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Unlocking the potential of solar PV electric cooking in households in sub-Saharan Africa – The case of pressurized solar electric cooker (PSEC)

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ABSTRACT

Many households in sub-Saharan Africa (SSA) depend on wood-fuel and biomass for cooking, with associated health and negative environmental impacts. Indoor air pollution from these traditional cooking technologies and practices lead to a number of deaths each year. Clean and smokeless cooking technologies are necessary to minimize respiratory related infections associated with traditional cooking technologies. In addition, modern energy cooking services (MECS), which have lower levelized lifecycle cost have a part to play for post COVID recovery and growth in the sub-region. In this study, a novel pressurized solar electric cooker (PSEC) using diodes as the heating element has been constructed and tested in Kumasi city, Ghana. The PSEC comprises 150 Wp solar panel, 3.3 Liter cooking volume, and with the system integrated with PCM for thermal energy storage. From the experiments conducted in this study, the diode-heating element was able to charge the PCM (erythritol) and maintain it at an average temperature of 118 °C to cook rice, which is a common staple food enjoyed in many households in SSA. The result revealed that when the PCM integrated as energy storage medium was fully charged, the PSEC had fast cooking time of 50 min. Financial analysis also revealed that the PSEC has potential cost savings of US$ 575 and US$ 365, compared to cooking with charcoal and grid electricity, respectively, over a 10-year period.

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Introduction

Countries in sub-Saharan Africa (SSA) are among the most energy deprived economies in the world [1,2]. The region is challenged with irregular electricity supply, with over 600 million of its people without access to electrical power for basic services such as phone charging, refrigeration, lighting, etc., [3,4]. Modern energy cooking services (MECS) using electrical

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Nomenclature

A	area (m^2)
C_p	specific heat capacity (J/kg/K)
h	heat transfer coefficient ($W/m^2/K$)
h_{fg}	latent heat of evaporation (kJ/kg)
I	current (A)
m	mass (kg)
N	number of diodes
P	power (W)
Q	heat transfer (J)
PCM	phase change material
t	time (s)
T	temperature (K)
V	voltage (V)
q_{cond}	conduction heat flux
q_{conv}	convection heat flux
q_{rad}	radiation heat flux
$T_{s,o}$	outer surface temperature of cooker
$T_{s,in}$	inner surface temperature of cooker
k	thermal conductivity of insulation material
T_∞	ambient temperature
G	Solar irradiance

Greek symbols

Δ	difference
Σ	summation
∞	ambient
ε	emissivity
σ	Stefan-Boltzmann constant

Subscript

f	food
w	water
PV	photovoltaic
s	surface
sur	surroundings
p	pot

power is also a challenge in the region [5,6]. Many households in SSA therefore heavily depend on wood-fuel or biomass for cooking with negative environmental impact and indoor air-pollution [7,8]. Worldwide, millions of people die each year, particularly children and women in SSA countries, as a result of air pollution from poor cooking technologies and practices [9].

Research and development of cleaner forms of cooking fuels and technologies in the region, including LPG [10] and solar cooking have therefore been of high interest for the past several years [6]. LPG and solar energy are considered to be cleaner forms of cooking fuels since they have little or zero emissions compared with traditional cooking fuels such as charcoal and fire-wood [11–13]. For example, different researchers have reported on solar thermal cooking technologies [14] and solar powered induction cooking technologies [15] as a potentially viable cooking option for places where solar irradiation levels are significant.

One of the challenges of solar thermal cooking is the fact that the systems are usually bulky, and the design configurations do not easily allow for indoor cooking, resulting in very low deployment and uptake by end-users [16]. Most of the solar thermal cookers which are reported in literature require them to be used outdoor during sunshine hours, which do not make them convenient to use [17,18].

