REDUCING ENERGY POVERTY IN COLOMBIAN OFF-GRID SETTLEMENTS THROUGH BIOMASS GASIFICATION

Diaz, Carlos, Universidad Autónoma de Bucaramanga, +57 3168344143, cdiaz23@unab.edu.co
Henao, Juan Felipe, State University of New York Polytechnic Institute, +1 315-792-7395, henaoj@sunypoly.edu

Overview

Off-grid electrification in developing countries is a critical challenge, and this study focuses on assessing the viability of biomass gasification-based electrification for 575 off-grid settlements in Colombia. Given the deficit in electricity services and the potential for residual biomass, exploring this renewable source becomes paramount. The study addresses the significance of employing biomass gasification to improve energy poverty indicators in these settlements.

Methods

A comprehensive optimization model was formulated based on technical and commercial service data. The model utilized the weighted sum method to determine optimal outcomes for energy supply, subsidies allocation, and enhanced energy service levels. Sensitivity analyses were conducted to evaluate the impact of subsidy budget changes and subsidy matching policies on the optimal solutions, comparing them to the existing policy characterized by unequal subsidy distribution.

Results

The optimization model yielded compelling results, highlighting the potential of biomass gasification-based electrification to significantly improve energy access and alleviate energy poverty in off-grid settlements.

Impact on Electricity Access: Compared to the current scenario reliant on diesel-based electricity, the model demonstrated a positive impact on the electricity access gap. The implementation of biomass gasification led to a substantial increase in the amount of electricity supplied to these settlements without exceeding the existing subsidy budget. This increase was observed across different energy service levels, particularly in settlements where biomass gasification alone was sufficient for electricity supply.

Trade-Off Minimization: Under the current subsidy policy characterized by unequal allocation, a trade-off between improving access to electricity and avoiding overspending on electricity bills was evident. The model, however, showcased that this trade-off could be significantly minimized by adjusting the subsidy policy to ensure an equal percentage for all settlements. By doing so, a more balanced distribution of subsidies among settlements was achieved, preventing compromises in electricity access while maintaining similar service levels and biomass energy shares.

Sensitivity Analyses: The sensitivity analyses conducted for subsidy budget variations provided insightful results. A slight increase in the subsidy budget demonstrated considerable impacts. This increase was effective in preventing settlements from nearing overspending thresholds, even as the energy supplied increased by over 100%. The analyses also underscored the importance of adjusting subsidy policies, potentially incentivizing operators to invest in renewable energy solutions without adversely affecting poor population.

Conclusions

This study draws several important conclusions. Firstly, biomass gasification can maintain a balance between affordability and accessibility, supported by government subsidies and an anticipated rise in average income in these settlements. The optimization model highlights the trade-offs caused by unequal subsidy distribution, emphasizing the need for a more equitable distribution to prevent compromising electricity access. Adjusting the current subsidy allocation policy can effectively prevent trade-offs while maintaining similar levels of service, the share of energy from biomass, and avoiding electricity overspending.

The proposed methodology is considered innovative as it uses low-disaggregated and accessible data, offering a decision-making tool for various stakeholders, including governments, service operators, and local communities. The model's applicability extends beyond Colombia, making it replicable in other developing regions where renewable resources for off-grid electrification require careful analysis.

Main References

Acuna, M., Silva, C., Tocaruncho, A., Vargas, D., Patiño, D., Barrera, D., & Peña, J. (2021). Operational Planning of Energy for Non-Interconnected Zones: A Simulation-Optimization Approach and a Case Study to Tackle Energy Poverty in Colombia. Energies 2021, Vol. 14, Page 2789, 14(10), 2789. https://doi.org/10.3390/EN14102789

Calvo, R., Álamos, N., Billi, M., Urquiza, A., & Contreras, R. (2021). Desarrollo de indicadores de pobreza energética en

