

Duthie, Mike; Ankel-Peters, Jörg; Mphasa, Carly; Bhat, Rashmi

Working Paper

The elusive quest for sustainable off-grid electrification: New evidence from Indonesia

Ruhr Economic Papers, No. 1049

Provided in Cooperation with:

RWI – Leibniz-Institut für Wirtschaftsforschung, Essen

Suggested Citation: Duthie, Mike; Ankel-Peters, Jörg; Mphasa, Carly; Bhat, Rashmi (2023) : The elusive quest for sustainable off-grid electrification: New evidence from Indonesia, Ruhr Economic Papers, No. 1049, ISBN 978-3-96973-218-2, RWI - Leibniz-Institut für Wirtschaftsforschung, Essen, <https://doi.org/10.4419/96973218>

This Version is available at:

<https://hdl.handle.net/10419/279545>

Standard-Nutzungsbedingungen:

Die Dokumente auf EconStor dürfen zu eigenen wissenschaftlichen Zwecken und zum Privatgebrauch gespeichert und kopiert werden.

Sie dürfen die Dokumente nicht für öffentliche oder kommerzielle Zwecke vervielfältigen, öffentlich ausstellen, öffentlich zugänglich machen, vertreiben oder anderweitig nutzen.

Sofern die Verfasser die Dokumente unter Open-Content-Lizenzen (insbesondere CC-Lizenzen) zur Verfügung gestellt haben sollten, gelten abweichend von diesen Nutzungsbedingungen die in der dort genannten Lizenz gewährten Nutzungsrechte.

Terms of use:

Documents in EconStor may be saved and copied for your personal and scholarly purposes.

You are not to copy documents for public or commercial purposes, to exhibit the documents publicly, to make them publicly available on the internet, or to distribute or otherwise use the documents in public.

If the documents have been made available under an Open Content Licence (especially Creative Commons Licences), you may exercise further usage rights as specified in the indicated licence.



RUHR

ECONOMIC PAPERS

Mike Duthie

Jörg Ankel-Peters

Carly Mphasa

Rashmi Bhat

The Elusive Quest for Sustainable Off-Grid Electrification: New Evidence from Indonesia

Imprint

Ruhr Economic Papers

Published by

RWI – Leibniz-Institut für Wirtschaftsforschung

Hohenzollernstr. 1-3, 45128 Essen, Germany

Ruhr-Universität Bochum (RUB), Department of Economics

Universitätsstr. 150, 44801 Bochum, Germany

Technische Universität Dortmund, Department of Economic and Social Sciences

Vogelpothsweg 87, 44227 Dortmund, Germany

Universität Duisburg-Essen, Department of Economics

Universitätsstr. 12, 45117 Essen, Germany

Editors

Prof. Dr. Thomas K. Bauer

RUB, Department of Economics, Empirical Economics

Phone: +49 (0) 234/3 22 83 41, e-mail: thomas.bauer@rub.de

Prof. Dr. Ludger Linnemann

Technische Universität Dortmund, Department of Business and Economics

Economics – Applied Economics

Phone: +49 (0) 231/7 55-3102, e-mail: Ludger.Linnemann@tu-dortmund.de

Prof. Dr. Volker Clausen

University of Duisburg-Essen, Department of Economics

International Economics

Phone: +49 (0) 201/1 83-3655, e-mail: vclausen@vwl.uni-due.de

Prof. Dr. Ronald Bachmann, Prof. Dr. Manuel Frondel, Prof. Dr. Torsten Schmidt,

Prof. Dr. Ansgar Wübker

RWI, Phone: +49 (0) 201/81 49-213, e-mail: presse@rwi-essen.de

Editorial Office

Sabine Weiler

RWI, Phone: +49 (0) 201/81 49-213, e-mail: sabine.weiler@rwi-essen.de

Ruhr Economic Papers #1049

Responsible Editor: Manuel Frondel

All rights reserved. Essen, Germany, 2023

ISSN 1864-4872 (online) – ISBN 978-3-96973-218-2

The working papers published in the series constitute work in progress circulated to stimulate discussion and critical comments. Views expressed represent exclusively the authors' own opinions and do not necessarily reflect those of the editors.

