African Journal of Emerging Issues
Peer reviewed | Double blind | Interdisciplinary

African Journal of Emerging Issues
(AJOEI)
Online ISSN: 2663 - 9335
Available at: https://ajoeijournals.org

SUSTAINABILITY

DEVELOPMENT AND EVALUATION OF A SUSTAINABLE SOLAR COOKER FOR OPERATIONS IN UGANDA

[*1]Sebunya Steven [2]Sendegeya AlMas & [3]Ssempijja Maureen Nalubowa

[1]Student, Department of Mechanical and Production Engineering,

P.O Box 1, Kyambogo University – Kampala (Uganda).

[2]Senior Lecturer, Electrical Power Systems / Renewable Energy

Department of Electrical and Electronics Engineering,

P.O Box 1, Kyambogo University – Kampala (Uganda).

[3]Lecturer, Department of Mechanical and Production Engineering,

P.O Box 1, Kyambogo University – Kampala (Uganda).

***Email of the Corresponding Author: sigosteven@gmail.com**

Publication Date: January 2025

ABSTRACT

Purpose of the Study: The research focused on developing and evaluating a solar cooker as a sustainable energy solution to address the cooking needs in Africa, using Uganda as a case study.

Statement of the Problem: While solar energy technologies have the potential to enhance energy sustainability and reduce greenhouse gas emissions, current solar cookers face limitations in addressing local cooking habits, energy demands, and geographical conditions in Uganda.

Methodology: The research established energy requirements for cooking based on common food types, average household size, and average solar irradiation in Uganda. A solar box cooker was designed and modeled using SOLIDWORKS software. Material selection and cost analysis were conducted for economic feasibility, and the optical and thermal performance was analyzed using COMSOL Multi-Physics software. A prototype was constructed using locally available materials to assess manufacturability and cost implications.

Results: A box-type solar cooker was developed with inner reflector walls at an optimal angle and internal insulation for better heat retention and efficiency. The cooker, with an aperture area of 0.1897 m^2, meets the thermal requirements for cooking common foods in major regions of Uganda. All materials used are locally available, making the cooker appropriate, sustainable, and affordable.

Conclusion: The proposed solar cooker offers a viable alternative to traditional cooking methods in Uganda. It effectively cooks common foods, is cost-effective, and provides environmental benefits, reducing reliance on charcoal.

Keywords: *Solar cookers; Sustainability; Solar box cooker; Cooking dynamics; Solar irradiation*

INTRODUCTION

Universal energy access and a decarbonised climate energy system are critical global development priorities (Nations, 2021). Renewable energy sources with developed technologies are being promoted more than ever before, particularly in developing countries (Falcone, 2023). Countries have been encouraged to accelerate electrification and invest more in renewable energy sources in order to achieve universal access by 2030 (Assembly et al., 2023). This is consistent with SDGs 7 and 13, which call for affordable, modern, and clean energy solutions, as well as immediate action on climate change (Misra et al., 2023). The report states that less than 10% of people in Sub-Saharan African countries have access to clean fuels and technologies (UN Assembly, 2023). If left unchecked, this growing access deficit could have an impact on the rising global energy access trend. According to the energy policy review, the use of modern renewable energy technology is increasing in Uganda.

Solar cookers, which work by focussing sunlight to provide direct thermal energy in a natural and renewable way to cook, are among the commendable options (Soro et al., 2020). These cookers are ideal for areas with medium to high insolation (Adiwal et al., 2017). Uganda currently relies heavily on biomass as an energy source due to the country's poor electricity distribution rates (NPA, 2020). The use of biomass energy sources (in their raw form) is devastating as one of the leading causes of environmental pollution and global warming (Soro et al., 2020). Charcoal and firewood fuel biomass utilisation have resulted in significant deforestation in Uganda, with long-term consequences for human health (Bamwesigye et al., 2020). Ugandans use three stone cookers for cooking at a rate of 53.5%, with 27.3% using a charcoal stove, 16.9% using an improved cooking stove and only 1.2% using electric cookers. Accordingly, renewable energy sources such as solar energy are a clean alternative to global energy requirements and are now being used more than ever before (Guzman et al., 2014).

On a global scale, it is critical and advantageous to have solar cookers of various geometrical designs, performance, and price (Akoy and Ahmed, 2015). As a result, improvements in reflective surface designs and materials may lead to new developments in solar cookers suitable for various locations. While solar energy technologies have enormous potential for improving energy sustainability and lowering greenhouse gas emissions, current solar cookers have limitations in addressing local cooking habits, energy demands, and diverse regional geographical conditions in Uganda. Ugandan households, particularly in rural areas, consume between 1.5 kg and 2 kg of charcoal per meal, and this heavy reliance has increased the cost and crisis of charcoal. Moreover, rising demand in cities and peri-urban areas has exacerbated deforestation and carbon emissions from charcoal production.

Northern and Eastern Uganda receive around 5.5 kWh/m²/day of solar energy, which is not fully utilised for solar cooking (Katongole et al., 2023). With all of this in mind, the Ugandan government plans to increase the use of modern clean energy from 15% to 50% by 2025, while decreasing the use of biomass as cooking fuel from 80% to 50% (Kajumba et al., 2020). Advocating for alternative non-conventional energy resources will help to reduce pollution, deforestation, and increased reliance on fossil fuels (Karande et al., 2017). Thus, the study focused on developing a box-style solar cooker while taking into account regional weather patterns and local cooking dynamics in Uganda. To encourage local adoption, construction materials were chosen based on their economic feasibility.