To address the challenges associated with solar thermal cooking, the potential of solar PV electric cooking has been explored in more recent times [6]. In the work of [19], they presented a $100 insulated solar electric cookstove (ISEC) as a potentially affordable cooking technology, with a case study in Uganda. They concluded that appropriate insulation of the ISEC was crucial in reducing power demand and making the system cost-competitive. In the study of [20], Direct DC Solar (DDS) electric cookstove using diode-chain as the heating element was evaluated. They reported that the DDS cookstove was able to cook food with lower power (less expensive) but with longer cooking time, running into several hours. Temperature is one of the important parameters in the design of cooking technologies. The maximum temperature that a heating element

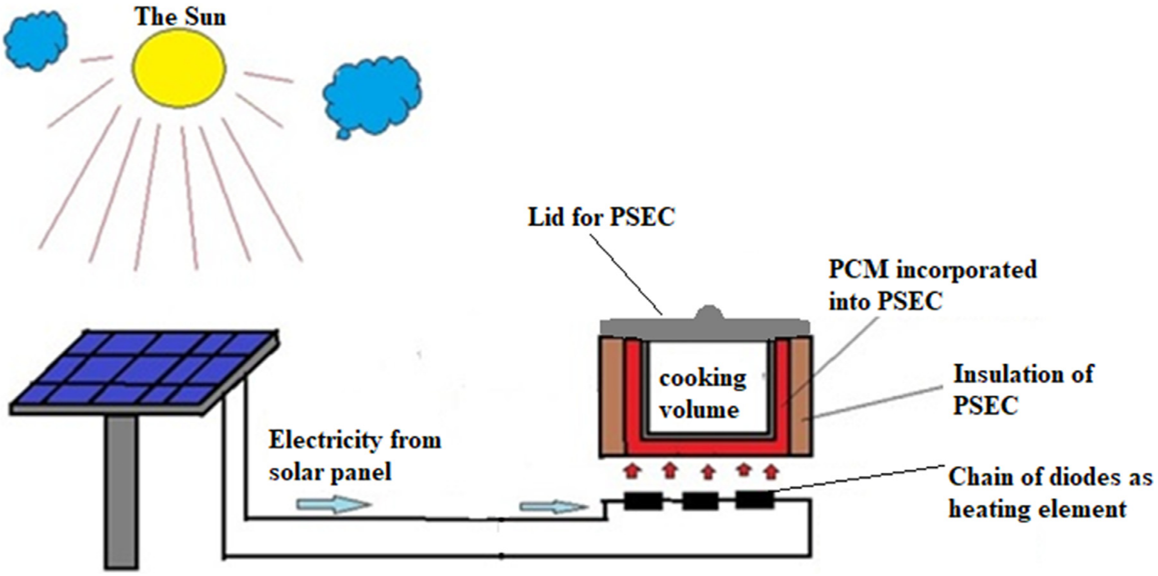


Fig. 1. Schematic diagram of the PSEC.

in a cooking device can reach gives an indication the type of cooking the device can do (boiling, simmering, poaching, frying, etc.).

From available literature, thermal energy storage [21,22], lower power density and longer cooking times [19,23] are the major challenges associated with solar cooking technologies. In this study, a novel pressurized solar PV electric cooker (PSEC), using diodes as the heating element, has been constructed and its performance evaluated in Kumasi city, Ghana. The deployment of diodes as the heating element was to optimize the operating conditions of the solar PV panels as already reported in the work of [20]. In order to address the issues of low power density and longer cooking time, phase change material (PCM) was integrated into the design of the PSEC undertaken in this study. Erythritol was used as the PCM as high-power density energy storage medium. In a case study, financial analysis was conducted on the PSEC and compared with the cost of cooking with grid electricity and charcoal in households in Ghana. Cooking of rice, which is a common staple food in SSA was considered in this study. The findings reported in this paper present opportunity to unlock clean and sustainable solar cooking in households in SSA for post COVID recovery and growth as far as cooking is concerned. The methodology that was used to undertake this study is presented in the following section.

Materials and methods

Design and fabrication of the PSEC

Fig. 1 shows the schematic diagram of the PSEC designed and fabricated in this study. The PSEC comprises solar PV panel as the energy source, and an insulated cooking chamber with diodes as heating elements. PCM is incorporated into the PSEC to serve as energy storage medium.

The fabrication process in making the PSEC is briefly presented in Fig. 2.

