



Empowering Renewable Energy Awareness through Promoting Sustainable Cooking Solution with Biomass Stove Demonstration towards Energy Self-sufficiency at a Rural Islamic Boarding School in North Aceh

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ABSTRACT

The growing need for sustainable and affordable energy in rural Islamic boarding schools presents both a challenge and an opportunity for innovation. This community service project showed the use of woodchip-fueled biomass stoves as an alternative cooking fuel at Al-'Urwatul Wutsqa Islamic Boarding School in Aceh Utara. It took place in Cot Seurani Village, Muara Batu Subdistrict. The scarcity and rising cost of LPG as the main cooking fuel were the main issues, limiting cooking options in the boarding school and remote communities. Onsite training and a practical demonstration of a rocket-type biomass stove using available woodchips comprised the activity. The team conducted a simple efficiency test and distributed an illustrated operational manual to support knowledge transfer. Results showed high student interest and positive response because of the stove's affordability, environmental benefits, and ease of use. This initiative raised awareness of renewable energy options, empowered the local community with practical solutions, and encouraged reduced reliance on fossil fuels (LPG). The program also laid the foundation for future development of energy self-sufficiency in the boarding school atmosphere.

1. Introduction

The use of biomass energy for household needs, especially cooking, has gained increasing attention in rural development strategies (Setiawan et al., 2018). Many rural communities in Indonesia continue to rely on traditional clay stoves fueled by firewood because of limited access to liquefied petroleum gas (LPG), which poses economic and environmental concerns. Biomass as a renewable energy resource offers a viable and sustainable alternative to fossil fuels. Its widespread availability, low cost, and potential to reduce greenhouse gas emissions make it an essential component in the transition toward green technology.

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Woodchip biomass, a by-product of sawmilling and carpentry, is one of the most underutilized energy sources despite its abundant presence in rural areas. Prior studies have emphasized the importance of improving combustion technology to increase thermal efficiency and reduce particulate emissions in biomass stoves (Widawati et al., 2019). Innovations such as rocket stove designs have demonstrated higher fuel efficiency and cleaner combustion compared to conventional three-stone stoves. However, dissemination of such technologies in educational or religious institutions such as Islamic boarding schools (pesantren) remains limited. In this context, the community service program introduced a biomass-fueled cooking stove using woodchips at Al-'Urwatul Wutsqa Islamic Boarding School in Cot Seurani Village, North Aceh shown in Figure 1. This initiative aimed to address two main problems: the scarcity of subsidized LPG and the lack of environmental education related to energy sustainability. The activity included socialization, demonstration, and efficiency comparisons of the biomass stove with traditional LPG stoves.

Despite various stove models being available, the use of local materials and simplified operating manuals enabled broader accessibility for the students at the boarding school. The significant research gap lies in the lack of practical and technical integration of biomass technologies in rural educational institutions. Therefore, this study aims to demonstrate the feasibility, efficiency, and educational impact of implementing woodchip-based biomass stoves in the boarding school settings to foster energy awareness and independence.

