Decision Support System for the Design of a Solar-Powered Baking - Oven

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Abstract

The use of fossil fuel, wood and charcoal in the traditional cooking and baking processes can present serious challenges to the health of the environment, and promote land degradation. Similarly, the present 21st century energy crisis in Nigeria and the entire globe, has suggested that solar energy is currently the cheapest and cleanest form of energy for diverse applications, through appropriately developed devices. This study therefore, designed a device for bread baking and other confectionary operations, using a decision support system (DSS) which minimizes the drudgery of under-designing or over-designing, thus making the design flexible and for meeting specific bread production targets. This device, which utilizes solar energy for bread baking is termed solar baking oven. It consists of a focusing collector (parabolic concentrator) and a flat plate collector termed the oven chamber or absorber unit. The following collector obtains direct radiation from the sun over a wide range of an area and converges it to its focal point where the oven chamber is positioned to receive both concentrated, and diffuse radiation from the sun. The oven chamber is a double-walled enclosure constructed from $0.75mm$ thick stainless-steel plates. The external wall measuring $(1090 \times 750 \times 500)mm$ is separated from the inner wall by a $50mm$ thick fiberglass insulation serving as lagging material. It is designed to raise low-level radiation to high-level radiation of the flat plate collector, while the flat plate collector collects, absorbs both diffuse and direct radiation (short-wave radiation) from the sun, and since the plain glasses are opaque to long-wave radiation, it traps and stores the heat energy from the sun. it is the heart of the device; hence it is integrated with the oven compartment. The solar baking oven consists of two reflectors made from plane mirrors which reflect the Sun's rays to the absorber plate placed in the baking chamber. The two reflectors (plain mirrors) intensify the incoming solar radiation into the baking chamber and increase the oven's thermal properties and efficiency, when the oven temperature is raised to $150℃$ and above, the dough is introduced into the oven chamber and heated for about $30min\ to\ 35min$ depending on the shelf-life of the intended bread produced. The DSS has shown its capability of assisting solar oven designers by minimizing drudgery of over and under-design, material selection, and time wastage on long-hand calculation, in which design calculation can be gotten in few seconds. Since, the differences in the comparative results is negligible, and the solar oven poses no risk to environmental health, hence, it does not contribute to the greenhouse gases. Its recommendations for further optimization are also extensively discussed.

Keywords: *Solar powered baking oven, Renewable Energy, parabolic concentrator, flat-plate collector, traditional cooking methods, solar insolation, Decision support system, Performance evaluation.*

1. Introduction

Shea Energy is considered a prime agent in wealth generation and a significant factor in the economic development of any nation. Currently, fossil fuels still have the highest share of energy consumption globally because they contribute about 80% of the global energy demand despite their environmental depletion. The increasing global focus on sustainable energy sources and environmentally friendly technologies has sparked interest in utilizing solar power for various applications such as, sterilization and solar cooking. A considerable proportion of the Nigerian population and many other developing countries in Africa, Asia, and Latin America, depend on fossil fuels and,

biomass for cooking, baking of food items, and domestic water heating. Domestic baking, cooking, and heating account for more than 70% of the energy demand by most households in Nigeria [7]. However, conventional sources of energy used for domestic baking, and cooking such as liquefied petroleum gas (LPG)/natural gas, kerosene, and electric power supplies are often characterized by irregular/epileptic supply, non-availability, outrageous price increases, while some harm the environment. Energy is required in all aspects of everyday life, including agriculture, drinking water, lighting, healthcare services, telecommunications, and domestic and industrial activities. The trend of total reliance on finite fossil

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fuels for daily energy demands must change for good; therefore, a collective effort is urgently needed to save the environment from climate change caused by acid rain, global warming, and other ecological degradations, which have adverse consequences on the environment [4]. These conventional sources of energy, however, will not last forever and have proven to be one of the main sources of environmental problems. Renewable energy sources, such as solar energy, cannot be depleted for all practical purposes. In contrast to fossil fuels, they are clean sources of energy and do not pollute the environment during the process of power generation. In time renewable energies will dominate the world's energy System, due to their inherent advantages such as mitigation of climate change, generation of employment, and reduction of poverty, as well as increased energy security and supply [2].