Ruhr Economic Papers #1049

Mike Duthie, Jörg Ankel-Peters, Carly Mphasa, and Rashmi Bhat

The Elusive Quest for Sustainable Off-Grid Electrification: New Evidence from Indonesia

Bibliografische Informationen der Deutschen Nationalbibliothek

The Deutsche Nationalbibliothek lists this publication in the Deutsche Nationalbibliografie;
detailed bibliographic data are available on the Internet at <http://dnb.dnb.de>

RWI is funded by the Federal Government and the federal state of North Rhine-Westphalia.

<http://dx.doi.org/10.4419/96973218>

ISSN 1864-4872 (online)

ISBN 978-3-96973-218-2

Mike Duthie, Jörg Ankel-Peters, Carly Mphasa, and Rashmi Bhat¹

The Elusive Quest for Sustainable Off-Grid Electrification: New Evidence from Indonesia

Abstract

High hopes are pinned to mini-grids for rural electrification, especially in remote and sparsely populated areas. This note presents new evidence from a large evaluation of a US Millennium Challenge Corporation investment into mini-grids in Indonesia. We find that, a few years after commissioning, many mini-grids in the program do not operate properly, corroborating older concerns about the sustainability of mini-grids and off-grid energy systems that have been voiced for several years. Operational costs are typically high and electricity demand low. Minigrid programs should take these structural challenges into account, and especially abstain from overly optimistic electricity demand projections.

JEL-Codes: H54, O13, O21, Q48

Keywords: Energy access; sustainability; infrastructure; mini-grids

October 2023

¹ Mike Duthie, Social Impact Inc., Arlington, USA; Jörg Ankel-Peters, RWI and University of Passau; Carly Mphasa, Social Impact Inc., Arlington, USA; Rashmi Bhat, Social Impact Inc., Arlington, USA. - We are grateful for valuable comments and suggestions by Marc Jeuland and Jonathan Phillips. The evaluation underlying this note was commissioned by the Millennium Challenge Corporation (MCC). - All correspondence to: Jörg Ankel-Peters, Hohenzollernstr. 1-3, 45128 Essen, Germany e-mail: joerg.peters@rwi-essen.de

1. Introduction

Providing reliable and powerful electricity to the hundreds of millions who are still lacking access remains a major global challenge. Mini-grids – fed by renewable energy sources like solar, hydro or biomass – can play a central role for remote last-mile regions or sparsely populated areas, supplying the powerful electricity of the centralized grid at lower cost than grid expansion (Trotter et al. 2019). Over the past decade or so, costs of mini-grids and other off-grid renewable energy (RE) equipment have decreased considerably, primarily due to cost declines for panels and batteries (ESMAP 2019).

In this note, we argue that sustainable operation of mini-grids remains challenging. We provide new evidence from a large-scale evaluation of 23 community-based off-grid (CBOG) RE grants, most of them mini-grids, in Indonesia confirming the structural problems documented in Peters et al. (2019): High transaction costs of operating mini-grids in rural areas collide with a low ability to pay and very limited commercial electricity demand. In our evaluation, four years post-commissioning, we find that 6 of 23 CBOG grants were not operational anymore and another 13 revealed substantial problems (Social Impact 2022).

We contend that the structural problems confirmed in our evaluation are inherent to the typical mini-grid program, which is therefore moribund as long as the program design does not appropriately address these patterns. Subsidization is widespread in the mini-grid sector, but in most cases addresses the capital costs, not the operation and maintenance (O&M) costs (AMDA 2022). The idea is that operators cover these O&M costs through their revenues, following a market-based paradigm: long-term financial incentives for operators are supposed to create a basis for sustainability. These long-term financial incentives, though, are contingent on being able to charge a cost-covering tariff and, oftentimes, on revenue growth from increasing demand (e.g., from new customers, or growth of economic activities using RE). We provide another piece of evidence that this model does not work – despite a program design with strong community ownership and accompanying measures fostering productive use of electricity.