As already mentioned, the solar electric cooker uses diode-based heating elements. The diodes were made into chains by twisting them together (Fig. 2a), after which the chains were glued to the bottom of the nest with a high temperature epoxy glue rated at approximately 300°C (Fig. 2b). A thermostat was connected to the diode chain (Fig. 2c) to protect the diode from damage due to overheating (temperatures above 150°C). The nest was then placed in a void of the PSEC housing and was riveted onto a raised platform at the base of the void (Fig. 2d). The void is the volume which is occupied with the PCM, and sealed. To provide a good thermal storage for the cooker and minimize heat losses, the outer void of the casing was insulated with fiberglass insulation (Fig. 2e). Fiberglass insulation has very good thermal resistance (that is low thermal conductivity, $k = 0.04$ W/m.K), which is good for high temperature applications. Selection of fiberglass insulation for the solar cooker was based on its good thermal resistance properties [24,25], high fire resistance properties, relatively lower cost and availability in the local market. The complete assembly of the PSEC is show in Fig. 2f.

Table 1 presents the various components and specifications of materials which were used in fabricating the PSEC.

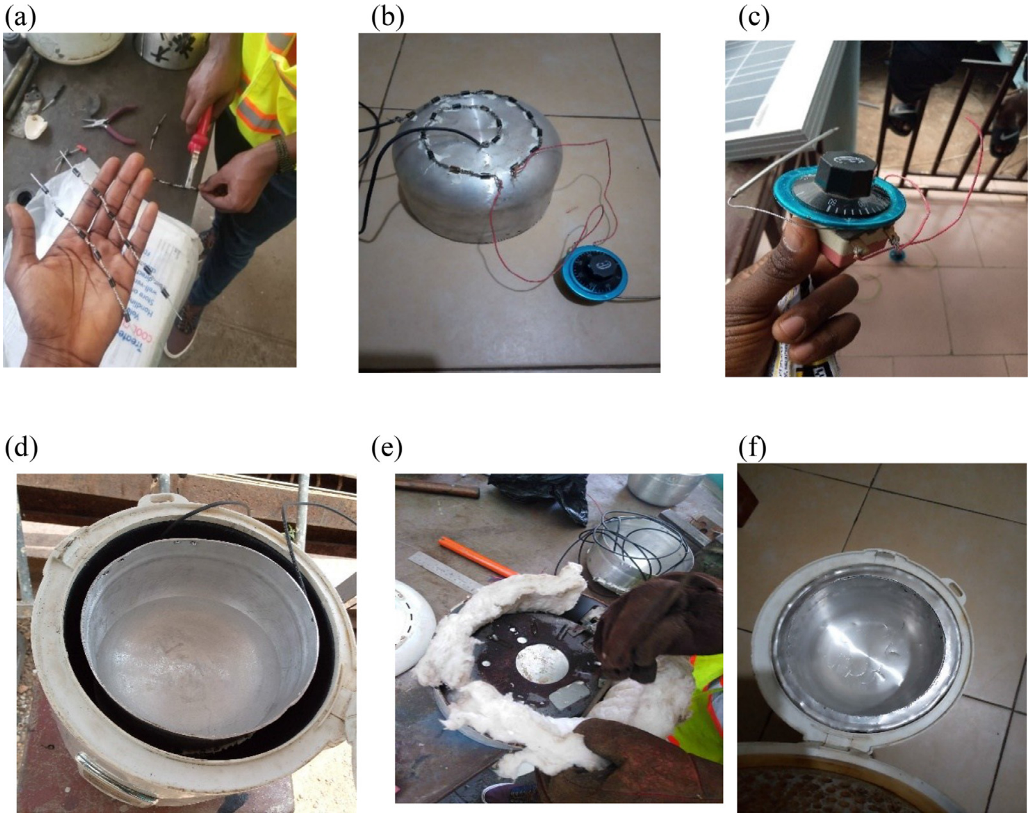


Fig. 2. Fabrication of the PSEC: (a) making of diode chain, (b) diode chain glued to bottom of heating pot, (c) thermostat connected to diode chain, (d) installation of inner cooker, (e) installation of fiberglass insulation (f) completed PSEC.

Table 1
Materials for fabrication of the PSEC.