Solar energy is one of the main alternative renewable sources of energy crucial to the search for domestic fuel replacements. This is because; it is the source of all renewable and non-renewable sources of energy. Also, it is one of the cleanest, it is free from environmental hazards, and it is readily available and inexhaustible. However, like the development of all other energy sources, the breakthrough of solar energy into the technological world will involve a lot of planning, organization, generation, and diffusion of information as well as the provision of infrastructure or devices to harness, it is an efficient and effective means. Annually, the total solar power that is incident on the earth's surface from the sun is equivalent to $1.5 \times 10^{18} \, kWh$ (1.9×10^{14} ton coal equivalent (Tec)); when compared to the annual world consumption of almost 10^{10} Tec [6]. On the other hand, photovoltaic applications of solar energy have the potential to meet the electricity demand of the world while on the other hand, solar thermal applications also have immense potential, especially in the domestic and industrial sectors to meet the global thermal energy demand. Throughout the annals of human civilization, the development of cooking technologies has played a pivotal role in shaping societies, influencing cultures, and sustaining human life. The evolution of ovens and kiln ovens, from their primitive origins to modern iterations, reflects the ingenuity of humanity in harnessing fire for culinary and industrial purposes. In recent times, the imperative for sustainable practices and the rising concern over environmental impacts have spurred innovative endeavours, leading to the emergence of thermal solar kiln ovens as a potentially transformative technology [3].

In the face of global challenges posed by climate change, energy scarcity, and the need for sustainable development, the exploration and advancement of renewable energy technologies have become imperative. Among these technologies, solar-powered systems have emerged as promising solutions for a diverse range of applications, including cooking. Traditional cooking methods, often reliant on non-renewable fuels, contribute significantly to environmental degradation and public health issues. This study examines the design of a decision support system for a Solar Oven using a Concentrated Mirror, to harness solar energy for efficient and sustainable baking activities in households and industries.

Kumar *et al.* [8] integrated innovative heat storage systems with parabolic reflector-based solar cookers. By incorporating phase-change materials and advanced thermal storage techniques, the researchers aim to extend the cooking duration beyond sunlight hours. And, the study evaluates the performance of a compound parabolic concentrator (CPC) for solar cooking. The study also assesses the cooker's efficiency in terms of temperature profile, cooking time, and energy utilization, providing insights into the practical applicability of CPC-based solar ovens that incorporates reflective foil for sunlight concentration and thermal storage for extended cooking durations. The study outlines the construction and performance of this solar oven, emphasizing its potential for off-grid and sustainable cooking applications.

Soto *et al.* [12] investigate the impact of advanced tracking systems on the performance of solar ovens with concentrated mirrors. By integrating sun-tracking mechanisms, the researchers aim to enhance the efficiency of solar ovens by optimizing sunlight exposure throughout the day. Sawarn *et al.* [10] provided a comprehensive review of various solar thermal cooking technologies, including those employing concentrated mirrors. The study assesses the state of the art, challenges, and potential future developments in the field, offering a holistic view of solar cooking advancements. Wang *et al.*[13] present case studies on innovative solar cooking solutions implemented in developing countries. The focus is on practical applications of solar ovens with concentrated mirrors, addressing local challenges and evaluating the socio-economic impact of these technologies.

Lopez *et al.* [9] explored recent materials advancements that contribute to the efficiency of solar concentrators in cooking applications, the study also highlights innovations in reflective coatings,

lightweight materials, and durability considerations, aiming to improve the overall performance and longevity of solar ovens. Garcia *et al*. [5] conduct a comparative analysis of different solar oven designs suitable for rural communities. The study assesses the feasibility, cost-effectiveness, and performance of solar ovens with concentrated mirrors, considering the unique requirements of off-grid and resource-limited settings. Therefore, the specific objectives of this study are to design a solar energy-powered baking oven for bread production, develop a Decision Support System for the design, and evaluate the model developed.