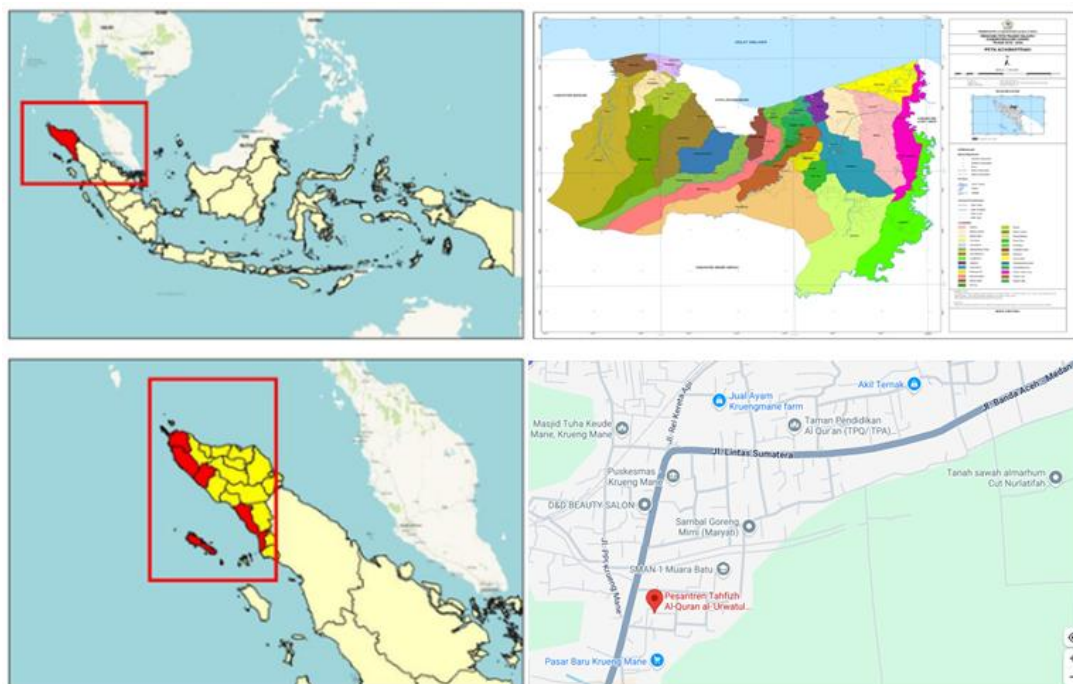


Fig. 1. Location of the Al-'Urwatul Wutsqa Islamic Boarding School, North Aceh, Indonesia

2. Methodology

This community service activity was conducted through a structured approach involving observation, design adaptation, field implementation, and participant engagement. The primary site for implementation was Al-'Urwatul Wutsqa Islamic Boarding School in Cot Seurani Village, Muara Batu Subdistrict, North Aceh. The methodology consisted of four main stages, namely pre-survey, training and socialization, demonstration, and post-evaluation.

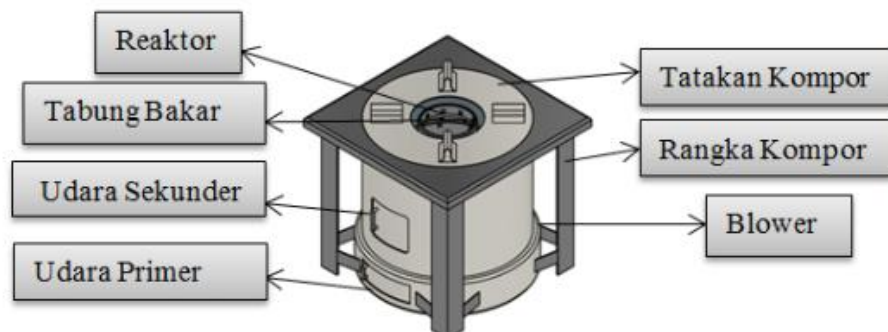
The initial stage involved an environmental survey to identify the potential of biomass sources around the boarding school. Local sawdust and woodchips resulting from carpentry activities were identified as the most abundant and untapped biomass materials. Dryness, size, and combustion behavior confirmed the suitability of these materials. Using locally available materials, a prototype biomass rocket stove has been constructed. The design was based on a double-combustion chamber concept with separate primary and secondary air pathways to increase thermal efficiency and reduce smoke output. The prototype was tested in a controlled setting before being introduced at the school.

The second phase involved educational training and socialization for students and teachers. Participants were introduced to basic renewable energy concepts, particularly the role of biomass in rural energy access. Printed module was used to support visual learning and the operational instruction and the main components of the stove (Figure 2).

In the demonstration stage, the stove was used to boil 1 liter of water using woodchip biomass as fuel. The time taken to reach boiling point and the amount of fuel used were recorded for simple efficiency evaluation. This was then compared with a conventional LPG stove using the same volume of water. As shown in Figure 3, the demonstration attracted significant attention from students, who were encouraged to operate the stove under supervision.



(a)



(b)

Fig. 2. (a) Printed operational instruction modul of the biomass stove (b) The main components of the stove

The final stage involved a feedback session and questionnaire distribution to assess participants' understanding and acceptance of the technology. The results were later compiled to inform the effectiveness of the community engagement and identify areas for improvement in stove design or implementation.



(a)



(b)

Fig. 3. (a) Preparation of the biomass stove demonstration using woodchip fuel (b) The demonstration during the community service activity

3. Results

The demonstration of the biomass stove using woodchip fuel was conducted successfully at Al-'Urwatul Wutsqa Islamic Boarding School. Students and teachers observed the operation of the

stove while participating in an interactive discussion about renewable energy applications in daily life. The activity was conducted in a hands-on manner, with students participating in feeding the stove with woodchips and monitoring the water boiling process.

