



Design and Fabrication of a Rocket Stove Thermoelectric Generator

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ABSTRACT

Lack of clean cooking energy and electricity in rural communities of most developing countries continues to remain a challenge. In Nigeria, it is estimated that more than 128,000 people died in 2019 from indoor air pollution caused by greenhouse gas emissions since over 175 million people in rural communities use open fires for cooking. In 2021, it was reported that almost 86 million Nigerians had no access to electricity. In this study, a rocket stove thermoelectric generator was designed, constructed, and tested to generate electricity and energy for cooking. The calorific value of wood was used to determine the heat generated during combustion. The stove was designed based on the combined principle of the J-type and L-type stove with a vertical section for feeding biomass and an oven to maximize the generated heat and a Platten for cooking pots. An SP1848 thermoelectric module having a maximum voltage output of 4.8 V and a heat resistance capacity of up to 150 °C to design the thermoelectric generator. 15 modules were used in total, three pairs of 5 were connected in series and then joined to each other in parallel to maximize output power to 48W. The thermoelectric generator was incorporated into the stove to convert excess heat to electricity generated in the combustion chamber to electricity. At an average temperature of 1200°C, the thermoelectric generator produces a power of up to 48W with the help of a voltage regulator, which could be used to power light bulbs, charge phones and other household gadgets or stored in the lithium batteries provided.

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INTRODUCTION

Nearly three billion people worldwide depend on open fireplaces for cooking, heating, and performing other domestic home activities (International Energy Agency (IEA) 2023). This has been the major cause of indoor air pollution and many health challenges such as respiratory diseases, cardiovascular diseases and eye problems. Each year, 3.2 million people die prematurely from illnesses attributable to the household air pollution caused by the incomplete combustion of solid fuels and kerosene used for cooking (World Health Organization (WHO) 2024). In 2021, it was reported that approximately 2.3 billion people worldwide still lacked access to clean cooking energy, and this number could

remain high, largely due to population growth in Sub-Saharan Africa slowing progress in access expansion (IEA, 2023).

This issue predominantly affects low-income and middle-income populations, with sub-Saharan Africa being the most affected region, because over 1 billion people rely on methods of cooking using open fires and rudimentary (clay) stoves. These methods of cooking have caused severe health issues, leading to about 3.7 million premature deaths annually due to poor indoor air quality, primarily affecting women and children (IEA, 2023) (World Health Organization (WHO)). Also, in these methods of cooking, more than 80% of the heat energy generated is usually wasted, making the process inefficient.

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Similarly, access to electricity in rural communities has continued to be a serious issue, with approximately 750 million people worldwide lacking access to electricity, and over 600 million of these population are from Africa. Sustainable Development Goal 7 (SDG-7) target indicates that by 2030, there will be universal access to modern energy services, which is affordable and reliable (United Nations (UN) 2023). The goal of SDG 7, which is to ensure access to affordable, reliable, sustainable, and clean energy, has been extended in some countries to 2060.

In order to achieve the target of SDG 7, concerted efforts are being made to provide clean and renewable energy for cooking to most of the population living without it. Patel et al, 2019, developed a low-cost thermoelectric cookstove to provide affordable electricity to rural communities in developing countries. The cookstove generated up to 3W of power and was affordable for rural households. It improved access to electricity for lighting and mobile phone charging, enhancing the quality of life. Raman et al focused on integrating thermoelectric generators with traditional biomass cookstoves used in rural India. The study found that the integrated system could generate up to 5W of power, sufficient to charge mobile phones and power LED lights. In this study, the aim is to design, fabricate, and test a rocket stove thermoelectric generator that will generate 48W of electricity and be used for cooking.

MATERIALS AND METHODS

Materials

The materials used for the construction of the stove include:

SP1847 27145 Thermoelectric module – this is shown in plate I. It was used to convert excess heat generated at the combustion chamber of the stove to electricity. For this study, 15 modules were used for the construction of the thermoelectric generator system.



Plate I. Thermoelectric module

Heat Sink – This is shown in plate II, and this was used to absorb and transfer heat directly from the combustion chamber to the thermoelectric module. The thermoelectric module is directly attached to this heat sink.