2. Materials and Methods
Machine Design
The Solar oven machine was designed using existing engineering standards and formulae, mathematical model development, decision support model programing and application, and drawn with SolidWorks software.

Table 1: Solar radiation spectrum

Electromagnetic Radiations		Wavelengths μm
Cosmic rays		10^{-12}
X-Rays		10^{-10}
		10^{-8}
Thermal	Ultra-Violet	10^{-6}
	Visible	
	Infrared Rays	10^{-4}
Hertzian (Microwaves)		10^{-2}
		10^{1}
Radio Waves	Short	10^{2}
		10^{4}
	Medium	10^{6}
	Long	10^{8}

Source: (Sharma *et al.,* [11])

Mathematical Model Development
According to Stefan-Boltzmann in the theory of radiation, all bodies radiate energy in the form of electromagnetic wave, which travels at a speed of about $3 \times 10^8 \, m/s$. The energy radiated is identified by its wavelength, and a band of diminishing wavelength is described as follows: Radio waves, Hertzian (micro-wave), infrared rays, visible (light rays), ultraviolet rays, X-rays, and cosmic rays (Table:1).

Selection of materials
The material best suited for designing the unit were carefully selected, having examined the following criteria: (a) The thermal conductivity of the material; (b) The availability of the material within and outside the locality; (c) Material cost considerations; (d) Corrosion and weather resistance; (e) Workability and durability.

Estimation of solar radiation intensity
Solar radiation intensity is the amount of sunlight that reaches a given area in a specific amount of time. It's measured in watts per square meter (W/m^2). Solar radiation constant above earth atmosphere is approximately 1380 per square meter. It is necessary to measure Solar insolation because of the differences in the range area of geographical locations. The estimation of solar radiation intensity is determined using Equation (1).

Distance of the sun to earth is calculated as follow:
By Lambert cosine law:
$$E_b = \pi I_b = \sigma T^4 \quad \therefore \quad I_b = \frac{Q}{A_p} \cdot \frac{1}{d_w} \qquad (1)$$

Concentration ratio (Cr) of a solar collector
The radiation intensities at absorbing surfaces can be increased by a wide range of ratios by applying the concentration ratio effect. The concentrator is also known as the aperture: An increase in concentration ratio means an increase in temperature at which energy is delivered to the receiver. The concentration ratio (C) is the ratio of the area of the aperture of the system to the area of the system receiver, the concentration ration is determined using Equation (5).
$$C = \frac{A_a}{A_r} \qquad (2)$$

Determination of the optical performance of the flat plate collector
This amount of energy is made available to the flat plate collector through the plain glass with a lot of losses incurred due to convection, conduction, and radiation.

Determination of the heat loss coefficients in solar oven
Heat is lost primarily in solar ovens by: (i) convection; (ii) radiation; (iii) wind action.
h_w
$= 5.7 + 3.8V$ [*where V is the speed of the wind*]

The three most significant Ways of heat transfer in an oven are: Conduction; Convection; and Radiation.

Convection
By convention process, energy is transferred from one point to another by the motion of a mass of materials between the two points. This is determined using the convective heat transfer (Q) as shown in Equation (3).

$$Q = hA(T_2 - T_1) \qquad (3)$$

Conduction
By the conduction process, the heat flows from the hotter end to the coldest end and the greater the temperature difference, the faster the heat will flow. Heat conduction of food substances is due to the impact of adjacent molecules that vibrate internal radiation. This is determined using Fourier's law of conduction in the one-dimensional state as shown in Equation (4).