LITERATURE REVIEW

Cooking Dynamics in Uganda

According to Katongole et al. (2023), Uganda is separated into four regions: The Northern, Central, Eastern, and Western regions. The cooking habits and types of food cooked in these regions can vary due to cultural, geographical, and historical factors, (Kajumba et al., 2020). With physical potentials estimated at 2GW for hydroelectric power, 0.45GW for geothermal, 1.65GW for biomass cogeneration, and an average of 5.1kWh/m2 per day for solar energy, Uganda has abundant energy resources, (Naluwagga et al., 2022). Cooking fuel options in Uganda are divided into three categories: contemporary fuels (LPG & electricity), transitional fuels (charcoal), and traditional biomass fuel (firewood), (Katutsi et al., 2020). According to Nsamba et al., (2021), with a percentage of 66.8%, forest firewood is the most widely utilized biomass fuel for cooking, followed by charcoal at 27.0%. Nsamba et al. (2021), noted that majority of households cook three times a day (breakfast, lunch, and dinner), with the average cooking time estimated at two hours. Regionally, the quantity of fuel used and the time taken to cook partially depend on the type of food being cooked, (Mainimo et al., 2022). The most common food types include rice, banana (Matooke or plantain) and cassava while boiling and simmering are the predominant cooking methods, as shown in the Table 1.

Table 1: Cooking Dynamics and Human Household Capacities Across Uganda

Factor	Result	Sources
Type of food	Banana	Nsamba et al., 2021
	Rice	Kajumba et al., 2022
	cassava	
No. of people	3 – 5 (Central)	Nsamba et al., 2021
	5 – 8 (Others)	Kajumba et al., 2022
Daily frequency of cooking	≥ 2	Nsamba et al., 2021
	3	Teodoro Sanchez & Pullenl, 2013
Cooking practice	Boiling	Nsamba et al., 2021

Solar Irradiation in Uganda

The type of solar cooker being used and the region's particular cooking requirements can affect the normal solar radiation required for solar cooker applications, (Kajumba et al., 2022). In nations with daily solar radiation levels of 5-7 kWh/m² and a high number of bright days throughout the year, solar cooking has enormous potential, (Ali Kakar et al., 2019). Solar resource maps and data sources reveal the variations in solar energy availability across Uganda, (Katongole et al., 2023). Notably, the northern and eastern Uganda receive the highest average daily global horizontal irradiation, while western Uganda which is south of the equator receives the lowest, (Camberlin, 2023). The solar irradiation intensities in the eastern and northern regions range between 823.9 – 831.6 $Wm{-}2$ and 829.2 – 822.2 $Wm{-}2$, (Mundu, 2021).

Table 2: The daily average temperature ranges and the average daily GHI for the major regions across Uganda

Region	Daily Average Temperature Ranges (°C)	Daily GHI (kWh/m^2/day)
Northern	25 - 25.8	5.16
Central	22.4 - 24.1	4.30
Eastern	23.3 - 25	4.94
Western	20.7 - 22.4	4.2

Different Technologies of Solar Cookers

Solar cookers produce heat in an environmentally friendly and renewable manner, potentially saving one ton of wood year in areas with plenty of sunshine, (Soro et al., 2020). These are relatively inexpensive, use no fuel and cost nothing to operate, (Aramesh et al., 2019). Many solar cooking technologies whose development suites different geographic location and climate across the globe are in existence, (Ali Kakar et al., 2019). The study review mainly focused on the direct solar cooker technologies which included the concentrating-type and box-type.

Concentrating Solar Cookers

Concentrating solar cookers employ optics to concentrate the sunrays on the receiver of the cooking unit, (Lentswe et al., 2021). A parabolic concentrator as shown in the Figure 1.1, is the most commonly used, (Misra et al., 2023). Due to high temperature generation (350 0C to n 400 0C), these are suitable for frying, baking, boiling, and roasting. In recent developments, a particular type of lens called the Fresnel lens has been used to concentrate sunlight precisely to a focused area, (Engoor, 2020).

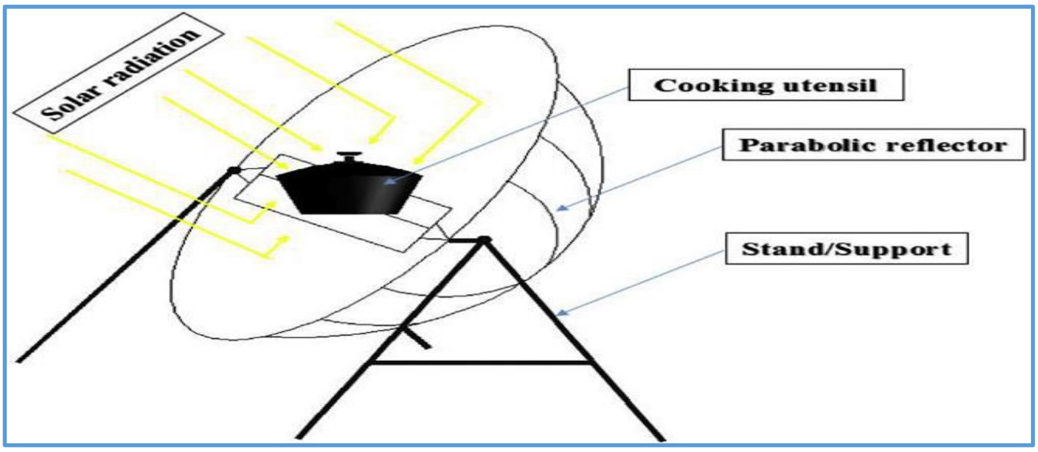

Figure 1: A Concentrating Solar Cooker

The Box–Type Solar Cookers

According to Aramesh et al. (2019), solar box cookers are third after liquefied petroleum gas (LPG) and stoves (including kerosene stoves) in the adoption rankings. As illustrated in the Figure 1.2, the general operating principle of these solar cookers is that they channel and concentrate sunlight through mirrors to an absorber cooking container, which is then converted to heat and used for cooking, (Iessa et al., 2017).