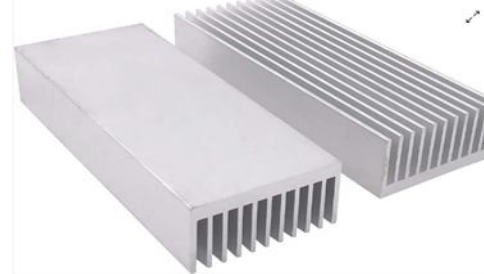


Plate II. Heat sink

Heat radiator/cooler – was used as a cooling mechanism to remove heat from the thermoelectric module.

12V DC brushless submersible water pump – this is shown in plate III and it was used for the circulation of water into the heat radiator, to remove heat absorbed by the radiator and to pass cooler water to the radiator.



Plate III. Water pump

XL4016 DC-DC Voltage Converter – This is shown in plate IV and it is used to adjust high input voltages from the thermoelectric module to an acceptable output voltage with high efficiency. The voltage converter acts as a power management circuit and helps regulate the voltage to a suitable voltage that can be safely stored in a battery.



Plate IV. XL4016 DC-DC Voltage converter

12V DC battery – this was used to store the energy generated by the thermoelectric module so that it can be used when the stove is not used for cooking.

Low Carbon Steel sheet – This low-carbon steel sheet, 2mm thick, was used for the construction of the body of the stove.

Methods

This section covers the design, design analysis, and fabrication of the different parts of the rocket stove thermoelectric generator.

Design of the combustion chamber of the rocket stove

The design parameters considered and designed for were the volume of the combustion chamber, air-fuel ratio, primary air supply, heat riser, chimney and exhaust pipe and primary air inlet

- a. Volume of the Combustion Chamber - The volume of the combustion chamber is crucial to ensure enough space for the fuel to burn efficiently. (Turns 2011).

$$V = L \times W \times H \text{ -----(i)}$$

Where: V = Volume of the combustion chamber (m^3), L = Length of the chamber (m), W = Width of the chamber (m), H = Height of the chamber (m)
Substitute 0.203m, 0.203m, and 0.381m respectively for the L, W and H in eqn1, the volume is obtained as follows;
 $V = 0.203 \times 0.203 \times 0.381 = 18m$

- b. Air-fuel ratio (AFR) – to know the rate at which complete combustion will take place, the air-fuel ratio (AFR) was calculated. (Heywood 1988).

Substituting $x = 1m$, $y = 8.2m$ in eqn(ii), the ARF is obtained as follows

$$AFR = \frac{x + \frac{y}{4} \times 137.28}{12x + y} = 14 \text{ -----(ii)}$$

- c. Heat Riser Dimension – The heat riser should be designed to create sufficient draft and maintain high temperatures for efficient combustion. The height (H_{riser}) and Diameter (D_{riser}) were determined as follows (Anderson, 2010):

$$H_{riser} = 3 \times H_{chamber} \text{ -----(iv)}$$

$$H_{chamber} = 0.381m$$

$$H_{riser} = 3 \times 0.381$$

$$H_{riser} = 1.14m$$

$$D_{riser} = 1.5 \times D_{chamber} \text{ -----(v)}$$

$$D_{chamber} = 0.102$$

$$D_{riser} = 1.5 \times 0.102 = 0.153m$$

- d. Chimney and Exhaust pipe – the height of the chimney was determined as follow (Van Bavel, 2012)

$$\text{Height} = 2 \times \text{Heat riser height} \text{ -----(vi)}$$

Substituting 0.381 for the $H_{chamber}$ in equation (iv)

$$\text{Heat riser height} = 1.14m$$

$$\text{Height} = 2 \times 1.14 = 2.3m$$

- e. Primary Air Inlet - The primary air inlet was placed on stove models at the bottom to provide excess air for drafting and better combustion. The hole size was smaller than the stoking hole. The Air draft force (F_{draft}) was determined as follows (Hottel et al, 1971)
 $F_{draft} = \rho_{air} \times g \times h \text{ -----(vii)}$

Where ρ_{air} = density of air = 1.225, g = acceleration due to gravity = 9.81, h = height = 2.3

Substituting the values of ρ_{air} , and h into eqn(vii)

$$F_{\text{draft}} = 1.225 \times 9.81 \times 2.3 = 27.64 \text{ N/m}^2$$

Design and construction of the Thermoelectric generator system

Design Consideration

The thermoelectric module SP1847 was connected in series and in parallel, this is done so as to get the required voltage output and current. It is noted that when voltage is connected in series, they add up, resulting in a higher total voltage output.