Materials	Specification
Fiberglass insulation	Thermal conductivity = 0.04 W/m.K; thickness = 3 cm
phase change material (pcm) name: erythritol	melting temperature: 118–120 °c enthalpy of fusion (@ 118 °c) = 39.40 kJ/mol. [26].
aluminum cooking pot (1050-h14 utensil)	inner diameter = 18 cm height =12 cm cooking volume = 3.3 liters
PN junction silicon diode (1N540X series)	Maximum heat dissipation = 6 W Operating and storage temperature: −65 to +150°C Maximum Forward Voltage drop at 1A DC: 1.1 Volt Nominal Power dissipation: 3.3 W Maximum Average Forward current: 3 Amps

Thermodynamic analysis of the PSEC

In the design of the PSEC, the first law of thermodynamics was applied to determine the system design characteristics. Eqs. (1)-(4) present the first law and the components of each of the terms used for the analysis. The rate of energy input is from the solar PV panel Eq. (2), and the total energy output Eq. (3) is what goes into cooking the food plus heat losses from the body of the PSEC to the surrounding. The change in energy associated with the PSEC system is due to energy storage within the PCM. The PCM energy storage comprises the sensible and latent components as presented in Eq. (4).

$$\sum \dot{E}_{in} - \sum \dot{E}_{out} = \frac{dE_{system,PCM}}{dt} \tag{1}$$

Table 2
Information from survey study & thermophysical properties of materials used.

Parameter	Value
Average mass of un-cooked food	0.45 ± 0.12 kg
Volume of cooking pot	2.5–3.8 liters
Volume of water used	0.5–1.0 liters
Specific heat capacity of rice	0.991 kJ/kg. °C
Specific heat capacity of water	4.2 kJ/kg. °C
Latent heat of vaporization of water	2257.5 kJ/kg

Table 3
Design specification of the PSEC.

Item	Specification
Solar panel	Pmax= 150 Wp Voc = 22.19 Isc = 8.62 A NOCT = 47±2°C
Cooking volume	3.3 Liters
Power rating of diode chain	72 W

$$\dot{E}_{in} = \dot{E}_{PV} = V(t) \times I(t) \tag{2}$$

$$\dot{E}_{out} = \dot{Q}_{cooking} + \dot{Q}_{loss} \tag{3}$$

$$\frac{dE_{system}}{dt}, pcm = \left(mC_p \frac{\Delta T_m}{\Delta t} \right) + L\frac{dm_{pcm}}{dt} \tag{4}$$

The heat loss from the PSEC in the form of convection and radiation heat losses from the body, as well as sensible heat absorption by the cooking pot is given by Eq. (5) [27]:

$$Q_{loss} = hA_s(T_s - T_\infty) + \varepsilon\sigma A_s\left(T_s^4 - T_{sur}^4\right) + m_p C_p \frac{\Delta T}{\Delta t} \tag{5}$$

Also, the thermal energy and power required to cook food is given by Eqs. (6) and (7), respectively [28].

$$Q_{cooking} = m_f C_{p,f} \Delta T + m_w C_{p,w} \Delta T + m_w h_{fg} \tag{6}$$

$$P_{cooking} = \frac{Q_{cooking}}{\Delta t} \tag{7}$$

It is imperative to note that during sunshine hours, and depending on the level of charge of the PCM, the heat source for cooking emanates from both the diode heating elements and the PCM energy storage medium. However, during non-sunshine hours (or night-times), only the PCM serves as the heat source for cooking.

The number of diodes used for the design of the PSEC is computed as the ratio of the rate of energy required for cooking to the power dissipation of the diodes, given by:

$$N = \frac{P_{cooking}}{P_{diode}} \tag{8}$$

where $P_{cooking}$ is the rate of heat energy required for cooking and P_{diode} is the power dissipation of each diode in the chain.

The overall efficiency of the solar cooker which is the ratio of the useful energy for cooking (desired output) to the amount of solar radiation received (energy input) is computed using Eq. (9).

$$\eta_o = \frac{Q_{cooking}}{G_{av} A \Delta t} = \frac{\left(m_f C_{p,f} \Delta T + m_w C_{p,w} \Delta T + m_w h_{fg}\right)}{G_{av} A \Delta t} \tag{9}$$

Where, all symbols have their meanings as defined in the nomenclature. In order to appropriately size the dimensions of the PSEC for household cooking, survey was conducted on 20 different families to ascertain the quantity of food cooked by an average family size of 3–4 persons. Cooking of rice was considered during the household survey to ascertain the quantity of food cooked. Table 2 presents information from the survey conducted. The specific heat capacity values and latent heat of vaporization of water used in the analysis are also presented in Table 2.