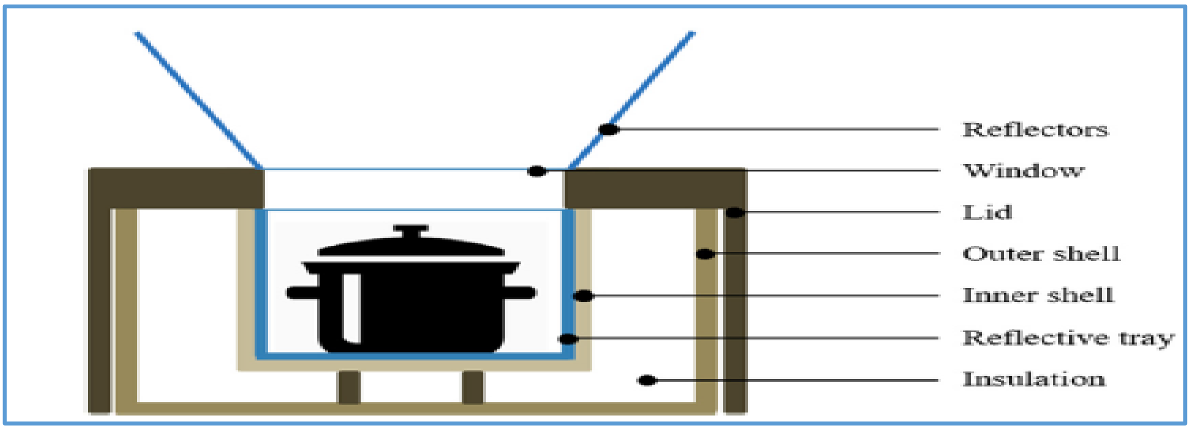

Figure 2: Sectional View of a Box-Type Solar Cooker

Typical box–type solar cookers are mainly made from plywood sheets, flat mirrors, an absorber, and are thermally insulated, (Soro et al., 2020). Understanding the design parameters, optical efficiency, and heat capacity of a box-type solar cooker is essential to enhancing its thermal performance, (Geddam et al., 2015). Box-type cookers have numerous benefits among which include the potential to produce incredibly nutrient-dense meals, virtually low maintenance and operating costs, and long-term usability, (Misra et al., 2023). Box-type solar cookers also make use of both diffuse and direct radiation, and intermittent cloud cover, (Kulla et al., 2020). Studies have also shown that, when fins are added to the cooking vessels used in box-type solar cookers, cooking time can be reduced, (Aramesh et al., 2019).

METHODOLOGY AND MATERIALS

The research methodology aimed to develop and evaluate a sustainable solar cooker for Uganda by establishing the energy requirements for cooking common food types like rice, matooke (plantain), and cassava, considering average household size and solar irradiation across the country's major regions. Theoretical calculations and literature review were used to determine the energy needs for cooking with electricity, charcoal, and solar, which informed the sizing of the cooker's aperture area. Optimum inclination angles for the internal reflector walls were established to enhance optical and thermal efficiency. The solar cooker design was modeled using SOLIDWORKS software, and materials were selected based on their optical, thermal, and local availability characteristics to ensure affordability and ease of manufacturing. Simulation software like SOLIDWORKS, ANSYS, and COMSOL Multiphysics were employed to assess the optical and thermal performance of the developed design, using input data such as geometry, material properties, environmental conditions, and operational parameters. A prototype was constructed to evaluate local manufacturability and cost implications. Economic feasibility was assessed by calculating the payback period and fuel savings compared to traditional cooking methods like electricity and charcoal, using equations for monthly savings and fuel consumption reduction. The prototype fabrication was conducted at Kyambogo University workshops to assess the feasibility of manufacturing the solar cooker using basic tools and skills available locally.

RESULTS AND DISCUSSIONS

Energy Requirements for Cooking

The energy requirements for cooking with electricity were determined through a literature review, considering the common types of foods prepared across the four major regions of Uganda. The findings are presented in Table 3.

Table 3: Energy Requirements for Cooking Some Foods Using Electricity

Food Item	Energy (kWh/kg)	Source
Rice (1kg)	0.64	Kajumba et al., 2022
	0.53	Kanyama, 2016
	0.1575	De et al., 2014
Matooke (1kg)	0.60	Kajumba et al., 2022
	1.06	MECS, 2020
Meat (1kg)	4.67	Tessier et al., 2015
	2.54	Pathare & Paul, 2016

Theoretical Energy Requirement for Cooking Using Charcoal

To estimate the theoretical energy requirements for cooking rice and matooke using charcoal, the study considered the mass of charcoal needed, the efficiency of improved charcoal stoves, and the calorific value of charcoal. Based on Asada (2019), the assumed mass of charcoal required to cook 1 kg of rice and 1 kg of matooke was taken as 0.8 kg and 0.6 kg, respectively. The efficiency of improved charcoal stoves was considered to be 35% and the calorific value of charcoal was taken as 28 MJ/kg (Miranda et al., 2020). Using Equation 2 from the methodology, the theoretical calculations showed that cooking 1 kg of rice on a modern charcoal stove required approximately 2.178 kWh of energy, while cooking 1 kg of matooke on a charcoal stove required approximately 1.633 kWh of energy.

Theoretical Energy Requirements for Cooking Using a Solar Cooker

The specific heat capacity (Cp) of rice and matooke were highlighted by Kajumba et al. (2022), as seen in the Table 4.

Table 4: Specific Heat Capacities of Rice, Matooke and Meat

Food Item	C_p (Model), KJ/kg/K	C_p, KJ/kg/K
Rice	1.80	1.65
Matooke	3.62	……
Meat (Beef)	……..	3.44

In the study design process, several assumptions were made to calculate the theoretical energy requirements for cooking using a solar cooker. The cooking vessel was considered to be made of aluminum, with a specific heat capacity of 0.90 kJ/kg/K (RET, 2024) or 0.896 kJ/kg/K (De et al., 2014), both of which were used in the design calculations. The initial ambient temperature was assumed to be 25°C, and the required cooking temperature was 100°C, as all the selected food types were to be boiled. The amount of water needed to cook 1 kg of rice and 1 kg of matooke was approximated at 2 liters and 1 liter, respectively (Kajumba et al., 2022). To ensure thorough cooking, the study assumed that 30% of the energy was required to maintain the same temperature throughout the cooking period. Based on these assumptions, the theoretical energy requirement to cook 1 kg of rice using a solar cooker was established as 0.3054 kWh/kg. Similarly, the theoretical energy requirements for cooking 1 kg of matooke and 1 kg of beef were calculated, and the results are summarized in Table 5.