Where I_1 = the current that flows through module 1. Note that the current in the series connection remains constant, and is represented by equation 9.

This implies that the current that flows through module 1 is the same as that which flows through module 2, etc, therefore current attained in the series connection is 0.669A. Conversely, when voltages are connected in parallel, the resulting voltages must be the same to avoid potential damage. (Brown, 2022)

In this study, five SP1847 were connected in series and their voltage as presented in eqn 8

$$V_{(a)\text{total}} = V_1 + V_2 + V_3 + V_4 + V_5 \text{ -----(iiix)}$$

where V_1 is the voltage of the 1st thermoelectric module

V_2 is the voltage of the 2nd thermoelectric module

V_3 is the voltage of the 3rd thermoelectric module

V_4 is the voltage of the 4th thermoelectric module

V_5 is the voltage of the 5th thermoelectric module

Substitute the value voltages in each module in

$$V_{(a)\text{total}} = 4.8 + 4.8 + 4.8 + 4.8 + 4.8 + 4.8 = 24 \text{ V}$$

Where I = current through the entire system.

$$I = 0.669 \text{ A}$$

When modules are connected in series, their voltages add up while the current remains the same. This configuration is useful if you need to increase the voltage to match the requirements of a specific application.

Connection of the SP1847 in Parallel connection; the voltage across the module's connection is the same expressed by eqn12, however, the current that flows in the module, it adds together as expressed in eqn13.

Total Voltage (V_{total}):

$$V_{\text{total}} = V_a = V_b = V_c \text{ -----(12)}$$

$$V_{\text{total}} = 24 = 24 = 24 = 24 \text{ V}$$

Total Current (I_{total}):

$$I_{\text{total}} = I_a + I_b + I_c \text{ -----(13)}$$

$$I_{\text{total}} = 0.669 + 0.669 + 0.669 = 2.007 \text{ A}$$

Power output is determined by the equation 14

$$\text{Power output} = I \times V \text{ -----(14)}$$

$$\text{Power output} = 24 \times 2.007 = 48 \text{ W}$$

The design and fabrication of inverter system:

This was use to convert the DC generated from the XL4016 Voltage Converter to AC current.

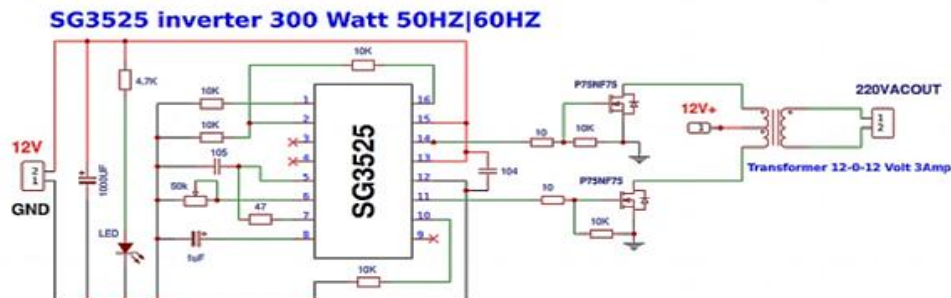


Figure 1. Inverter Circuit

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It was designed and constructed using a SG3525, transformer, Vevo board capacitors, fixed and variable resistors, and MOSFET. All these works together to convert the DC voltage generated by the thermoelectric generator system to AC voltage.

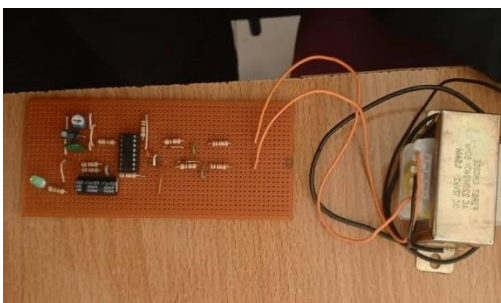


Plate 5. Fabricated Inverter System

Fabrication of Rocket Stove

The body of the rocket stove was fabricated locally using low carbon steel with thickness of 2mm, while most of the other parts which include the thermoelectric generator system and electrical component were sorted locally. The body of the stove consist of combustion chamber, cooking plate, chimney, ash pan, etc.