Based on the information gathered from the survey, and the design equations presented under section 2.2, Table 3 presents the specifications of the components of the PSEC fabricated in this study.

In determining the appropriate thickness (dx) of the fiberglass insulation (as presented in Table 1), heat transfer analysis at steady state condition was conducted considering heat conduction (q_{cond}) through the insulation material, and convection (q_{conv}) & radiation (q_{rad}) heat loss from the outer surface of the cooker. Eqs. (10)-(12) present the heat transfer equations used.

$$q_{cond} = q_{conv} + q_{rad} \tag{10}$$

$$k\frac{(T_{s,in} - T_{s,o})}{dx} = h(T_{s,o} - T_{\infty}) + \varepsilon\sigma\left(T_{s,o}^4 - T_{\infty}^4\right) \tag{11}$$

$$dx = \frac{k(T_{s,in} - T_{s,o})}{h(T_{s,o} - T_{\infty}) + \varepsilon\sigma\left(T_{s,o}^4 - T_{\infty}^4\right)} \tag{12}$$

For Eqs. (10)–(12), all symbols have their meanings as defined in the nomenclature section. The properties of the materials were obtained from [24,25]. Insulation thickness of 3 cm was computed to the be appropriate for designing the PSEC.

Experimental setup

Fig. 3 shows the experimental setup used for data collection on the PSEC. The PSEC was instrumented with K-type thermocouples for temperature measurement (with range: 0 – 250 °C; accuracy ± 1.5%). The instantaneous power output from the solar PV panel as well as the power drawn by the diodes was measured with power quality analyzer (Fluke 345) with voltage and current range of 0–100 VDC, ± 0.1 V; and 0- 200 Amps, ± 1.5%, respectively. During the cooking test experiment, solar radiation data were measured using a Suntron weather station at the study site [29].

The average seasonal radiation levels in the study area, Kumasi city, Ghana, are in the range of 3.3 to 4.9 kWh/m^2-day [30]. Experiments were conducted on the PSEC for a number of days and the results obtained are presented in the next section, under results and discussion.

For statistical analysis of the measured data, the mean values and the standard errors of the mean associated with the data were computed using Eqs. (13) and (14), respectively.

$$\overline{X_t} = \frac{1}{N}\cdot\sum_{i=1}^{N} X_i \tag{13}$$

$$\sigma_s = \frac{1}{\sqrt{N}} \times \sqrt{\frac{\sum_{1}^{N}\left(X_i - \overline{X}\right)^2}{N-1}} \tag{14}$$

where, N is the number of data points, X_i is the i$^{\text{th}}$ data point at time i, and $\overline{X_t}$ is the mean value of all data taken at time i. For example, $\overline{X_9}$ implies the mean value of all data taken at 9 am for the experimental days. In this study, we used standard error of the mean for the statistical analysis because it gives a very good estimate of how well the sample data measured from the experiments represent the whole population [31]. That is, the standard error gives good statistical estimate of the data for the whole year if data were taken from January to December. The average values and the errors are presented in the form of graphs in the results section.