Table 5: Established Theoretical Energy Requirements for Cooking Using A Solar Cooker

Food type	Water used (ltr)	C_p (kJ/kg/K)	Energy requirement (kWh/kg)
Rice (1 kg)	2	1.8	0.3054
Matooke (1 kg)	1	3.62	0.2409
Beef – Meat (1 kg)	0.8	3.44	0.2133

From Table 5, it is evident that cooking with charcoal consumes significantly more energy compared to cooking with electricity or using a solar cooker. Among the three selected foods, meat requires the most energy for preparation, while matooke requires the least. Interestingly, the theoretical calculations showed that cooking rice using a solar cooker required more energy than cooking matooke or meat. This finding was attributed to the fact that rice requires a larger amount of water for its preparation (Kajumba et al., 2022). Therefore, rice was chosen as the basis for calculating the aperture area in the solar cooker design.

Table 6: Summary of the Energy Requirements for Cooking

Type of Dish	Energy Requirement (kWh/kg)		
	Electricity	Charcoal (Theoretic)	Solar Cooker (Theoretic)
Rice (1 kg)	0.64	2.178	0.3054
Matooke (1 kg)	0.60	1.633	0.2409
Meat (1 kg)	2.54	— — —	0.2133

Development of a Solar Box Cooker

The study focused on developing a solar box cooker, referred to as the Developed Solar Box Cooker (DSBC), based on simplicity and technical requirements. To establish the active area (aperture area), assumptions were made, including an energy efficiency of 35% (Taylor et al., 2006) and an average daily Global Horizontal Irradiation (GHI) of 4.60 kWh/m² for Uganda (Katongole et al., 2023). Using equations 6, 7, and 8, the aperture area was calculated to be 0.1897 m², which was considered the absorber plate area for the non-concentrating solar box cooker. The absorber plate dimensions were established as 0.60 m in length and 0.32 m in width to accommodate two cooking vessels with an average diameter of 200 mm. The side-wall inclination angles were determined for the simulation date of June 1st, 2024, when solar irradiation is lowest in Uganda. Considering solar noon, hour angle ($\omega = 0°$), and a southern region location with a latitude (φ) of -0.6110°, the declination angle was calculated as 22.170° using equation 11. The side-wall inclination angles were then calculated using equation 10 and letting $\theta = (90 - \beta)$, with the results summarized in Table 3.5 for the solar noon hour.

Table 7: Internal Side Walls' Inclination Angles Due to The Four Major Compass Directions

S/N	Directional angle (γ)	Inclination angle (β)
South	0^0	34^0
North	180^0	56^0
West	270^0	43^0
East	90^0	43^0

The Figure 3 shows a diagrammatic illustration of how the angles were represented. From the Figure 3, the dimensions of each of the internal side wall reflectors were established. An insulation spacing of 20 mm between the side-wall reflector material and the interior of the outside wooded box frame internal profile was considered. Also given that the wood frame was of thickness 20mm, the outer length, width and height of the box were computed as 1109 mm, 830 mm and 300 mm respectively. The 30 mm extension from the top of the internal side wall reflectors was considered so as to accommodate the glazing assembly system designed to slide horizontally. Figure 4 gives the full modeled design assembly of the proposed solar cooker.

