustainable Development*, 58, pp. 100−111, *doi.org/10.1016/j.esd.2020.07.004*.

Hamburger, D., J. Jaeger, P. Bayer, R. Kennedy, J. Yang and J. Urpelainen (2019), "Shades of Darkness or Light? A Systematic Review of Geographic Bias in Impact Evaluations of Electricity Access", *Energy Research & Social Science*, 58, 101236, *doi.org/10.1016/j.erss.2019.101236*.

IEG (2008), *The Welfare Impacts of Rural Electrification: A Reassessment of the Costs and Benefits*, Independent Evaluation Group (IEG) Impact Evaluation, World Bank, Washington, *https://ieg.worldbankgroup.org/sites/default/files/Data/reports/rural_elec_full_eval.pdf* (accessed on 01.07.2024).

Jack, D. W., K. Ayuurebobi, C. F. Gould, E. Boamah-Kaali, A. G. Lee, M. N. Mujtaba, S. Chillrud, S. Kaali, A. K. Quinn, S. Gyaase and F. B. Oppong (2021), "A Cluster Randomised Trial of Cookstove Interventions to Improve Infant Health in Ghana", *BMJ Global Health*, 6(8), p.e005599, *doi.org/10.1136/bmjgh-2021-005599*.

Jenkins, K., D. McCauley, R. Heffron, H. Stephan and R. Rehner (2016), "Energy Justice: A Conceptual Review", *Energy Research & Social Science*, 11, pp. 174–182, *doi.org/10.1016/j.erss.2015.10.004*.

Kakwani, N. and E. M. Pernia (2000), "What is Pro-poor Growth?", *Asian Development Review*, 18(01), pp. 1−16, *doi.org/10.1142/S0116110500000014*.

Kizilcec, V. and P. Parikh (2020), “Solar Home Systems: A Comprehensive Literature Review for Sub-Saharan Africa”, *Energy for Sustainable Development*, 58, pp. 78–89, *doi.org/10.1016/j.esd.2020.07.010*.

Krishnapriya, P.P., M. Chandrasekaran, M. Jeuland and S. K. Pattanayak (2021), “Do Improved Cookstoves Save Time and Improve Gender Outcomes? Evidence from Six Developing Countries”, *Energy Economics*, 102, p. 105456, *doi.org/10.1016/j.eneco.2021.105456*.

LaFave, D., A. D. Beyene, R. Bluffstone, S. T. Dissanayake, Z. Gebreegziabher, A. Mekonnen and M. Toman (2021), “Impacts of Improved Biomass Cookstoves on Child and Adult Health: Experimental Evidence from Rural Ethiopia”, *World Development*, 140, p. 105332, *doi.org/10.1016/j.worlddev.2020.105332*.

Lee, K., E. Miguel and C. Wolfram (2020a), “Experimental Evidence on the Economics of Rural Electrification”, *Journal of Political Economy*, 128(4), pp. 1523−1565.

Lee, K., E. Miguel and C. Wolfram (2020b), “Does Household Electrification Supercharge Economic Development?”, *Journal of Economic Perspectives*, 34(1), pp. 122−144, *doi.org/10.1257/jep.34.1.122*.

Lenz, L., A. Munyehirwe, J. Peters and M. Sievert (2017), “Does Large-Scale Infrastructure Investment Alleviate Poverty? Impacts of Rwanda’s Electricity Access Roll-Out Programme”, *World Development*, 89, pp. 88−110, *doi.org/10.1016/j.worlddev.2016.08.003*.

Lukuyu, J., G. Bensch, T. Conlon, A. Patel, V. Modi and J. Taneja (2022), “Diesel GenSat: Using Satellite Data to Detect Diesel-Powered Irrigation for Guiding Electrification in Ethiopia”, *In Proceedings of the Thirteenth ACM International Conference on Future Energy Systems*, pp. 325−337.

Lenz, L., A. Munyehirwe, J. Peters and M. Sievert (2017), “Does Large-Scale Infrastructure Investment Alleviate Poverty? Impacts of Rwanda’s Electricity Access Roll-Out Programme”, *World Development*, 89, pp. 88−110, *doi.org/10.1016/j.worlddev.2016.08.003*.