- i. The Combustion Chamber - It was fabricated using a 2 mm thick low-carbon steel plate. The sheet was cut to specification and welded to the required shape using arc welding. This chamber ensures efficient combustion by concentrating heat and controlling the air-fuel mixture. The biomass feeder and air inlet system are attached to the combustion chamber. they work together to ensure efficient combustion of biomass. The combustion chamber is shown in plate 6.



Plate 6. Combustion Chamber

- ii. Cooking Flatten - The cooking flatten is where pots or pans are placed for cooking. It was constructed using low-carbon steel, cutting it to size and securely mounting it in line with the combustion chamber to ensure effective heat transfer. It was made 2mm thick for efficient heat transfer to the cooking surface. The cooking flatten is shown in plate 7.



Plate 7. Cooking Flatten.

- iii. Chimney – is the part of the rocket stove through which exhaust gases and any smoke are removed. The **chimney** vents the combustion gases and smokes out of the rocket stove. It was fabricated using 2mm thick low-carbon steel, the sheet was cut into specification and welded into a vertical stack that channels exhaust gases away from the cooking area. The chimney is shown in plate 8.



Plate 8. chimney

- iv. Ash pan - collects ash and residues from the burning fuel. It was fabricated using 2mm thick low-carbon steel, including a handle for easy removal and cleaning. The ash pan facilitates maintenance and prevents clogging.
- v. Air inlet – this part of the stove allows for the air inflow into the combustion chamber for the complete combustion of the biomass i.e. wood.
- vi. Heat Riser - is a vertical tube that channels flame from the combustion chamber upwards, creating a strong draft and maintaining high temperatures. Unlike most conventional rocket stoves, the heat riser was constructed adjacent to the combustion chamber. It was fabricated using a 2 mm thick low-carbon steel square pipe, the pipe was cut to the appropriate length, and attached securely to the combustion chamber.
- vii. Feed pan – it is where the wood or briquette is introduced into the combustion chamber, creating a rectangular feed tube that allows easy loading of wood while minimizing air leaks. It was constructed 2mm low-carbon steel sheet, this pan provides a steady supply of wood or briquette to the combustion chamber. The feed pan is show in plate 9.



Plate 9. Feed pan

- viii. Oven – Aside from the cooking plate, there is a mini oven designed for baking or keeping food at a controlled temperature by ensuring stable and even heat distribution. It was constructed using a 2mm thick low-carbon steel sheet. The sheet was cut to specification and welded to produce a box-

like shape. A hinged door with a tight seal and a small vent for airflow control helps regulate the cooking temperature. This allows for precise temperature control. The oven compartment is show in plate 10.



Plate 10. Oven Compartment

Evaluation of the performance of the Rocket stove thermoelectric generator

The voltage generated from the 15 SP1847 modules connected together was measured at different temperatures. The process was repeated three times and the average value of the voltage was determined for each temperature as presented in the table below. The voltage of thermoelectric generator (TEG) module voltage was measured and recorded immediately combustion started, and different voltages at different temperature gradients. The voltage was measured 5 pairs as connected in series. The results are summarized as follows:

Table 1: Average Voltage Generated

Temp °C	Average voltage V
0	0
10	2.53
20	4.95
30	5.63
40	9.57
50	11.63
60	12.47
70	13.73
80	16.17
90	17.47

Performance evaluation of the Rocket Stove

The rocket stove performance was evaluated by determining the fuel consumption, combustion efficiency and heat output. Firstly, 2kg of wood was weighed and placed on the stove. The temperature of the stove was taken after 30 minutes. This was done three times and the temperature of was recorded. The average temperature was also calculated.