América Latina y el Caribe. Comisión Económica para América Latina y el Caribe (CEPAL). www.cepal.org/apps
Cedeno, E. B. (2019b). Optimization model to minimize budget subsidies considering uncertainty in electricity demand. Global Journal of Engineering Science and Researches, 6(6), 210–219. https://doi.org/10.5281/ZENODO.3262358
Culver, L. C. (2017, May). Energy Poverty: What You Measure Matters. Reducing Energy Poverty with Natural Gas: Changing Political, Business, and Technology Paradigms.
Fuso Nerini, F., Tomei, J., To, L. S., Bisaga, I., Parikh, P., Black, M., Borrion, A., Spataru, C., Castán Broto, V., Anandarajah, G., Milligan, B., & Mulugetta, Y. (2018). Mapping synergies and trade-offs between energy and the Sustainable Development Goals. Nature Energy, 3(1), 10–15. https://doi.org/10.1038/s41560-017-0036-5
G20. (2021). Energy Poverty: addressing the intersection of Sustainable Development Goal 7 (SDG7), development and resilience. https://www.seforall.org/system/files?file=2021-06/G20-SEforALL-Energy-poverty-executive-note.pdf
Garces, E., Franco, C. J., Tomei, J., & Dyner, I. (2023). Sustainable electricity supply for small off-grid communities in Colombia: A system dynamics approach. Energy Policy, 172, 113314. https://doi.org/10.1016/J.ENPOL.2022.113314
González-Eguino, M. (2015). Energy poverty: An overview. Renewable and Sustainable Energy Reviews, 47, 377–385. https://doi.org/10.1016/J.RSER.2015.03.013
Harold, J., Cullinan, J., & Lyons, S. (2017). The income elasticity of household energy demand: a quantile regression analysis. https://doi.org/10.1080/00036846.2017.1313952
IAEA. (2005). Energy indicators for Sustainable Development: Guidelines and Methodologies. IAEA. https://doi.org/10.1016/j.energy.2006.08.006
Iddrisu, I., & Bhattacharyya, S. C. (2015). Sustainable Energy Development Index: A multi-dimensional indicator for measuring sustainable energy development. Renewable and Sustainable Energy Reviews, 50, 513–530. https://doi.org/10.1016/J.RSER.2015.05.032
International Renewable Energy Agency IRENA. (2019). Off-grid renewable energy solutions to expand electricity access An opportunity not to be missed. In International Renewable Energy Agency, Abu Dhabi. https://www.irena.org/publications/2019/Jan/Off-grid-renewable-energy-solutions-to-expand-electricity-to-access-An-opportunity-not-to-be-missed
Jimenez, R., & Yepez-Garcia, A. (2017). Understanding the Drivers of Household Energy Spending: Micro Evidence for Latin America. http://www.iadb.org
Liddle, B., & Huntington, H. (2020). Revisiting the Income Elasticity of Energy Consumption: A Heterogeneous, Common Factor, Dynamic OECD & non-OECD Country Panel Analysis. https://doi.org/10.5547/01956574.41.3.blid
Ligus, M., & Peternek, P. (2021). The Sustainable Energy Development Index—An Application for European Union Member States. Energies 2021, Vol. 14, Page 1117, 14(4), 1117. https://doi.org/10.3390/EN14041117
Martínez Cortés, B. (2021). Propuesta para oficializar y calcular la pobreza energética en Colombia. Universidad Colegio Mayor de Cundinamarca.
Mirza, B., & Szirmai, A. (2010). Towards a new measurement of energy poverty: A cross-community analysis of rural Pakistan. UNU-MERIT.
Moore, N., Glandon, D., Tripney, J., Kozakiewicz, T., Shisler, S., Eyres, J., Zalfou, R., Daniela, M., Leon, A., Kurkjian, V., Snilstveit, B., & Perdana, A. (2020). Evaluation Independent Effects of Access to Electricity Interventions on Socioeconomic Outcomes in Low-and Middle-Income Countries Systematic Review Report.
Mould, R., & Baker, K. J. (2017). Documenting fuel poverty from the householders' perspective. Energy Research & Social Science, 31, 21–31. https://doi.org/10.1016/J.ERSS.2017.06.004
Nussbaumer, P., Bazilian, M., & Modi, V. (2012). Measuring energy poverty: Focusing on what matters. Renewable and Sustainable Energy Reviews, 16(1), 231–243. https://doi.org/10.1016/J.RSER.2011.07.150
Pablo-Romero, M. D. P., & de Jesús, J. (2016). Economic growth and energy consumption: The Energy-Environmental Kuznets Curve for Latin America and the Caribbean. Renewable and Sustainable Energy Reviews, 60, 1343–1350. https://doi.org/10.1016/J.RSER.2016.03.029
Pereira, G., González, A., & Ríos, R. (2021). Capturing Multidimensional Energy Poverty in South America: A Comparative Study of Argentina, Brazil, Uruguay, and Paraguay. Frontiers in Sustainable Cities, 3. https://doi.org/10.3389/frsc.2021.632009
POWERPOOR project. (2021). Energy poverty guidebook for energy planning. https://energy-communities-repository.ec.europa.eu/support/toolbox/energy-poverty-guidebook-energy-planning_en
Sharma, K. R., & Chan, G. (2016). Energy poverty: Electrification and well-being. Nature Energy 2016 1:11, 1(11), 1–2. https://doi.org/10.1038/nenergy.2016.171
Silva, D., & Nakata, T. (2009). Multi-objective assessment of rural electrification in remote areas with poverty considerations. Energy Policy, 37(8), 3096–3108. https://doi.org/10.1016/j.enpol.2009.03.060
Viteri, J. P., Henao, F., Cherni, J., & Dyner, I. (2019). Optimizing the insertion of renewable energy in the off-grid regions of Colombia. Journal of Cleaner Production, 235, 535–548. https://doi.org/10.1016/j.jclepro.2019.06.327