$$Q = \frac{KA\,dT}{dx} \qquad (4)$$

Heat Loss by Radiation
Whenever a ray or rays of solar radiation are incident on a surface, part of it is reflected while part is absorbed or transmitted through the medium. The incident ray which is the sum of transmittance (τ), reflectance (ρ), and absorptance (α), which is equalled to unity (1). This is determined using Equation (5) as shown below.

$$\tau + \rho + \alpha = 1 \qquad (5)$$

Transmittance (τ): Transmittance is the proportion of an incident ray that passes through a medium when compared with the incident radiation of magnitude 1. This is determined using Equation (6). (while neglecting absorption α)

$$\tau = 1 - \rho \qquad (6)$$

Reflectance (ρ): Whenever a beam of light strikes the surface of a medium, parts of the rays are absorbed, parts are transmitted but parts are also reflected. The proportion of the reflected rays to unity is termed reflectance. This is determined using reflectance formulae as shown in Equation (7).

$$\frac{I_r}{I_0} = \rho = \frac{1}{2}\left[\frac{sin^2(\theta_2 - \theta_1)}{sin^2(\theta_2 + \theta_1)} + \frac{tan^2(\theta_2 - \theta_1)}{tan^2(\theta_2 + \theta_1)}\right] \qquad (7)$$

Absorptance (α): According to Prasanna and Umanand (2011), absorption radiation (dI) is directly proportional to the local intensity in the medium (I) and the distance traveled in the medium (x). This is determined using Equation (8).

$$dI \propto I \times x \; ; \quad \frac{I_L}{I_0} = e^{-KL} = \tau_a \qquad (8)$$

Transmittance - Absorptance product
The solar radiation passes through the cover system (glass) and strikes the absorber plate. Some are absorbed, reflected, and transmitted. The rays that are reflected to the cover of the system are not entirely lost since some of them are again reflected to the absorber plate. The absorption of solar radiation by the absorber plate is given by the magnitude of "$\tau\alpha$". This is determined using effective transmittance - absorptance equation as shown in Equation (9).

$$\tau\alpha_e = \frac{\tau\alpha}{1-(1-\alpha)\rho d} \qquad (9)$$

Determination of the Energy utilized for baking
Yamikani *et al.* [14] ascertained that for a baking process: $46\,kW$ of energy is required to bake a nominal $800g$ loaf (with flour at 14% moisture content, water absorption 60.7% on flour wt, and oven loss 85) (Culled from Bread Making Technology). Useful energy for baking $'Q_u' = 46kW$.

The flat plate collector or solar oven chamber
The maximum energy (radiation) flux that is available to a flat plate collector is about 80% of the solar constant as a result of radiation absorption by cloud and air particles. A flat plate can be designed to work at a temperature of about $100°C$ above the ambient temperature [1].

 Advantages of Flat Plate Collector

 (i) It can intercept both diffuse and direct beam radiation.

 (ii) It does not require a special orientation towards the sun, although it may be done.

(iii) The absorbing surface is the same as the intercepting surface, hence optical loss through the intercept factor is not applicable.

Determination of the heat transfer coefficient of a solar flat plate collector
The heat transfer coefficient of a solar flat plate collector is determined using Solar energy absorbed by the absorber plate (Q_s) as shown in Equation (10).

$$Q_s = [HR(\tau\alpha)]_{Beam} + [HR(\tau\alpha)]_{Diffuse} \qquad (10)$$

Determination of the Energy losses on flat plate collector (solar oven chamber)
The Energy losses on flat plate collector or solar oven chamber is determined using Equation (11) and Equation (12) respectively.

 (i) Heat loss coefficient by convection

$$h_{p-c_1} = [1 - 0.0018(\bar{T} - 283)]\frac{1.14\,\Delta T^{0.31}}{Z^{0.07}} \qquad (11)$$

(ii) Heat loss coefficient by radiation

$$h_{r_{p-c_2}} = \sigma \frac{(T^2_{cover1} + T^2_{cover2})(T_{cover1} + T_{cover2})}{\frac{1}{\varepsilon_{glass1}} + \frac{1}{\varepsilon_{glass2}} - 1} \quad (12)$$

Determination of the overall heat loss coefficient of the solar oven

The overall heat loss coefficient of the solar oven is determined using Equation (13) the total resistance; Equation (14) the overall loss coefficient; Equation (15) total energy loss; Equation (16) cover 1 glass temp.; and Equation (17) cover 2 glass temp.