Table 2: The temperature of the different part of the Rocket Stove Thermoelectric Generator

Stove Part	Average Temp
Wall Temperature (°C)	182
Surface Temperature (°C)	97
Oven Temperature (°C)	426

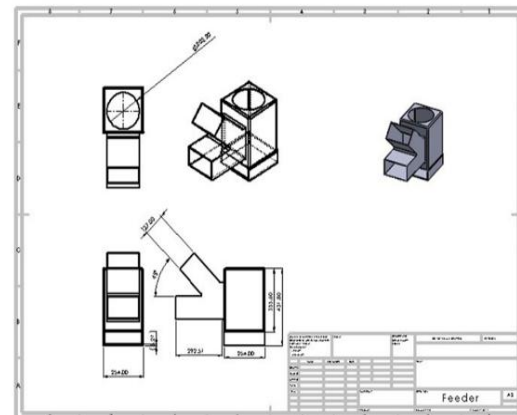
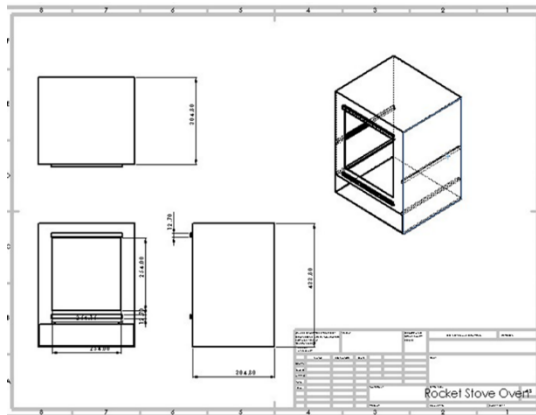
A test was carried out to determine the efficiency of the stove and how long it will take to boil 1 litre and 2 litres of water.

Table 3: Water Boiling Test Using 1KG of Wood.

Water in Liters	Initial Temp °C	Final Temp °C	Time (mins)
1L	18 °C	100 °C	30
2L	18 °C	100 °C	48

APPENDICES

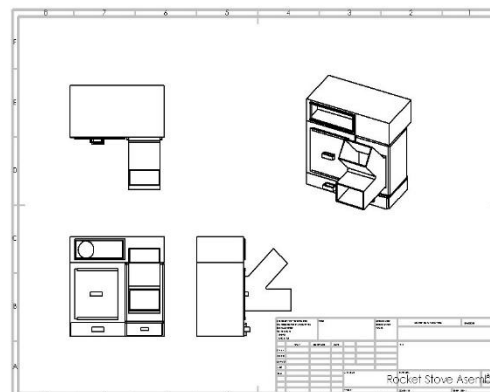
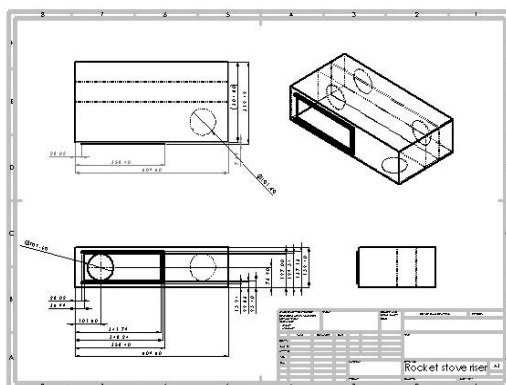
Appendix 1: Engineering Drawings



CONCLUSION

The rocket stove thermoelectric was designed and fabricated and its performance was evaluated. The stove was fabricated using 2mm thick low-carbon steel to reduce cost. The stove was built three times the size of a cooking stove with an oven compartment. A thermoelectric generator system was incorporated to enable the stove to generate electricity by absorbing the heat directly from the combustion chamber of the stove. Because of the stove design, it serves a dual purpose, which is cooking and baking majorly, but it can be used for other purposes. This stove was designed and constructed to solve the problem encountered while cooking and also show the possibility of generating electricity by harnessing heat energy. An AC inverter was incorporated into the system, converting DC to AC making it suitable for use.

This project has shed light on what could be done regarding making cooking stoves in Nigeria and other developing countries clean and accessible. This project aims at solving the energy crisis as well as climate change through sustainable cooking, reducing indoor air pollution, and provide electricity to power small appliances.