Lukuyu, J. and J. Taneja (2023), “Powering Up in Africa: Electricity Demand Stimulation to Build Inclusive Economies, Reduce Inequality, and Improve Power System Sustainability”, *Current Sustainable/Renewable Energy Reports*, 10(1), pp. 1−11, *doi.org/10.1007/s40518-023-00207-4*.

Masselus, L., J. Ankel-Peters, V. Modi, A. Munyehirwe, N. Williams and M. Sievert (2024), “Ten Years After: Long Term Adoption of Electricity in Rural Rwanda”, *Ruhr Economic Papers, 1086, doi.org/10.4419/96973261*.

Mekonnen, A., A. Beyene, R. Bluffstone, Z. Gebreegziabher, P. Martinsson, M. Toman and F. Vieider (2022), “Do Improved Biomass Cookstoves Reduce Fuelwood Consumption and Carbon Emissions? Evidence From a Field Experiment in Rural Ethiopia”, *Ecological Economics*, 198, 107467, *doi.org/10.1016/j.ecolecon.2022.107467*.

Meriggi, N. F., E. Bulte and A. M. Mobarak (2021), “Subsidies for Technology Adoption: Experimental Evidence from Rural Cameroon”, *Journal of Development Economics*, 153, 102710. *doi.org/10.1016/j.jdeveco.2021.102710*.

Moner-Girona, M., G. Kakoulaki, G. Falchetta, D. J. Weiss and N. Taylor (2021), “Achieving Universal Electrification of Rural Healthcare Facilities in Sub-Saharan Africa with Decentralized Renewable Energy Technologies”, *Joule*, 5(10), pp. 2687−2714, *doi.org/10.1016/j.joule.2021.09.010*.

Mortimer, K., C. B. Ndamala, A. W. Naunje, J. Malava, C. Katundu, W. Weston, D. Havens, D. Pope, N. G. Bruce, M. Nyirenda and D. Wang (2017), “A Cleaner Burning Biomass-Fuelled Cookstove Intervention to Prevent Pneumonia in Children under 5 Years Old in Rural Malawi (The Cooking and Pneumonia Study): A Cluster Randomised Controlled Trial”, *The Lancet*, 389(10065), pp. 167−175, *doi.org/10.1016/S0140-6736(16)32507-7*.

Mukoro, V., M. Sharmina and A. Gallego-Schmid (2022), “A Review of Business Models for Access to Affordable and Clean Energy in Africa: Do They Deliver Social, Economic, and Environmental Value?”, *Energy Research & Social Science*, 88, 102530, *doi.org/10.1016/j.erss.2022.102530*.

Munro, P., G. Van Der Horst and S. Healy (2017), “Energy Justice for All? Rethinking Sustainable Development Goal 7 Through Struggles over Traditional Energy Practices in Sierra Leone”, *Energy Policy*, 105, pp. 635−641, *doi.org/10.1016/j.enpol.2017.01.038*.

Munyehirwe, A., J. Peters, M. Sievert, E. H. Bulte and N. Fiala (2022), “Energy Efficiency and Local Rebound Effects: Theory and Experimental Evidence from Rwanda”, *Ruhr Economic Papers*, 934, *doi.org/10.4419/96973094*.

Pattanayak, S. K., M. Jeuland, J. J. Lewis, F. Usmani, N. Brooks, V. Bhojvaid, A. Kar, L. Lipinski, L. Morrison, O. Patange, N. Ramanathan, I. H. Rehman, R. Thadani, M. Vora and V. Ramanathan (2019), “Experimental Evidence on Promotion of Electric and Improved Biomass Cookstoves”, *Proceedings of the National Academy of Sciences*, 116(27), pp. 13282–13287, *doi.org/10.1073/pnas.1808827116*.

Peters, J. and M. Sievert (2016), “Impacts of Rural Electrification Revisited – the African Context”, *Journal of Development Effectiveness*, 8(3), pp. 327−345, *doi.org/10.4419/86788637*.