Total resistance:
$$'R' = R_1 + R_2 + R_3 \quad (13)$$
Overall loss coefficient:
$$'U'_t = \frac{1}{R_1 + R_2 + R_3} \quad (14)$$
Total energy loss:
$$'q'_{loss} = U_t(T_{plate} - T_{sky}) \quad (15)$$
Cover 1 glass Temp.:
$$'T'_{c_1} = T_p - U_t(T_p - T_a)R_1 \quad (16)$$
Cover 2 glass Temp.:
$$'T'_{c_2} = T_{c_1} - U_t(T_p - T_a)R_2 \quad (17)$$

Determination of the overall heat transfer coefficient for the solar oven

The overall heat transfer coefficient for the solar oven is determined using Equation (18) heat loss coefficient by convection; Equation (19) heat loss by convection, Equation (20) heat loss coefficient of radiation, and Equation (21) heat loss by radiation.

(i) Heat loss coefficient by convection
$$h_{p-c_1} = [1 - 0.0018(\bar{T} - 283)]\frac{1.14\,\Delta T^{0.31}}{Z^{0.07}} \quad (18)$$
Heat loss by convection
$$q_{loss1} = h_{p-c_1}(T_p - T_c) \quad (19)$$
(ii) Heat loss coefficient of radiation
$$h_{r_{p-c_1}} = \frac{\sigma(T^2_{plate} + T^2_{cover1})}{\frac{1}{\varepsilon_{plate}} + \frac{1}{\varepsilon_{glass}} - 1}(T_{plate} + T_{cover}) \quad (20)$$
Heat loss by radiation
$$q_{r1} = h_{r_{p-c_1}}(T_{plate} - T_{cover}) \quad (21)$$

Design Methodology of the Solar Baking Oven

Stainless sheet of $0.75mm$ thickness is used to design an outer box of dimension $(1090 \times 750 \times 500)mm$ lagged with fibre glass $50mm$ thickness, then, an inner box of the same material and a dimension $(990 \times 650 \times 400)mm$ is placed inside the outer box, thereby forming he solar oven compartment. Two plain mirrors of $3mm$ thickness is used as the top cover of the baking oven. An aluminium absorber plate or oven chamber of dimension $1695mm(total\ dimension)$ and placed below the

second plain glass, it serves as the heat absorber and storage unit where the bread is baked, an aluminium drying plate of dimension $(910 \times 610 \times 0.75)mm$ placed below the oven chamber. A stainless sheet access door of dimension $(1090 \times 56 \times 500)mm$ designed as the front cover of the oven compartment.

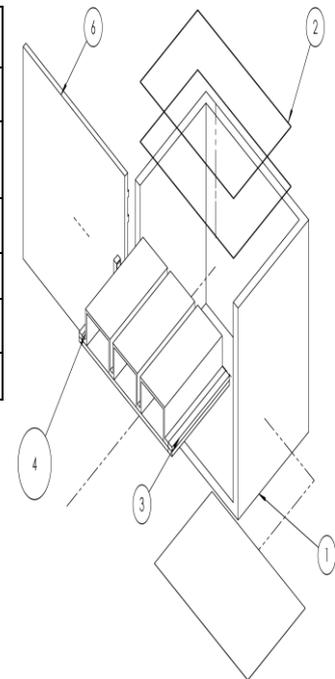| ITEM NO.	PART NUMBER	QTY
1	oven chamber	1
2	First and Second Glass	2
3	Absorber chamber	1
4	Lower plate	1
5	Drying plate	1
6	Door	1