Our findings add to a growing literature on mini-grids and their operational challenges. Several very recent contributions have improved the evidence base considerably: Both Pueyo

et al. (2022) and Zigah et al. (2023) examine mini-grids in Tanzania and diagnose profound sustainability issues. Lukuyu et al. (2023), also for mini-grids in Tanzania, observe very low consumption levels. Van Hove et al. (2022) particularly focus on productive use potentials and their role for sustainability (and bankability) in Sierra Leone. Likewise, Pueyo and DeMartino find that electricity consumption of small enterprises in villages connected to mini-grids in Kenya is very low. While AMDA (2022), a report by the Africa Minigrid Developers Association, is generally more optimistic, it also documents that 70% of mini-grid customers in 2020 consume less than 4 kWh and 30% less than 1 kWh per month. Duran and Sahinyazan (2021) and Ikejemba et al. (2017) provide analyses of success factors across a large number of mini-grid schemes of which, in fact, many have failed. Productive use promotion activities have been under scrutiny in van Hove et al. (2022), Kyriakarakos et al. (2020), Lukuyu et al. (2021), and Lukuyu and Taneja (2023). Our note also speaks to the findings in Egli et al. (2023) who diagnose more generally that electrification strategies often fail because of “misguided planning” and “oversizing”.

The regulatory framework is not the focus this note, but it was included in the evaluation approach as far as the CBOG grants were affected. For example, some of the mini-grids were close to the central grid run by the national utility, creating well-known uncertainties for operators about what happens in case the mini-grid is swallowed by the central grid (Comello et al. 2017, Tenenbaum et al. 2018). The regulatory framework and its implications for mini-grid sustainability are examined in Namujju et al. (2023), Peters et al. (2019) and Reber and Boothe (2018), for example. In a similar vein, Jeuland et al. (2023) examine enabling factors of private sector renewable energy developers.

2. The Green Prosperity Program in Indonesia

From 2013-2018, the Millennium Challenge Corporation (MCC), in partnership with the Government of Indonesia, invested \$56.4 million in a portfolio of 24 CBOG RE grants that aimed to increase productivity and reduce reliance on fossil fuels by expanding access to reliable renewable electricity.¹ Grantees proposed the RE technologies taking account of the local economic context and available renewable energy resources. The technology utilized

¹One grant consisting of a single biogas digester was excluded from the evaluation, which therefor covers 23 CBOG grants.

ranged from stand-alone systems of solar and hydro-power water pumps (3 grants), biogas digesters (2), solar home systems (3), and solar plants targeted at single entity productive use (5), as well as mini-grids in solar (5), hydro (8), and biogas (1 grant; some grants utilized multiple technologies). The scale of RE investments varied substantially across the portfolio, ranging from a disbursement of \$38,264 for construction of a solar water pump in one village, to \$9.8 million for the construction of three solar mini-grids and one water pump across three villages.

We conducted an extensive ex-post performance evaluation (Social Impact 2022) of the CBOG portfolio, including in-depth case studies of six grants.² We implemented a baseline in 2017, a midterm evaluation in 2020 and an endline in 2022. For all 23 grants, we collected data through document review and protocols, and also surveyed grantees and beneficiaries. For the in-depth case studies, we conducted interviews with local government, grantees, and beneficiaries at the CBOG grant sites.