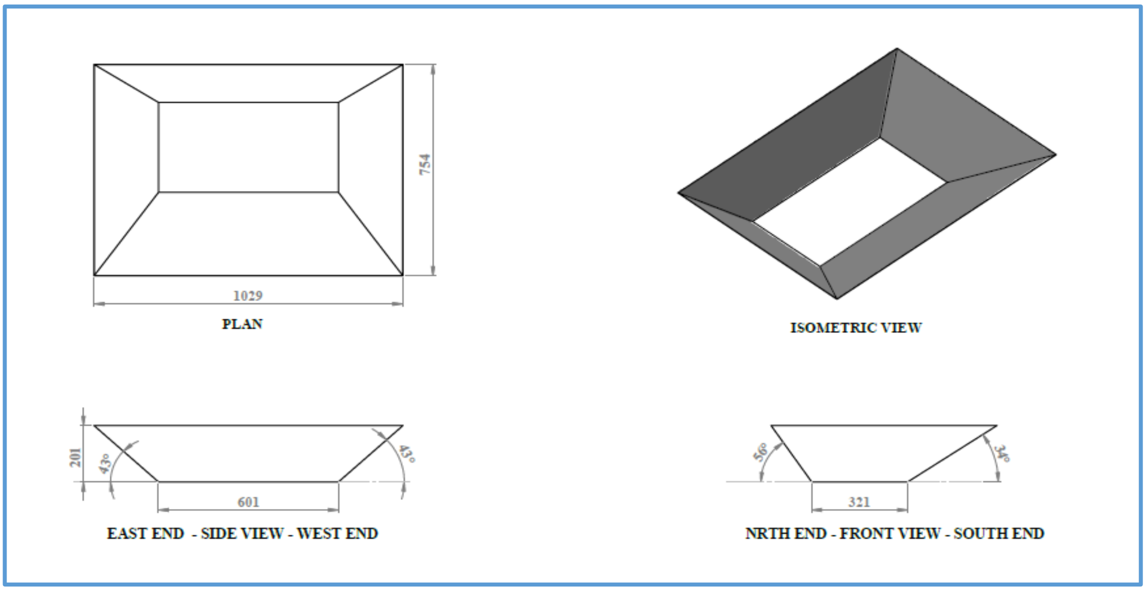

Figure 3: Views Showing the Internal Side - Wall Reflector Angles

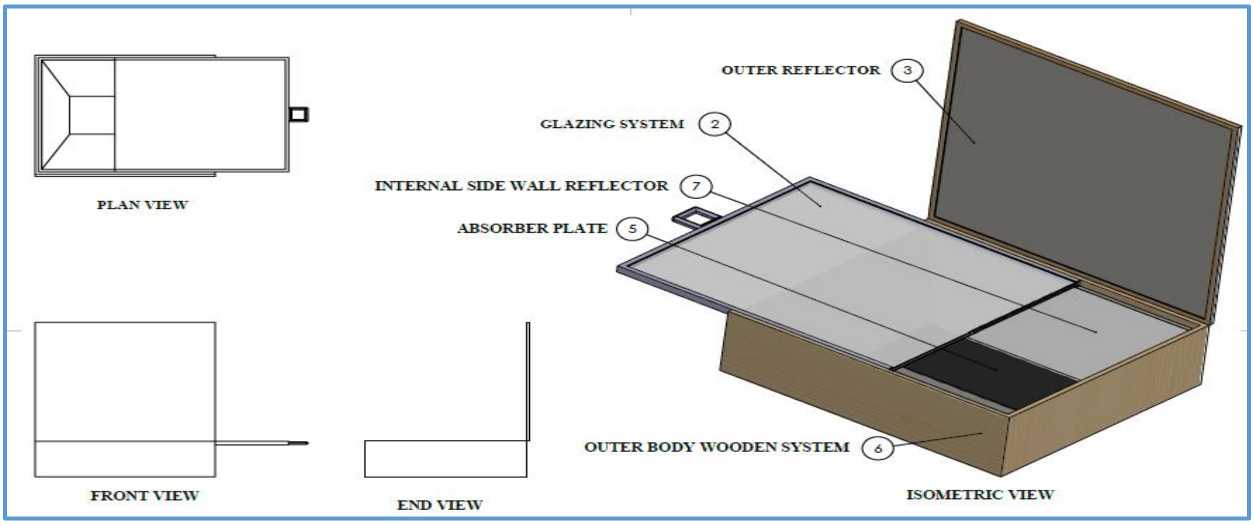

Figure 4: Full assembly drawing of the Box Solar Cooker

The Table 8 below gives a summary of the established main design specifications for the DBSC. Material selection for each of the component part was conducted putting into consideration the thermal and optical characteristics to maximize efficiency. Other selections were made basing on the experiences from the study review with major considerations based on local availability of the material in context.

Table 8: Summary of the design specifications for the DBSC

S/n	Parameter	Values
1	Outer dimensions of cooker	1109 mm x 830 mm x 300 mm
2	Insulator thickness	20 mm
3	Inner height	200 mm
4	Area of the absorber plate	0.1897 m^2
5	Area of the glazer (Glass plate)	0.7759 m^2
6	Thickness of the glazer material	4mm each

Material Selection

The Table 9 shows material section made on basis of high-quality material performance properties and experimentations from the study review while putting into consideration their local availability.

Table 9: Material Selection for The Solar Box Cooker Component Parts

S/n	Component	Material Used	Reasons
1	Outer Frame	Wood	- Availability - Good manufacturability - Weight factor
2	Insulation	Rose Wool	- law thermal conductivity ≤ 0.044 - Combustion performance (no burning class A) - Density Tolerance ± 15%
3	Absorber plate	Aluminium painted with black matte paint	- Good thermal conductivity - Corrosion resistant - Cost friendly
4	Glazing	Fiberglass reinforced polyester	- Good thermal insulation - Temperature resistant - High mechanical strength
5	Reflector	S – Reflect (Non – adhesive)	- High reflectivity > 90% - Very light and flexible
6	Cooking vessel	Tormado (Al polished)	- Good thermal conductivity - Corrosion resistant - Cost friendly

Simulation Results

The ambient temperature at the non-solar hour was assumed to be 297 K, with the weather conditions of the western region of Uganda serving as boundary conditions. Thermal analysis of the absorber plate and the internal side wall reflecting surfaces was carried out using COMSOL Multiphysics 5.5 software. Figure 5 shows that thermal temperature kept building up within the system, and as time passed, the absorber plate gained more temperature of up to about 460 K (dark red zone) due to concertation of solar heat energy onto it.

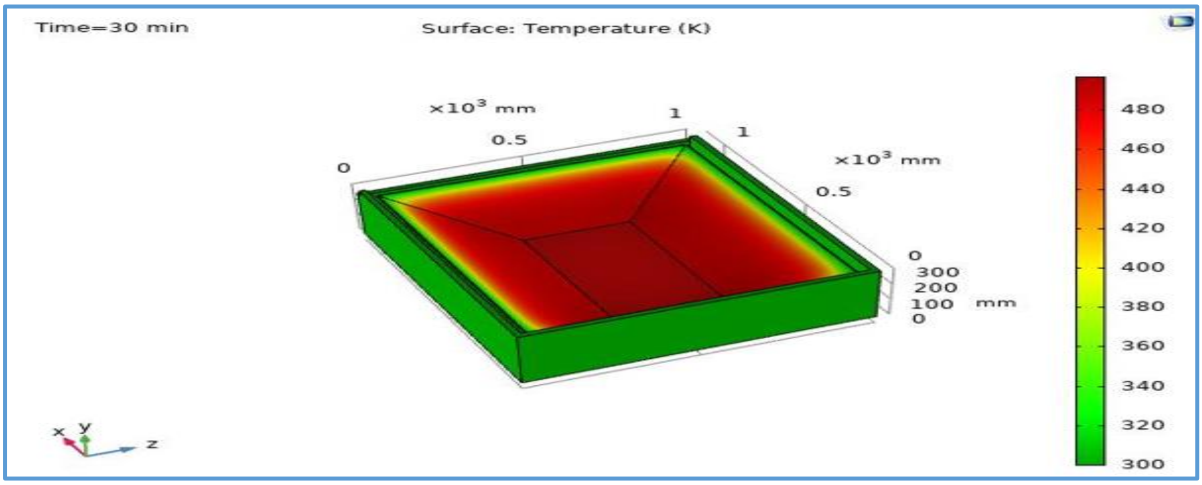

Figure 5: Simulated Heat Transfer Distribution with in the Interior of the DBSC

Figure 6 shows the surface radiosity in the interior of the system and here it can also be observed that there is high radiosity (light brownish zone) from the absorber plate onto which the cooking vessel is placed due to its high heat transfer rate compared to that of the reflector surfaces (light yellowish zone). Since the reflective surfaces converge the solar radiations, they absorb little amounts of heat energy which is conduct to the insulating material (Light to dark blue zone) given insulation around them.