Figure1: Assembly Drawing of the Solar Powered Oven and part description table
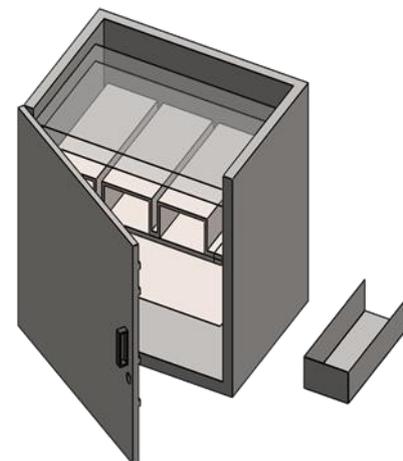

Figure 2: CAD Design of a Solar Baking Oven and its Baking Pan

Decision Support System

The Decision Support System (DSS) model is capable of guiding designers in the design process, as shown in **Figure** 1 the generated CAD design of a solar oven **Figure** 1 shows the assembly drawing of the solar oven with different parts and components identification and arrangement of how these components and parts can be assembled into compartment, such that, each parts and components performs its specialized functions respectively to form an assembled baking oven unit. **Figure** 2 depicts the CAD design of a Solar baking oven and its baking pan; which serves as a housing where the dough is poured before been placed in a horizontal arrangement inside the baking chamber.

Experimental procedure/operation of the Oven

Procedure 1:

Solar insolation from the sun is focused unto the reflectors/plain glasses in the oven by a focusing collector or parabolic concentrator, which is made of a hollow hemisphere disc with the inside lined carefully with small rectangular plain glasses to direct all reflected rays, to a common focus on the principal axis, of the hemisphere. However, shortly before the focal point on the principal axis, a secondary reflector is positioned to redirect all radiation through a space provided in the disc, for incidence on the absorber unit.

Procedure 2:

This secondary reflector is made of a convex mirror to enable all light rays to converge on the absorber, after reflection from it. The secondary reflector is made of a convergence on the absorber after reflection from it. The focusing collector is hinged on a stand and is oriented towards the sun. For best results, or better performance it should be made to track the sun as the earth rotates on its axis around the sun. Two or more focusing concentrators might be needed depending on the temperature with which the oven is designed to operate.

Procedure 3:

The reflectors (plain mirrors) of dimension $950mm \times 610mm \times 3mm$ will collect all direct and diffuse radiation from the sun impinging on its surface, together with all radiation from the focusing collector. The solar baking oven consists of two reflectors made from plane mirrors which reflect the Sun's rays to the absorber plate placed in the baking chamber. The two reflectors (plain mirrors) intensify the incoming solar radiation into the baking chamber and increase the oven's thermal properties and

efficiency, resulting in shorter cooking time. The radiation will be absorbed through the plain glasses into the absorber plate of dimension $950mm \times 610mm \times 0.75mm$. Though, there will be weak reflections in between the glasses all radiation will be trapped within the absorber unit because no reflected radiation can get out of the equipment. Radiation (short-wave) that passes through the cover (plain mirror) of the absorber unit will on reflection become long-wave radiation. Plain mirror is, however, opaque to longwave radiation. Hence, all reflected long-wave radiation remains trapped between the absorber plate and the glass, leading to heat accumulation.

Procedure 4:

The absorber plate made of copper or aluminium material absorbed the trapped solar radiation (accumulated heat). The temperature of the absorber plate is raised exceedingly together with the oven compartment. Thus, any material (food items or equipment) placed in the oven compartment receives enough heat either for cooking, and baking. The oven compartments an integral part of the absorber are equally made of copper or aluminium enclosure in a rectangular form. The baking boxes containing items to be baked are placed in those compartments for baking activities. A thoroughly, lagged access door is provided to conserve heat within the oven compartment thus minimizing thermal losses to the atmosphere. Heat is poured continuously into the oven compartment by conduction, radiation, and convective movement of air in the oven space.