A practical comparison was conducted between the biomass stove and a conventional 3 kg LPG stove to evaluate fuel efficiency. Under similar ambient conditions, 1 liter of water was boiled for the test. The time required to reach the boiling point and the cost implications of each fuel type were recorded. The summarized results are presented in Table 1.

Table 1

Comparison of Fuel Efficiency Between Biomass Stove and LPG Stove

Parameter	Biomass Stove (Woodchip)	LPG Stove (3 kg Cylinder)
Fuel used	70 grams of woodchip	12 grams of LPG
Boiling time (1 liter of water)	6 minutes 40 seconds	5 minutes 20 seconds
Estimated fuel cost	Rp 0 (from local waste)	Rp 90
Smoke emission	Low (due to double combustion)	Negligible

The table shows that although the biomass stove required slightly more time to boil water, it was considerably more economical, as the woodchip fuel was collected for free from nearby sawmill waste. Furthermore, the double combustion system used in the stove reduced smoke emissions, making it a cleaner alternative compared to traditional wood-burning stoves.

Feedback collected from students through informal interviews, and questionnaires indicated a high level of interest in the stove. Many expressed surprise that waste wood could be used so efficiently. The activity also sparked discussions about how students could replicate or improve the design using local materials, thus supporting the idea of technological empowerment in the boarding school, shown in Figure 4.

Overall, the results confirmed that the biomass stove is a feasible, low-cost, and environmentally friendly solution suitable for rural educational institutions with limited access to subsidized LPG.



Fig. 4. Students and teachers of Al-'Urwatul Wutsqa Islamic Boarding School, North Aceh

4. Conclusions

The implementation of a biomass stove using woodchip fuel at Al-'Urwatul Wutsqa Islamic Boarding School demonstrated the practical viability of renewable energy solutions in rural educational environments. This community service initiative successfully addressed the challenges of limited LPG availability and introduced a low-cost, sustainable cooking technology. The activity provided students with direct exposure to the concept of biomass energy and its environmental benefits.

The results showed that the biomass stove could efficiently boil 1 liter of water using locally available wood waste, offering significant economic and ecological advantages. Although slightly less efficient than LPG to boiling time, the stove's ability to utilize free, renewable fuel makes it highly applicable for the boarding school and the rural communities.

This activity also highlighted the potential of educational institutions to become pioneers in adopting green technology through hands-on learning. More systematic trials and longer-term use studies are recommended to further evaluate the stove's performance, safety, and adoption potential. Future research may also explore design optimizations, fuel alternatives, and strategies for broader implementation within the school's network.

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References

- [1] Alvenher, E. (2012). "Pengaruh celah dan tinggi selimut panci terhadap kinerja tungku rumahan." (*Undergraduate thesis*). Department of Agriculture, Faculty of Agriculture, Universitas Lampung, Bandar Lampung.
- [2] Ayo, S. A. (2009). "Design, construction and testing of an improved wood stove." *Journal of Mechanical Engineering, Federal University of Technology Minna Nigeria*, 13.
- [3] Barnes, V., & Srivastava, R. K. (1994). "No transition metal chemistry of main group azides: Platinum complexes of diphosphanyl hydrazides $R_2PN(Me)N(Me)PR_2$." *Transition Metal Chemistry*.
- [4] Fitria, L., Fitrianingsih, Y., & Jumiati, J. (2020). "Penerapan teknologi penanaman mangrove di Kabupaten Mempawah, Provinsi Kalimantan Barat, Indonesia." *Panrita Abdi: Jurnal Pengabdian Kepada Masyarakat*, 4(2): 126–135.
- [5] Forest, E., Rumidatul, A., & Hidayat, Y. (2021). "Aplikasi teknologi biopelet limbah kopi sebagai bahan bakar alternatif dalam pengembangan desa mandiri energi di Desa Jatiroke." *Jurnal Pengabdian Kepada Masyarakat ITB*, 5(3): 256–265.
- [6] Giyanto. (2020). "Kajian preferensi penggunaan kompor biomassa pelet kayu sebagai alternatif pengganti tungku tradisional (Studi kasus di Kecamatan Geger, Kabupaten Bangkalan)." *Proceedings of NCIET Conference*, 1, 6–19. <http://www.conf.nciet.id/index.php/nciet/article/view/63>
- [7] Jacob, N. J. (2013). "Promotion and use of improved cook stoves in the conservation of biomass resources and biomass briquettes from solid waste in The Gambia." *ISESCO Journal of Science and Technology*, 9(15).
- [8] Prihandana, R., & Henroko, R. (2007). "Energi hijau pilihan bijak menuju negeri mandiri energi." *Penebar Swadaya*.
- [9] Faisal, Setiawan, A., Wusnah, Khairil, Luthfi (2018). "Effective height of chimney for biomass cook stove simulated by computational fluid dynamics." *IOP Conference Series: Materials Science and Engineering*.