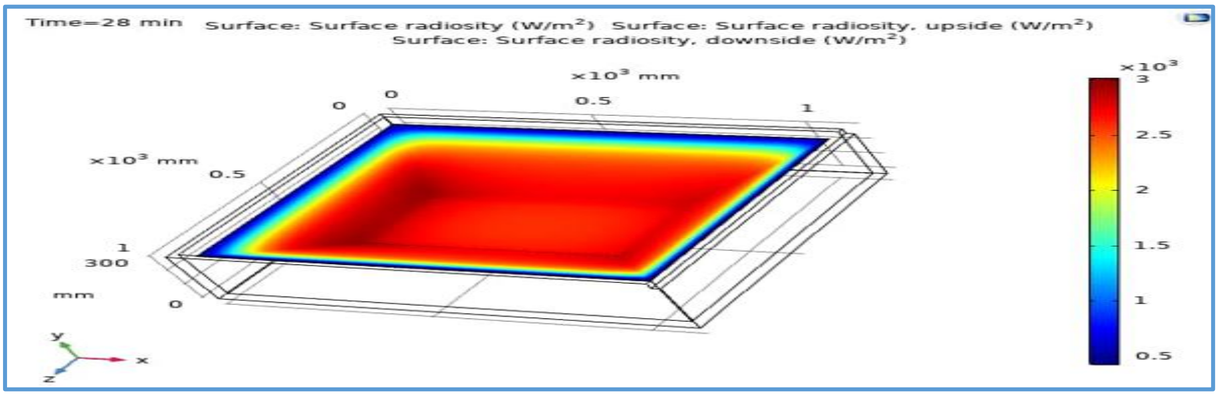

Figure 6: Surface Radiosity of The Absorber Plate and The Internal Reflectors

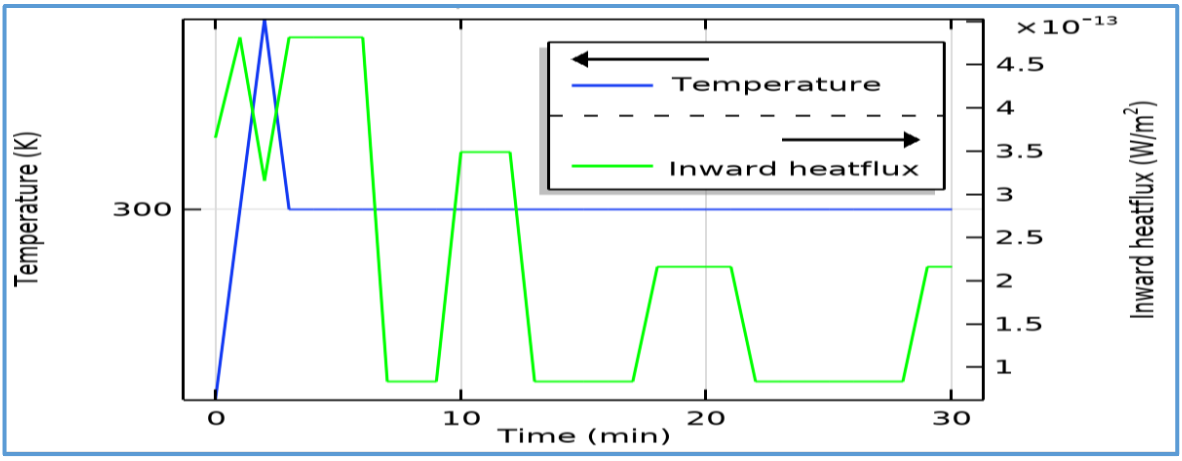

Figure 7: Relationship Between the Solar Radiosity and Temperature with Time

In Figure 7, the temperature (blue line) starts at around 300 K and experiences a sharp rise within the first few minutes. After the initial spike, the temperature stabilizes at around 300 K for the remainder of the time. The inward heat flux (green line) begins with an initial fluctuation, then stabilizes for a short period before showing periodic spikes and drops, oscillating between approximately 0 W/m² and a peak value slightly below 4.5×10^{-13} W/m². The initial spike in temperature suggests a rapid heating phase, which could be due to the initial exposure to sunlight. The stabilization of temperature at 300 K indicates the attainment of thermal equilibrium, where the rate of heat input balances the rate of heat loss. The oscillating pattern of the inward heat flux signifies periodic changes in the heat input due to environmental factors like changes in solar intensity, wind speed, or shading that periodically affect the heat input. The lack of a direct correlation between temperature and inward heat flux after the initial spike suggests that the system quickly reaches thermal equilibrium. Once equilibrium is reached, the temperature remains relatively constant despite the periodic changes in inward heat flux, indicating the system's good thermal stability and insulation.

Cost Analysis of the Solar Box Cooker

This included the establishment of the bill of quantity of single unit of the solar box cooker to enable material procurement and product construction. The materials considered were those which were locally available in Ugandan markets or could be availed through import dealers within the country. Table 10, presents the bill of engineering measurement and evaluation (BEME) for the dissertation design with all costs presented in US dollars.

Table 10: Bill of Engineering Measurement and Evaluation

Item	Description	Quantity	Unit Cost	Total Cost
Timber (Musizi)	3600 x 300 x 20 mm	2 pc	10.88	21.76
Plywood	2400 x 1200 x 6 mm	1 pc	21.76	21.76
Aluminium plate	2400 x 1200 x 2 mm	1/8 pc	81.6	10.064
Sheep wool	Standard	10 kg	27.2	27.2
Mylar reflective	15000x1200x 2mm	1/6 pc	108.8	19.04
Plastic glass	2400x1200 x 4mm	3/4 pcs	48.96	36.72
Drawer Handle	Ordinally	3 pcs	1.088	3.264
Hinges	50 mm	1 pair	0.816	0.816
Locks	Padlock type	1 pc	1.088	1.088
Nails and glue	Normal	1 pc	1.36	1.36
Finishing	Normal	1 set	4.08	4.08
	Total material cost			**147.152**

The labor cost for the solar box cooker was calculated as 30% of the total material cost, amounting to 44.1456 USD. Adding this to the material cost resulted in a total project cost of 191.2976 USD. When considering indirect costs at 10% of the total project cost (19.12976 USD), the initial investment cost of the solar box cooker, using the best locally available materials in the Ugandan markets, was calculated as 210.43 USD. Compared to the cost ranges of improved small-scale box-type solar cookers, which fall between 120 USD and 130 USD according to Herez et al. (2018), the cost of the developed solar cooker was 0.6 times greater, making it slightly more expensive. This higher cost was attributed to the fact that purchases were made for a single unit product, and with batch production of the solar box cooker, the unit cost would likely decrease. Furthermore, the cost of mylar reflective material and plastic glass was relatively high in the local market due to the fact that these materials are imported.