Procedure 5:

When the oven temperature is raised to 230℃, hence, the oven is already pre-heated at that temperature, the dough is introduced into the oven chamber and heated for about $30min\ to\ 35min$ depending on the type dough, targeted moisture content, and shelf-life of the intended bread produced.

The experimental data obtained from both mathematical iteration or long hand calculation and the DSS model were used to determine the differences between the long hand calculation and the DSS model calculation the differences is computed and compared, and were used to evaluate and compared the efficiency of the two method of oven design and to assess influence of the DSS on solar oven design. Table 2 presents the data obtained from different multiple mathematical iterations and results of the machine performance assessment.
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Table 2: Experimental data of comparative analysis of DSS result and long-hand calculations

S/N	Operation	Computed result	Long hand Calculated Result	Percentage (%) difference
1.	Solar Intensity $'I_b'$	$1377.47 \ w/m^2$	$1377.5/m^2$	0.003
2	Angle of Refraction $'\theta_2'$	$0°$	$0°$	
3.	The reflectance of glass $'\rho'$	$4.336155 \ x \ 10^{-2}$	0.043	0.000
4.	Transmittance due to solar absorption τa	0.6986382	0.703593	0.00704
5.	Absolute Transmittance $\tau = \tau_a.\tau_r$	0.6986382	0.703593	0.00704
6.	Effective Transmittance Absorption $\tau\alpha_e$	0.7071237	0.67653173	0.0435
7.	Energy absorbed on a cloudy day alone on absorber plate	$114.8086 \ w/m^2$	$104.6 \ w/m^2$	0.088918
8.	Concentration Ratio $\frac{A_a}{A_r}$	555.5556	554.7	0.0028
9.	Radius Ratio CR	0.02	0.02	0.0000
10.	Intercept factor γ	0.7630723	0.763	$9.47 \ X \ 10^{-5}$
11.	Energy from focusing Collector	$165480. \ W/m^2$	$157774.7182W/m^2$	0.04656
12.	Energy Absorbed by the Absorber [Direct and Diffuse Radiation]	$545.6853 \ W/m^2$	$520.5 \ W/m^2$	0.046
13.	Total Energy Absorbed on Absorber	$166026. \ W/m^2$	$158295.23 \ W/m^2$	0.0466
14.	Cover 1 Temperature Cover 2 Temperature	$441.347 \ K$ $345.347 \ K$	$444.3K$ $334.923K$	0.007 0.003
15.	FINAL HEAT LOSS SECTION 1 a Heat loss by convention b Heat loss by Radiation SECTION 2 a Heat loss by convention b Heat loss by Radiation SECTION 3 a Heat loss by convention b Heat loss by Radiation	From the sixth iteration $157.926w/m^2$ $1275.486 \ w/m^2$ $337.2555 \ w/m^2$ $1095.323w/m^2$ $1120.7 \ w/m^2$ $312.509/m^2$	After the 2nd iteration $145.584 \ w/m^2$ $1219.773w/m^2$ $405.178 \ w/m^2$ $1224.506w/m^2$ $862.5981w/m^2$ $228.76 \ w/m^2$	0.073 0.044 0.1676 0.10549 0.22987 0.074771219
16.	Energy loss by radiation and convention Q_L	$947.2432 \ w$	$944.812 \ w$	0.0025666
17.	Total energy absorbed $'Q_T'$	$99615.67 \ w$	$94977.14892 \ w$	0.04656417
18.	Energy Stored $'Q_s'$	$47924.39766 \ w$	48032.33692	0.00223
19.	Efficiency $\eta = \ Q_U/Q_T$	0.4617747	0.4843	0.0465