- [10] Tabah, P., Arif, R., & Darmanto, U. (2019). "Uji efisiensi tungku roket berbahan bata ringan." *Majalah Ilmiah Momentum*, 14(1): 25–30.
- [11] Wahyudi, T. C., Handono, S. D., & Yuono, L. D. (2021). "Pengaruh komposisi perekat dan diameter briket biopellet terhadap karakteristik dan temperatur pembakaran pada kompor gasifikasi." *Jurnal Teknik Mesin*, 10(2): 279–287.
- [12] Widawati, E., Octaviani, S., Lawrence, L., & Sudharma, L. R. P. (2019). "Kompor roket berbahan bahan bakar biomassa." *Prosiding Applicable Innovation of Engineering and Science Research*: 1053–1060.
- [13] Bhattacharya, S. C., Albina, D. O., & Salam, P. A. (2002). "Emission factors of wood and charcoal-fired cookstoves." *Biomass and Bioenergy*, 23(6): 453–469. [https://doi.org/10.1016/S0961-9534\(02\)00072-7](https://doi.org/10.1016/S0961-9534(02)00072-7)
- [14] MacCarty, N., Still, D., & Ogle, D. (2010). "Fuel use and emissions performance of fifty cooking stoves in the laboratory and related benchmarks of performance." *Energy for Sustainable Development*, 14(3): 161–171. <https://doi.org/10.1016/j.esd.2010.06.002>
- [15] Venkataraman, C., & Rao, G. U. (2001). "Emission factors of carbon monoxide and size-resolved aerosols from biofuel combustion." *Environmental Science & Technology*, 35(10): 2100–2107. <https://doi.org/10.1021/es0016070>
- [16] Jetter, J. J., Zhao, Y., Smith, K. R., Khan, B., Yelverton, T., DeCarlo, P., & Hays, M. D. (2012). "Pollutant emissions and energy efficiency under controlled conditions for household biomass cookstoves and implications for metrics useful in setting international test standards." *Environmental Science & Technology*, 46(19): 10827–10834. <https://doi.org/10.1021/es301693f>
- [17] Bailis, R., Cowan, A., Berrueta, V., & Masera, O. (2009). "Arresting the killer in the kitchen: The promises and pitfalls of commercializing improved cookstoves." *World Development*, 37(10): 1694–1705. <https://doi.org/10.1016/j.worlddev.2009.03.004>
- [18] Still, D., & MacCarty, N. (2011). "Clean burning biomass cookstoves." *Boiling Point*, 59: 12–14.
- [19] World Health Organization. (2016). "Burning opportunity: Clean household energy for health, sustainable development, and wellbeing of women and children." *WHO Press*. <https://www.who.int/publications/i/item/9789241565233>
- [20] Quinn, A. K., Bruce, N., Puzzolo, E., Dickinson, K., Sturke, R., Jack, D. W., ... & Rosenthal, J. P. (2018). "An analysis of efforts to scale up clean household energy for cooking around the world." *Energy for Sustainable Development*, 46: 1–10. <https://doi.org/10.1016/j.esd.2018.06.011>
- [21] Putra, R., Muhammad, M., Asnawi, A., Islami, N., Sayuti, M., Murdani, M., & Wahyuni, R. (2023). Retooling Coconut Peeling Machine for Community Empowerment in Paloh Punti Village Muara Satu. *JURNAL HURRIAH: Jurnal Evaluasi Pendidikan Dan Penelitian*, 4(4), 368-375. <https://doi.org/10.56806/jh.v4i4.161>
- [22] Kshirsagar, M. P., & Kalamkar, V. R. (2014). "A comprehensive review on biomass cookstoves and a systematic approach for modern cookstove design." *Renewable and Sustainable Energy Reviews*, 30: 580–603. <https://doi.org/10.1016/j.rser.2013.10.039>