According to Kajumba et al. (2022) and Adam (2024), the average daily food consumption per person is 300g of rice, 200g of matooke, and 227g of beef meat. For a typical household of 5 people, the total daily consumption of rice, matooke, and beef meat was calculated to be 1 kg, 1.5 kg, and 1.135 kg, respectively. The energy requirement for cooking each food item was determined by multiplying the specific energy (kWh required to cook one kilogram of that food) by the quantity (in kilograms) of food cooked. Table 10 presents the energy requirements per kilogram for cooking using electricity, charcoal, and a solar cooker. By relating these values to the quantities of the selected foods and sauce, the energy requirements for cooking each meal were obtained, as shown in Table 11.

Table 11: Overview of Energy Requirements for Daily Cooking

Type of Food	**Electricity (kWh)**	**Charcoal (kWh)**	**Solar Cooker (kWh)**
Rice	0.64	2.178	0.3054
Matooke	0.9	2.449	0.36135
Meat	2.883	2.472	0.242
Rice & Meat	3.523	4.65	0.5474
Matooke & Meat	3.783	4.921	0.60335

For monthly electricity costs, the total electric energy requirement consumed in a month was related to the cost per kWh of electricity. This gave a total amount of 11.844 USD for a rice meal and 12.718 USD for a matooke meal since the domestic cooking tariff in Uganda is at 0.112064 USD for unit ranges of 81 kWh to 150 kWh, (UMEME, 2024). For monthly charcoal cost, an approximate of 1.4 kg of charcoal use per day was considered, (Asada, 2019). This computed for 30 days and multiplied by a cost of 0.408 USD for I kg of charcoal gave a total cost of 17.136 USD, (Kajumba et al., 2022). Therefore, the monthly saving for cooking using electricity and charcoal were given as 12.718 USD and 17.136 USD respectively. From the Equation 15, the payback period for switching from electricity to solar cooking was computed as $\mathbf{16.55\ Months}$ while the payback period for switching from charcoal to solar cooking was computed as $\mathbf{12.28\ Months}$.

CONCLUSIONS

The Solar Box Cooker offers a promising solution to traditional cooking methods in areas with abundant solar energy. It effectively cooks common local foods while providing cost savings and environmental benefits, making it an attractive option for reducing dependence on diminishing resources like charcoal and costly electricity. The feasibility of the proposed cooker is further enhanced by its affordability, sustainability, and suitability, thanks to the use of locally sourced materials in its construction, which encourages widespread and rapid adoption. Even in the southern region, which has the lowest Global Horizontal Irradiation (GHI) in Uganda, the cooker can achieve temperatures exceeding 100°C, sufficient for boiling water and supporting various cooking methods. This suggests that the system's efficiency will be even higher in regions receiving greater solar irradiation, such as the northern and eastern parts of the country. The economic analysis reveals that investing in a solar cooker is a financially prudent decision, with a payback period of less than 1.5 years for both electricity and charcoal users. Transitioning from traditional cooking methods to solar cooking not only provides significant monthly savings but also contributes to Uganda's environmental sustainability efforts.

REFERENCES

Adam. (2024). How Much Meat per Person: Portion Sizes for Different Meat Types. In Smoke Guys (p. 1). https://smokeguys.com/how-much-meat-per-person/

Adeyemi, K., Lawal, N., & Asere, A. (2017). Thermal Performance of Improved Charcoal Stove as A Clean Development Mechanism Project – A Case Study of Bauchi. FUOYE Journal of Engineering and Technology, 2(1). https://doi.org/10.46792/fuoyejet.v2i1.62

Akumu, G., Ogenrwoth, B., Mugisha, J., & Muyonga, J. H. (2023). Dietary Patterns in Uganda and Their Influencing Factors: a Critical Review. African Journal of Food, Agriculture, Nutrition and Development, 23(2), 22328–22353. https://doi.org/10.18697/ajfand.117.22345

Ali Kakar, M., Kasi, J. K., Kasi, A. K., Bokhari, M., Latif, M., & Ayaz, M. (2019). The efficiency of a solar cooker in Pakistan’s Quetta Region. Polish Journal of Environmental Studies, 28(6), 4213–4220. https://doi.org/10.15244/pjoes/95034

Aramesh, M., Ghalebani, M., Kasaeian, A., & Zamani, H. (2019). A review of recent advances in solar cooking technology. Renew. Energy, 140, 419–435. https://doi.org/10.1016/j.renene.2019.03.021

Ayub, H. R., Ambusso, W. J., Manene, F. M., & Nyaanga, D. M. (2022). A Review of Cooking Systems and Energy Efficiencies A Review of Cooking Systems and Energy Efficiencies. February. https://doi.org/10.11648/j.ajee.20210901.11

Bamwesigye, D., Kupec, P., Chekuimo, G., Pavlis, J., Asamoah, O., Darkwah, S. A., & Hlaváčková, P. (2020). Charcoal and wood biomass utilization in uganda: The socioeconomic and environmental dynamics and implications. Sustain., 12(20), 1–18. https://doi.org/10.3390/su12208337

De, D. K., Nathaniel, M., & De, N. N. (2014). Cooking rice with minimum energy. 013138, 1–13. https://doi.org/10.1063/1.4865794

Engoor, G. G. (2020). Experimental investigation of a box-type solar cooker incorporated with Fresnel lens magnifier. Energy Sources, Part A Recover. Util. Environ. Eff., 00(00), 1–16. https://doi.org/10.1080/15567036.2020.1826009