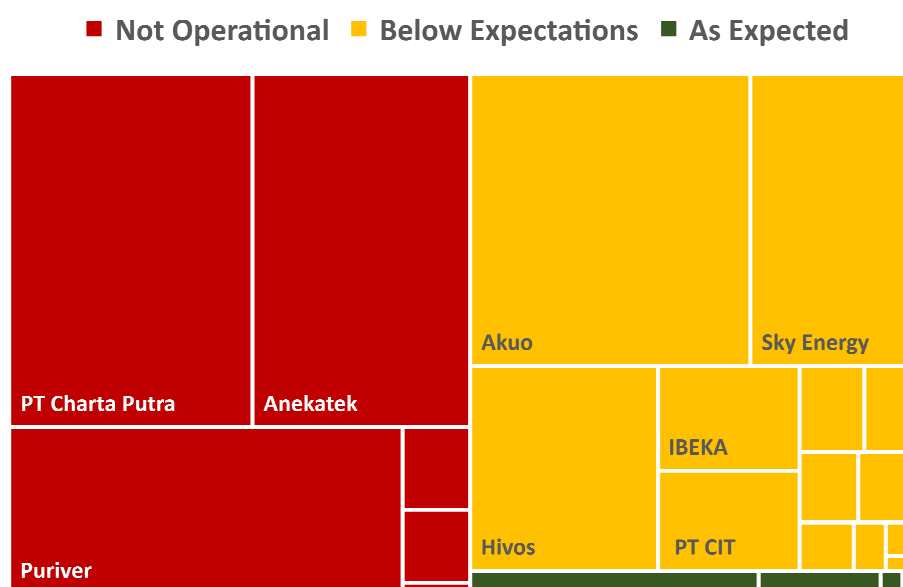
3. Findings

Overall, four years post-commissioning we find poor functionality of grant-funded infrastructure across the portfolio, with many technologies defunct or no longer in use (see Figure 1). A quarter of the grant-supported projects were completely non-operational at endline – these six grants accounted for roughly 50 percent of the overall investment (\$28.7 million). Another 13 grants were operating well below expectations, representing an additional 47 percent of the portfolio's RE investment (\$26.5 million). Only four grants were functioning in line with expectations across their entire grantee portfolio. These four grants were simpler in their scope (operated in a single location each and provided only one type of RE technology), and at \$1.3 million represented a mere two percent of the portfolio's RE investment.

The CBOG projects in this investment portfolio, serve a target population with a low ability to pay. The CBOG projects did attempt to stimulate economic activity by establishing agriculture production houses, providing equipment for processing and packing of products, as well as

²See MCC's Evidence Platform for our evaluation report and more information on the program and the evaluation including a lessons learned memorandum: <https://mcc.icpsr.umich.edu/evaluations/index.php/catalog/207>

training community members on processing agricultural products. Our evaluation revealed, though, that only a third of production houses were active at endline due to faulty machinery, limited working capital and community motivation, and low market access. In sum, these decentralized RE projects primarily served a residential target population with a low ability to pay. Complementary measures to stimulate productive energy use, essential to the project's sustainability approach, were not successful.



in Indonesia, such as lightning strikes, cyclones, and flooding. Outside of weather events, at least four grants had major equipment quality deficiencies, particularly those with solar-charged batteries. Under these conditions, revenues from tariffs are not high enough to cover O&M costs.

In terms of revenues, an important challenge was that obtaining sufficient financing for O&M was a big issue for most of the portfolio grants. Even for mini-grids that utilized pre-paid meters, low consumption levels by connected users constrained revenue potential. Most mini-grids overestimated demand in the planning phase, anticipating higher commercial and residential take-up. While 86 percent of grantees in the endline survey noted that demand for the technology was as anticipated, beneficiary and on-the-ground verification revealed multiple instances where demand failed to meet the projections made in grantees' business models. This leads to a dilemma: under a market-based paradigm, the mutual occurrence of high costs and low demand would require very high tariffs to sustain operations. High tariffs, though, are at odds with the low ability to pay in remote rural communities, and oftentimes also with government regulations that do not allow tariffs to exceed those paid by consumers connected to the national grid.