REFERENCES

- Anderson, A. (2010). *Design and development of the rocket stove: A study of principles and practices for improved wood-burning stoves*. Aprovecho Research Center.
- Ahmed, S., Khan, M., & Baloch, A. (2021). Smart Thermoelectric Biomass Stove for Off-Grid Communities. *Energy Conversion and Management*, 228, 113715.
- Ahmed, S., Khan, M., & Baloch, A. (2021). Smart Thermoelectric Biomass Stove for Off-Grid Communities. *Energy Conversion and Management*, 228, 113715.
- Alliance Fuel 2020 A Handbook for Biomass Cookstove Research, Design, and Development A practical guide to Implementing Recent Advances (www.cleanstoves.org)
- Anderson, A. *Design and Development of the Rocket Stove*. (2010).
- Augustyn A. "BRITANNICA," 2018. [Online]. Available: <https://www.britannica.com/biography/Thomas-Johann-Seebeck>. [Accessed 25 10 2019]
- Barnes, D. F., Krutilla, K., & Hyde, W. F. (2004). *The Urban Household Energy Transition: Social and Environmental Impacts in the Developing World*. Resources for the Future.
- Bentson, R., Mortimer, K., & Pope, D. (2013). Environmental health impacts of household solid fuel use: The need for improved stove. *Annals of Global Health*, 79(1), 1-13.
- Buschow, K. Jurgen, *Encyclopedia of Materials: Science and Technology*, 2001
- Bryden, M., Still, D., Scott, P., Hoffa, G., Ogle, D., Bailis, R., & Goyer, K. (2006). *Design principles for wood-burning cook stoves*. Aprovecho Research Center.
- Champier, D., Bedecarrats, J. P., Rivaletto, M., & Strub, F. (2010). Thermoelectric power generation from biomass cook stoves. *Energy*, 35(2), 935-942.
- Danie Morros, September 2, 2021. a rocket stove and how does Rocket Stove work .<https://fireandsaw.com/what-is-a-rocket-stove/>
- Evans, I., & Jackson, L. (2005). **Rocket mass heaters: Superefficient woodstoves YOU can build*. Cob Cottage Publications.
- Hottel, H. C., & Howard, G. H. (1971). *Radiative Transfer*. McGraw-Hill.

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- Ibikunle, R. A., Akinbulire, T. O., & Olusunle, S. O. O. (2015). Development of thermoelectric power generation system for cooking applications in rural areas. *Energy Reports*, 1, 12-17
- IEA, IRENA, UNSD, World Bank, WHO. 2024. Tracking SDG 7: The Energy Progress Report. World Bank, Washington DC. © World Bank. License: Creative Commons Attribution—NonCommercial 3.0 IGO (CC BY-NC 3.0 IGO)
- IEA, I. E. A. (2023). SDG7: data and projections. Retrieved [30.11.2023],
- International Energy Agency (IEA). (2019). Africa Energy Outlook 2019. Paris: IEA.
- International Energy Agency. (2023). *Tracking SDG7: The energy progress report 2023*.
<https://www.iea.org/reports/tracking-sdg7-the-energy-progress-report-2023>
- Li, G., Liang, Y., & Yang, H. (2016). Experimental study of a hybrid solar-biomass thermoelectric generation system. *Applied Thermal Engineering*, 106, 754-762.
- M. Huijben, P. Brinks, Epitaxial Growth of Complex Metal Oxides, Woodhead Publishing, 2015
- O. Ostroverkhova, Handbook of Organic Materials for Electronic and Photonic Devices, 2nd Ed., Woodhead Publishing, 2019
- Patel, R., Singh, K., & Mehta, P. (2019). Low-Cost Thermoelectric Cookstove for Rural Electrification. *Journal of Sustainable Energy*, 12(3), 220-227.
- Permaculture Principles (2022). The Rocket Stove: How it Works"-[Permaculture Principles](<https://permacultureprinciples.com/post/rocket-stove/>), 2022
- Puthumana JS, Ngaage LM, Borrelli MR, Rada EM, Caffrey J, Rasko Y: Risk factors for cooking-related burn injuries in children, WHO Global Burn Registry. Bull World Health Organ. 2021 Jun 1;99(6):439-445.
<https://doi.org/10.2471%2FBLT.20.279786>
- Raman, P., Murali, J., Sakthivadivel, D., & Vigneswaran, V. S. (2014). Performance evaluation of a thermoelectric generator integrated with a biomass cook stove. *Energy for Sustainable Development*, 23, 1-6
- Van Bavel, B. (2012). *Understanding and Implementing Rocket Stove Principles*. Aprovecho Research Center.
- World Bank. (2017). State of Electricity Access Report. Washington, D.C.: World Bank.