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Sustainable Oven

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ABSTRACT

The use of firewood as the main source of energy in rural communities remains a common practice, although traditional ovens show low thermal efficiency. This results in high fuel consumption, greater pollutant emissions, and significant economic costs, which negatively affect the quality of life and health of families, especially women and children exposed to smoke during cooking. The 'Sustainable Oven' project emerges as an innovative alternative aimed at designing and developing an improved wood-fired oven, capable of optimizing heat distribution, reducing energy losses, and decreasing firewood consumption, without altering the culturally accepted functionality of the traditional oven. In doing so, it seeks to benefit low-income households, promote environmental conservation, reduce exposure to harmful smoke, and decrease the need to collect or purchase large amounts of firewood. The proposal is based on principles of thermal engineering, sustainability, and social responsibility, combining technical knowledge with a humanitarian vision. It involves the creation of manuals, guides, and educational videos, as well as the use of local, recycled, and low-cost materials to encourage replicability and adaptation in different community contexts. The process includes testing cycles and continuous improvements to ensure efficiency, functionality, and social acceptance. Overall, the 'Sustainable Oven' represents a model of social innovation and environmental commitment capable of transforming communities in an integral and sustainable way.

Keywords: sustainability; manufacturing; environmental impact.

INTRODUCTION

In many rural communities, firewood remains a primary source of energy for cooking and heating. However, traditional ovens have low thermal efficiency, which results in high fuel consumption, increased pollutant emissions, and a considerable economic burden for families that depend on this resource. This situation not only impacts the environment but also affects the quality of life of those living in conditions of energy vulnerability. This approach not only contributes to environmental protection but also improves people's health by minimizing their exposure to toxic smoke during food preparation.

The project Sustainable Oven proposes the design and development of an improved wood-fired oven aimed at maximizing the use of heat generated by combustion. In turn, it reduces energy losses, optimizes heat distribution, and decreases firewood consumption without compromising the traditional functionality of the oven.

This innovation seeks to positively impact low-income households by reducing the need to collect or purchase large amounts of firewood, while also promoting environmental conservation and reducing exposure to harmful smoke, especially among women and children, who are often more exposed.

The project is based on principles of thermal engineering, sustainability, and social responsibility, to generate an appropriate, replicable, and adaptable technology for different community contexts. It aims to demonstrate that improving traditional systems can be an effective pathway for social and environmental development when technical knowledge is combined with a humanitarian vision.

This collaborative work methodology has strengthened community bonds and boosted the development of local capacities; the Sustainable Oven also generates a positive economic impact.

In addition, the proposal encourages community participation through hands-on workshops, enabling beneficiaries to learn how to build their own ovens, thus fostering a sense of ownership and autonomy.

By reducing firewood consumption, household expenses decrease, and a more rational use of natural resources is promoted. It is a strategy that generates sustainability, health, education, and economic benefits. The Sustainable Oven is a clear example of how social innovation and environmental commitment can transform communities in a lasting way.

JUSTIFICATION

Solving an energy efficiency problem: The existence of ovens that lack materials that help reduce heat energy loss, resulting in high firewood consumption and impacting the environment. The design, based on thermal engineering principles applied to the sustainable oven, aims to optimize the use of heat generated by combustion by utilizing recycled and low-cost materials to maintain an average temperature for longer periods of time and using the least amount of firewood.

The development of this oven reduces manufacturing costs due to the use of recycled materials, creating community cohesion among families, which promotes knowledge appropriation and strengthens the local capacities of those who use these ovens, in a sustainable development model that can be replicated. The project is capable of generating tangible benefits in three key dimensions: economic, by reducing energy costs; environmental, by promoting the rational use of natural resources; and social, by improving well-being and health by reducing smoke exposure in families, especially women and children, who tend to spend more time in domestic environments exposed to polluting carbon dioxide emissions.

SCOPE

The project involves the design, development, and comprehensive evaluation of a sustainable oven model that optimizes energy use and reduces pollutant emissions. It includes a quantitative comparison with conventional ovens in terms of thermal efficiency and operating costs, a proposal for appropriate materials and technologies for manufacturing using local resources, and an assessment of the environmental and social impact resulting from its implementation in a representative community. The results will determine the technical, economic, and social feasibility of the proposed model, as well as its potential for replication in other rural or urban contexts.

FUNCTIONAL TESTS

The functional tests performed on our Sustainable Oven were intended to verify the proper functioning of each of its systems, as well as evaluate its energy efficiency and thermal performance under controlled conditions. The procedures and results obtained are described below:

Test 1: Heating System Ignition and Calibration

The oven's ignition and temperature control system were verified. To do this, thermal sensors were connected to the main controller, and the system's response to different temperature setpoints was monitored. The oven reached the programmed values without significant fluctuations, demonstrating proper calibration and thermal stability during operation.