4. Conclusion

To conclude, it is important to stress that the implementation context of the CBOG grants is similar to that of other decentralized RE projects. Specifically, such projects are typically located in remote areas far from the centralized grid and, as a consequence, are also far away from other key infrastructures (such as quality roads and vibrant market exchanges). Access to agricultural products is difficult in such areas, and non-agricultural incomes are largely absent.

A major findings from this evaluation, the low electricity demand and the absence of considerable productive uses, are also aligned with much of the recent impact evaluation literature on on-grid extension into previously unserved rural areas in Burkina Faso, Kenya, Rwanda, and Tanzania (see Bensch et al. 2019; Chaplin et al. 2017; Lenz et al. 2018; Lee et al. 2020, Moradi and Schmidt 2022, Taneja 2018). The take-away for future off-grid and mini-grid programs is that project designs and accompanying business models should be scrutinized more critically, especially with regards to assumptions about demand and prospects for

commercial activities. In most rural areas, this will reveal a tension between required demand trajectories and tariffs. Simply adding elements geared to stimulating productive use does not address the underlying market-connectivity challenges and may therefore even further increase risks.

In terms of ownership models, our evaluation did not test different models against each other, but all schemes in the portfolio had a strong community ownership component (mostly village governments, village owned enterprises and specific purpose vehicles). We do not question the importance of community ownership, as it is for example emphasized in Duran and Sahinyazan (2021), and it is very plausible that no mini-grid scheme will sustainably operate without community involvement. However, community involvement is not sufficient to solve the high-costs-low-demand conundrum. Anecdotally, we found those schemes to operate more sustainably that have a business model which anticipated and mitigated potential problems post-implementation (for example technology failure and demand-related challenges). Simplicity also helps, we found, that is, having one technology that focuses on one location.

A potential approach for funding agencies to improve mini-grid sustainability at scale is to work on subsidy schemes that not only support the initial investment, but also ensure sustainable operation of mini-grids. This could be in the spirit of results-based financing (RBF) approaches, but with 'results' that are based on sustained connections, or could operate via a kWh-based subsidy akin to a feed-in tariff. Both design options are not easy to implement and require careful examination in the planning phase and ongoing monitoring during the implementation phase. These measures will make mini-grid projects more expensive in the first place, but the goal would be to achieve greater long-term success and cost-efficiency, as demand grows over time.

References

- AMDA, 2022. Benchmarking Africa's Minigrids Report. Africa Minigrid Developers Association (AMDA).
- Bensch, G., Cornelissen, W., Peters, J., Wagner, N., Reichert, J. and Stepanikova, V., 2019. Electrifying Rural Tanzania. A Grid Extension and Reliability Improvement Intervention.
- Chaplin, D., Mamun, A., Protik, A., Schurrer, J., Vohra, D., Bos, K., Burak, H., Meyer, L., Dumitrescu, A., Ksoll, C. and Cook, T., 2017. Grid Electricity Expansion in Tanzania by MCC: Findings from a Rigorous Impact Evaluation. Report submitted to the Millennium Challenge Corporation, Washington, DC: Mathematica Policy Research.
- Comello, S.D., Reichelstein, S.J., Sahoo, A. and Schmidt, T.S., 2017. Enabling mini-grid development in rural India. *World Development*, 93, pp.94-107.
- Duran, A.S. and Sahinyazan, F.G., 2021. An analysis of renewable mini-grid projects for rural electrification. *Socio-Economic Planning Sciences*, 77, p.100999.
- Egli, F., Agutu, C., Steffen, B. and Schmidt, T.S., 2023. The cost of electrifying all households in 40 Sub-Saharan African countries by 2030. *Nature Communications*, 14(1), p.5066.
- Energy Sector Management Assistance Program (ESMAP) 2019. Mini Grids for Half a Billion People: Market Outlook and Handbook for Decision Makers. World Bank.
- van Hove, E., Johnson, N.G. and Blechinger, P., 2022. Evaluating the impact of productive uses of electricity on mini-grid bankability. *Energy for Sustainable Development*, 71, pp.238-250.
- Ikejamba, E.C., Mpuan, P.B., Schuur, P.C. and Van Hillegersberg, J., 2017. The empirical reality & sustainable management failures of renewable energy projects in Sub-Saharan Africa (part 1 of 2). *Renewable Energy*, 102, pp.234-240.
- Jeuland, M., Babyenda, P., Beyene, A., Hinju, G., Mulwa, R., Phillips, J. and Zewdie, S.A., 2023. Barriers to off-grid energy development: Evidence from a comparative survey of private sector energy service providers in Eastern Africa. *Renewable Energy*, 216, p.119098.
- Kyriakarakos, G., Balafoutis, A.T. and Bochtis, D., 2020. Proposing a paradigm shift in rural electrification investments in Sub-Saharan Africa through Agriculture. *Sustainability*, 12(8), p.3096.
- Lukuyu, J. and Taneja, J., 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.
- Lukuyu, J., Shiran, M., Kennedy, R., Urpelainen, J. and Taneja, J., 2023. Purchasing power: Examining customer profiles and patterns for decentralized electricity systems in East Africa. *Energy Policy*, 172, p.113331.