Table 2 is the comparative analysis of DSS result and long-hand calculations, the results obtain are the combination of both the long-hand calculated results which is obtained from the long iteration and long hand calculation of the design parameters using established formulas and constants of oven parameters, while, that of the computer DSS generated results is obtain from the data input into the software program that has been expertly written for this purpose. Hence, the result gotten in Table 2 is extensively compared and it is found that the differences are negligible. Long-hand calculation refers to the fundamental part or processes of solving mathematical problems using traditional arithmetic methods, without the reliance on electronic tools. Though this method is very good, but it is prone to error of so many types due to the hassle of several computation, iteration, and truncations and human errors. It is also dauntingly stressful and time consuming. In the design of the solar oven, calculations and iterations of several parameters are pertinently required, but the rigorous calculation of the long-hand approach makes it a cumbersome task hence, cumulating into drudgery of designing the oven. The results gotten from these long-hand calculations corresponds to those gotten by the DSS, with minimal or negligible differences that are not significant in distorting the overall result of the oven.

The computer software programs to perform the various design works are written by experts for use on computers in any of the computer languages (high or low languages). These programs will generate the desired designs and design calculations when appropriate information is fed through the input device into the computer system. However, the DSS for a solar oven is a software program developed for designing a solar oven will operate effectively through various supplied data or appropriate information. The Energy analysis of the oven is carried out to determine its performance valuation by this program; sequel to the design input parameters. The DSS assist in determining the design calculation using appropriate formulas and constants that has been written and pre-installed in the software by experts thereby undaunting the task of getting result, and it also assist designers to choose best material is suitable for a particular solar oven specification, specification which is determine by the oven capacity; which includes but not limited to, product size (quantity and dimension) and power ratings, oven chamber, thickness of absorber plate, thickness of the plane mirror, lagging material, etc. hence it saves time and reduces the stress of rigorous calculations to determine the oven design, also it minimizes the drudgery of over/under design of the oven.

The software program output from the computer compared favourably with the long-hand calculated results with a marginal or negligible difference. The computer output is however more authentic because of the multiple iterations of the order of ten, this is shown in Table 2, the comparison of the computed result of the DSS, and the long hand calculation. Moreover, due to the various approximations in the long-hand calculation, a built-up or accumulated error results. This error is again partly responsible for the slight variations in the comparative computation. However, since the slight variations are very negligible, we can hereby conclude that the software program for the computer-aided design of solar oven is valid for use in design work. Computer calculation is time-saving as it is done at an unimaginable speed of a few milliseconds while the long hand computation is cumbersome and time-consuming. Row (ii) shows that there are negligible differences between the DSS and long-hand calculation of the solar radiation intensity $'I_b'$. Row(iii) present results of no variation in the Angle of refraction $'\theta_2'$, calculated by the DSS and that of the long-hand mathematical iteration.

3. Conclusions

The energy source for the operation of solar ovens is the sun itself whose energy is unlimited, vast, abundant, and renewable. Unlike the conventional type of oven which depends on oil, natural gas, or electricity, which is expensive to manufacture; operate; and maintain. Solar powered oven attracts no running cost after set up. The DSS program developed for its design and Engineering analysis will assist the designer a great deal in determining a design choice that suite the following: (i) Type of baking oven [Design, Size, Capacity, etc.]; (2) Operating temperature of the absorber components; (3) Material selection. However, if the policymakers in this country can recline the policy on the nation's absolute dependency on non-renewable energy sources and concentrate more on harnessing renewable energy sources such as solar, tidal, wind, geothermal, etc. there will be a rapid technological breakthrough and advancement, and economic growth in this country. Since the DSS has proven to be more efficient and a reliable tool that can assist designers in decision making in the course of designing a solar baking oven, an automatic or on-the-go drawing of the solar oven that will further assist decision-makers in the construction of the solar oven, and, Solar energy storage capabilities should be considered to accommodate oven usage at night. Also, a more robust, comprehensive, and user-friendly Graphics User Interface (GUI), and certain measuring equipment that will adequately measure Solar insolation to determine hourly energy collection, and thorough Solar energy analysis of a location may be incorporated, to make the operation experience and interaction much more seamless.

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