Peters, J., M. Sievert and M. A. Toman (2019), “Rural Electrification Through Mini-Grids: Challenges Ahead”, *Energy Policy*, 132, pp. 27−31, *doi.org/10.4419/86788909*.

Peters, J., C. Vance and M. Harsdorff (2011), “Grid Extension in Rural Benin: Micro-Manufacturers and the Electrification Trap”, *World Development*, 39(5), pp. 773−783, *doi.org/10.1016/j.worlddev.2010.09.015.*

Puzzolo, E., D. Pope, D. Stanistreet, E. A. Rehfuess and N. G. Bruce (2016), “Clean Fuels for Resource-Poor Settings: A Systematic Review of Barriers and Enablers to Adoption and Sustained Use”, *Environmental Research*, 146, pp.218-234, *doi.org/10.1016/j.envres.2016.01.002*.

Radley, B. and P. Lehmann-Grube (2022), “Off-Grid Solar Expansion and Economic Development in the Global South: A Critical Review and Research Agenda”, *Energy Research & Social Science*, 89, 102673, *doi.org/10.1016/j.erss.2022.102673*.

Ravallion, M. and S. Chen (2003), “Measuring Pro-poor Growth”, *Economics Letters*, 78(1), pp. 93−99, *doi.org/10.1016/S0165-1765(02)00205-7*.

Rupf, G. V., P. A. Bahri, K. De Boer and M. P. McHenry (2015), “Barriers and Opportunities of Biogas Dissemination in Sub-Saharan Africa and Lessons Learned from Rwanda, Tanzania, China, India, and Nepal”, *Renewable and Sustainable Energy Reviews*, 52, pp. 468–476, *doi.org/10.1016/j.rser.2015.07.107*.

Schmidt, M. and M. Moradi (2023), “Community Effects of Electrification: Evidence from Burkina Faso's Grid Extension”, *doi.org/10.2139/ssrn.4523234* (accessed on 01.07.2024).

Smith, M. G. and J. Urpelainen (2016), “Rural Electrification and Groundwater Pumps in India: Evidence from the 1982–1999 period”, *Resource and Energy Economics*, 45, pp. 31–45, *doi.org/10.1016/j.reseneeco.2016.05.004*.

Sovacool, B. K. and M. H. Dworkin (2014), *Global Energy Justice*, Cambridge University Press, Cambridge, *https://doi.org/10.1017/CBO9781107323605*.

Stojanovski, O., M. C. Thurber, F. A. Wolak, G. Muwowo and K. Harrison (2021), “Assessing Opportunities for Solar Lanterns to Improve Educational Outcomes in Off-Grid Rural Areas: Results from a Randomized Controlled Trial”, *The World Bank Economic Review*, 35(4), pp. 999−1018, *doi.org/10.1093/wber/lhab002*.

Taneja, J. (2018), *If You Build It, Will They Consume? Key Challenges for Universal, Reliable, and Low-Cost Electricity Delivery in Kenya*. Center for Global Development, Working Paper, 491, Washington, *https://dx.doi.org/10.2139/ssrn.3310479.*

Usmani, F., J. Steele and M. Jeuland (2017), "Can Economic Incentives Enhance Adoption and Use of a Household Energy Technology? Evidence from a Pilot Study in Cambodia", *Environmental Research Letters*, 12(3), 035009, *doi.org/10.1088/1748-9326/aa6008.*

Wamalwa, F., L. Maqelepo and N. Williams (2023), "Unlocking the Nexus Potential: A Techno-economic Analysis of Joint Deployment of Minigrids with Smallholder Irrigation", *Energy for Sustainable Development*, 77, 101345, *doi.org/10.1016/j.esd.2023.101345*.

Xie, H., C. Ringler and M. A. H. Mondal (2021), "Solar or Diesel: A Comparison of Costs for Groundwater-fed Irrigation in sub-Saharan Africa Under Two Energy Solutions", *Earth's Future*, 9(4), e2020EF001611, *doi.org/10.1029/2020EF001611*.