- Lukuyu, J., Fetter, R., Krishnapriya, P.P., Williams, N. and Taneja, J., 2021. Building the supply of demand: Experiments in mini-grid demand stimulation. *Development Engineering*, 6, p.100058.
- Lee, K., Miguel, E. and Wolfram, C., 2020. Experimental evidence on the economics of rural electrification. *Journal of Political Economy*, 128(4), pp.1523-1565.
- Lenz, L., Munyehirwe, A., Peters, J. and Sievert, M., 2017. Does large-scale infrastructure investment alleviate poverty? Impacts of Rwanda's electricity access roll-out program. *World Development*, 89, pp.88-110.
- Moradi, A. and Schmidt, M., 2022. Community effects of electrification: evidence from Burkina Faso's grid extension.
- Namujju, L.D., Acquah-Swanzy, H. and Ngoti, I.F., 2023. An IAD framework analysis of minigrid institutions for sustainable rural electrification in East Africa: A comparative study of Uganda and Tanzania. *Energy Policy*, 182, p.113742.
- Peters, J., Sievert, M. and Toman, M.A., 2019. Rural electrification through mini-grids: Challenges ahead. *Energy Policy*, 132, pp.27-31.
- Pueyo, A. and DeMartino, S., 2018. The impact of solar mini-grids on Kenya's rural enterprises. *Energy for Sustainable Development*, 45, pp.28-37.
- Pueyo, A., Ngoo, G., Daulinge, E. and Fajardo Mazorra, A., 2022. The Quest for Scalable Business Models for Mini-Grids in Africa: Implementing the Keymaker Model in Tanzania.
- Reber, T. and Booth, S., 2018. Tariff structures to encourage micro-grid deployment in Sub-Saharan Africa: Review and recent trends. *Current Sustainable/Renewable Energy Reports*, 5, pp.199-204.
- Social Impact, 2022. Indonesia Green Prosperity Project Community-Based Off-Grid Renewable Energy Grant Portfolio – Endline Evaluation Report. Millennium Challenge Corporation.
- 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).
- Tenenbaum, B., Greacen, C. and Vaghela, D., 2018. Mini-grids and arrival of the main grid. World Bank. Washington, DC.
- Trotter, P. A., Cooper, N. J., & Wilson, P. R., 2019. A multi-criteria, long-term energy planning optimisation model with integrated on-grid and off-grid electrification–The case of Uganda. *Applied Energy*, 243, 288-312.
- Zigah, E., Barry, M. and Creti, A., 2023. *Are Mini-Grid Projects in Tanzania Financially Sustainable?* Electricity Access, Decarbonization, and Integration of Renewables, p.233-261.