Falcone, P. M. (2023). Sustainable Energy Policies in Developing Countries: A Review of Challenges and Opportunities. Energies, 16(18). https://doi.org/10.3390/en16186682

Geddam, S., Dinesh, G. K., & Sivasankar, T. (2015). Determination of thermal performance of a box type solar cooker. Solar Energy, 113, 324–331. https://doi.org/10.1016/j.solener.2015.01.014

Guzman, L., Henao, A., & Vasquez, R. (2014). Simulation and optimization of a parabolic trough solar power plant in the city of Barranquilla by using system advisor model (SAM). Energy Procedia, 57, 497–506. https://doi.org/10.1016/j.egypro.2014.10.203

Hager, T. J., & Morawicki, R. (2013). Energy consumption during cooking in the residential sector of developed nations : A review. Food Policy, 40, 54–63. https://doi.org/10.1016/j.foodpol.2013.02.003

IEA. (2023). Uganda 2023 Energy Policy Review. Ministry of Energy and Mineral Development -Uganda, 1–184. www.iea.org/t&c/%0Ahttps://memd.go.ug/wp-content/uploads/2020/07/Uganda2023-Energy-Policy-Review.pdf

Iessa, L., Vries, Y. A. De, Swinkels, C. E., Smits, M., & Butijn, C. A. A. (2017). Energy Research & Social Science What ' s cooking ? Unveri fi ed assumptions , overlooking of local needs and pro-solution biases in the solar cooking literature. Energy Res. Soc. Sci., 28(May), 98–108. https://doi.org/10.1016/j.erss.2017.04.007

Kahsay, M. B., Paintin, J., Mustefa, A., Haileselassie, A., Tesfay, M., & Gebray, B. (2014). Theoretical and Experimental Comparison of Box Solar Cookers with and without Internal Reflector. Energy Procedia, 57, 1613–1622. https://doi.org/10.1016/j.egypro.2014.10.153

Kajumba, P. K., Okello, D., Nyeinga, K., & Nydal, O. J. (2020). Experimental investigation of a cooking unit integrated with thermal energy storage system. J. Energy Storage, 32(August 2019), 101949. https://doi.org/10.1016/j.est.2020.101949

Kajumba, P. K., Okello, D., Nyeinga, K., & Nydal, O. J. (2022). Energy for Sustainable Development Assessment of the energy needs for cooking local food in Uganda : A strategy for sizing thermal energy storage with cooker system. Energy for Sustainable Development, 67, 67–80. https://doi.org/10.1016/j.esd.2022.01.005

Katongole, D. N., Nyeinga, K., Okello, D., & Mukiibi, D. (2023). Spatial and Temporal Solar Potential Variation Analysis in Uganda Using Measured Data. 49(1), 1–14.

Katutsi, V., Dickson, T., & Migisha, A. G. (2020). Drivers of Fuel Choice for Cooking among Uganda ' s Households. 111–129. https://doi.org/10.4236/ojee.2020.93008

Kulla, D. M., Umaru, S., & Usman, K. M. (2020). Simulation, Construction and Performance Evaluation of Solar Box Cooker. Journal Of Science Technology And Education, 8(1), 318–328. https://www.researchgate.net/publication/340418027

Lentswe, K., Mawire, A., Owusu, P., & Shobo, A. (2021). Heliyon Review article A review of parabolic solar cookers with thermal energy storage. Heliyon, 7(September), e08226. https://doi.org/10.1016/j.heliyon.2021.e08226

Mainimo, E. N., Okello, D. M., Mambo, W., & Mugonola, B. (2022). Drivers of household demand for cooking energy: A case of Central Uganda. Heliyon, 8(3), e09118. https://doi.org/10.1016/j.heliyon.2022.e09118

Miranda, M. R. da S., Veras, C. A. G., & Ghesti, G. F. (2020). Charcoal production from waste pequi seeds for heat and power generation. Waste Management, 103, 177–186. https://doi.org/10.1016/j.wasman.2019.12.025

Misra, N., Anand, A., Pandey, S., Kant, K., Misra, N., Anand, A., Pandey, S., Kant, K., & Shukla, A. (2023). Box-Type Solar Cookers : An Overview of Technological Advancement , Energy , Environmental , and Economic Benefits To cite this version : HAL Id : hal-03983854

Mundu, M. M. (2021). Modelling and Navigation of Solar Electric Power Potential and Generation in the Four Regions of Uganda.

Nsamba, H. K., Ssali, R., Ssali, S. N., Matovu, F., Wasswa, J., & Balimunsi, H. K. (2021).

Evaluation of the Cooking Cultures and Practices in Rural Uganda. 33–44. https://doi.org/10.4236/jsbs.2021.111003

Pathare, P. B., & Paul, A. (2016). Quality and Energy Evaluation in Meat Cooking. Food Eng. Rev., 8(4), 435–447. https://doi.org/10.1007/s12393-016-9143-5

RET. (2014). Lesson 18: Performance Evaluation of Solar Cookers. In Renew. Energy Technoloy. http://ecoursesonline.iasri.res.in/mod/page/view.php?id=128351

Schindelholz, R., Notzon, D., Chaciga, J., Julia, O., Ongaro, C., Dutheil, J., Burnier, L., Manwani, K., Fleury, J., Kwarikunda, N., & Schüler, A. (2024). Performances studies of a basket-based solar cooker for humanitarian aid in Uganda. Solar Energy, 268(December 2023), 112272. https://doi.org/10.1016/j.solener.2023.112272

Soro, D., Soro, D., Sidibé, M., Doumbia, Y., Touré, S., & Marí, B. (2020). Theoretical and Experimental Studies of a Box-Type Solar Cooker in Unfavorable Climatic Conditions. 51–60. https://doi.org/10.4236/sgre.2020.114004

Vaidya, H., Rathod, M., & Channiwala, S. (2023). Design , development , and analysis of a box type solar cooker with optimally reflecting side walls. 9(3), 637–647. https://doi.org/10.18186/thermal.1297564