Design and Validation of a Sustainable Rocket Stove for Off-Grid Cooking and Heating in Underprivileged Communities

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Abstract: Sustainable off-grid cooking remains a significant challenge for engineers: solar stoves are often too slow, while open fires are inefficient and resource-intensive. This study develops a cost-effective and safe rocket stove for frugal off-grid cooking in underprivileged communities, offering a practical alternative that delivers efficient cooking performance, preserves cultural practices, and provides a low-cost solution. An iterative approach was followed, involving requirements analysis, laboratory testing, field testing, and prototyping. The final requirements identified cooking and space heating as primary needs. Prototypes were designed and refined to assess thermal behavior according to ISO 19867, cooking capabilities following ISO 1860-1, and environmental performance using life-cycle assessment (ISO 14040). Field trials were then conducted to evaluate social integration and stakeholder satisfaction. The research resulted in the development of a sustainable, low-cost rocket stove design that complies with international standards Laboratory tests in accordance with ISO standards established safe thermal behavior, ensuring the shell remained safe to touch while enabling slow heat release for space heating. Field tests evaluated social integration and stakeholder satisfaction. Findings suggest that rocket stove technology holds considerable potential to improve cooking practices and provide household heating for South African communities lacking access to the national power grid.

Keywords—component, formatting, style, styling, insert (*key words****)***

I. Introduction

It is well known that much of Southern Africa is sparesly populated. This is not reflected in the average population per square meter since many of the large cities have now experienced rapid urbanisation. Yet, small communities still persist due to culutural nomadism or historic economic reasons such as farm hands, settlements, and towns.

1. Modest energy needs across much of the region.

   Home solarPV systems are well suited for rural settlements as they have modest energy needs of around 100 watts (Barnes et al., 2009), considering lighting, household appliances, computers, and water pumps . Note the exclusion of thermal loads.

   1. While much of the regions industrial sectors prioritize renewable energy for economic sustainability reasons (Steed et al., 2025), rural african's do not benefit from this transition. These complexities of rural finances mean completely different financial models and incentives are being investigated (Dibaba et al., 2023).
   2. Energy justice and the JET
2. Challenges of energy infrastrucutre in micro-communities
3. The benefits of energy introduced micro-communities
   1. Social
   2. Entrepreneurial
   3. Economic, through adoption
4. Fragmented efforts and the advantage of an open platform for such integration

   Swarm grids are envisioned as a peer-to-peer energy sharing platform (Sheridan et al., 2023).

   Previous efforts like developed a SolarPV (Vermaak et al., 2025)

   A roadmap is a “”

II. Method

A. Roadmap

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B. Phase 1: Solar PV for lighting and smartphone charging

The first phase of this project developed a cost-effective solar PV prototype[1]. The prototype was installed in a community and the feedback was evaluated. The resulting post implementation feedback demonstrated the prototype met the user needs, but elicited that the community appetite was increasing.

C. Phase 2: Rocket stoves for cooking and demand profiling

Recalling that in phase 1, solarPV cooking was infeasible this phase introduced a woodfired rocket stove for cooking.

1) Rocket stove

This stove was designed for low-cost cooking and environmental sustainability. Secondary safety and space heating emerged as feasible requirements and were persued.

For example, local material and manufacturing methods were used. Local brush/wood was used for fuel and sand and rock was used to create a thermal battery for insulation.

2) Demand profiling

As users familiarty with energy grows, so does their appetite. While many demand profile synthesizers are available for industrial systems, fewer are available for residential, and none (to the authors knowledge) are available for rural energy users. This may be due to a lack of data. Therefore, the next requirement is the measuring and monitoring of users energy usage patterns to better aid in sizing energy systems and detecting when a capacity upgrade is neededed. Feasibility revealed that this subsystem can also be used to tarrif the user, which may lead to business opportunity by monetizing the nano-energy grid.

III. Results

IV. Conclusion

Acknowledgment *(Heading 5)*

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References

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[4] K. Elissa, “Title of paper if known,” unpublished.

[5] R. Nicole, “Title of paper with only first word capitalized,” J. Name Stand. Abbrev., in press.

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[1] Note that prototype in this context means a fully functioning product/system.

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