Test 2: Thermal Insulation

To evaluate the insulation's efficiency, the oven's internal and external temperatures were monitored using thermocouples located at strategic points throughout the structure. The results demonstrated that the insulation fulfilled its function, maintaining a stable internal temperature and reducing heat loss to the environment, which contributes to greater energy efficiency.

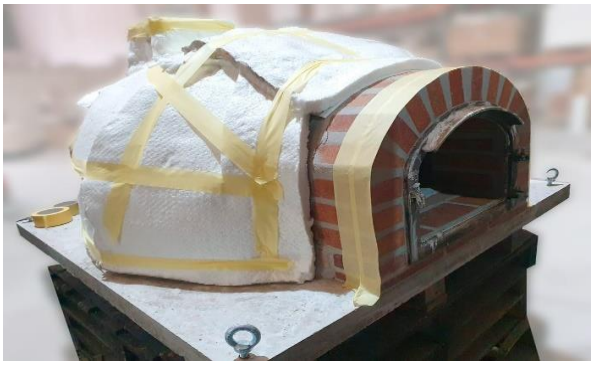

FIGURE 1: Insulating layer to maintain the oven´s internal temperature. *Source:* Own, year 2025.

Test 3: Energy Efficiency

Energy consumption was recorded during a complete operating cycle. The analysis showed that the sustainable oven has reduced consumption compared to a conventional oven, thanks to the optimal use of the energy source used (electric, solar, or biomass, depending on the prototype configuration). This confirms the viability of the system as a low-environmental impact alternative.

Test 4: Ventilation and Safety System

The operation of the ventilation system was evaluated, as well as the response of the integrated safety mechanisms. During operation, the temperature sensors and automatic shut-off systems responded appropriately to critical conditions, ensuring the protection of internal components and the user. The ventilation allowed for adequate dissipation of residual heat, preventing overpressure or gas buildup.

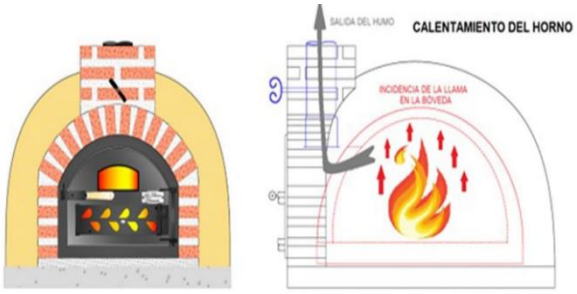

FIGURE 2: Oven breathing system. *Source:* Unknown, year 2025.

Test 5: Thermal Performance and Cooking
Experimental tests were conducted with different materials and food products to analyze heating uniformity and efficiency. The results obtained demonstrated even heat distribution throughout the oven and a significant reduction in cooking time compared to traditional equipment. This validates the design's functionality and effectiveness in practical applications.

FIGURE 3: Cooking food.
Source: Own, year 2025.

RESULTS

The values obtained during the testing of the sustainable oven support the observed outcomes. The maximum temperature reached, 320 °C, and the thermal uniformity with a variation of only ±10 °C demonstrate greater stability and heat distribution, allowing for more efficient cooking. The heating time of 35 minutes to reach 200 °C reflects a faster start-up compared to traditional ovens, which typically require between 45 and 60 minutes. In addition, the wood consumption of 4.2 kg per cooking cycle confirms an approximate 30% reduction compared to the 6 kg commonly used in conventional ovens, indicating lower energy expenditure. The low smoke level suggests more complete combustion, reducing soot emissions and improving environmental and health conditions. Finally, the thermal efficiency of 68% exceeds the average of traditional ovens (50–55%), validating that the implemented design optimizes energy utilization and meets the proposed sustainability and innovation criteria.

ANALYSIS OF TESTS

TABLE 1: Summary of Performance Tests and Suitability Assessment of the Sustainable Oven.

Test	Obtained result	Suitable/ Not suitable
Maximum temperature reached	320°C	Suitable
Heating time	35min to reach 200°C	Suitable
Firewood consumption	4.2 kg per cooking cycle	Suitable
Thermal efficiency	68%	Suitable
Smoke level	Low (light visual emission, no soot)	Suitable
Heat uniformity	Maximum difference of +10°C between zones	Suitable

CONCLUSIONS

Sustainable ovens represent an innovative and eco-friendly solution in the effort to reduce the environmental impact of food cooking and industrial production. These ovens, designed to harness renewable energy sources such as solar, biomass, or even geothermal energy, allow for efficient cooking with minimal consumption of fossil fuels. Their implementation not only decreases greenhouse gas emissions but also helps reduce deforestation associated with the intensive use of firewood and charcoal common issues in rural communities and low-income areas.

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