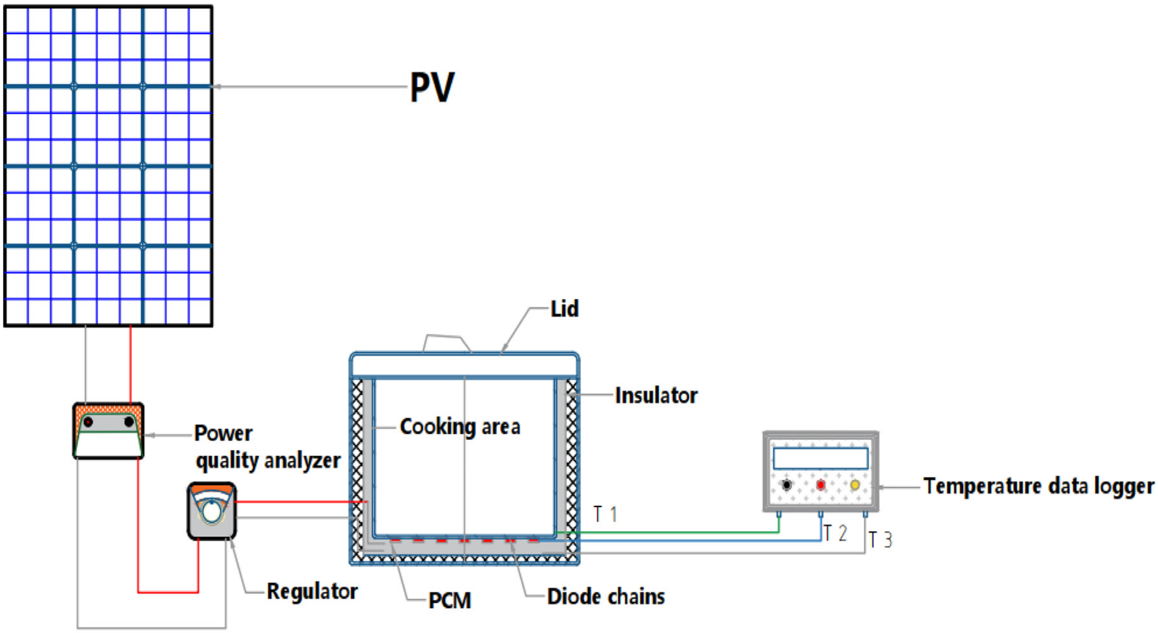
Comparative financial analysis of cooking with PSEC, coal-pot and grid electricity

To ascertain the financial viability and competitiveness of the solar cooker with other cooking technologies such as coal-pot (using charcoal fuel) and hot plate (using grid electricity), lifecycle analysis (LCA) was conducted as presented in Eq. (15).

$$LCA = I_i + \sum_{n=1}^{N} MR(n) + C_E(n) \tag{15}$$

where I_i is the initial cost of the cooking technology, *MR* is the maintenance and repair cost in year n, N is the period for the lifecycle analysis and C_E is the cost of fuel/electricity for the cooking technology. The values used for the LCA is presented in Table 4. From the household survey conducted, it was ascertained that cooking with coal-pot and hot-plate usually have marginal maintenance and repair cost. Their fuel cost is, however, very high. When hotplates and coal-pots have been used for so many times, and they are weak, they are replaced with new ones. From the survey responses, hotplates and coal-pots can last over five years. For the solar cooker, maintenance of the system including cleaning of the panels from dust to ensure optimum operation was considered. Based on information gathered from solar PV vendors in Ghana, maintenance (cleaning of panels) cost of averagely US$ 0.15 per W per year was considered. The diodes for making the solar cooker can last for more than ten years when operated within the manufacturer's specifications.

(a) Instrumentation of the PSEC for data collection



(b) schematic diagram

Fig. 3. Experimental setup for data collection on PSEC.

Results and discussion

Temperature profile of the diode heating element

In this study, the temperature profile of the diode-chain heating element used in the PSEC was monitored during sunshine hours within the day and the result is presented in Fig. 4. The temperature contour of the diode chain was also monitored using infrared thermal camera and it is shown in Fig. 5.

From the results of Figs. 4 and 5, it is observed that the maximum temperature attained by the diode chain is about 149 °C, which is one degree Celsius lower than the manufacturer's safe operating temperature of 150 °C [33]. Operating diodes above their maximum rated temperatures can destroy their wire leads [20], thereby rendering the whole heating element and the cooking device non-functional. Safe operation of diode below its rated temperature is therefore very imperative when used in cooking, in order to ensure longevity.

Table 4
Cost of cooking with different technologies in Ghana per day.

S/N	Cooking technology & fuel used	Cost of fuel for cooking per day
1	Coal-pot with charcoal. Cost of the coal-pot ranges between US$ 12 –15, for household use. Maintenance and repair cost is US$ 5 –10 per year.	Gh₵ 1.0 (US$ 0.17 eqv.),
2	Hotplate with grid electricity (usually in some few homes in the cities). Hotplate (single head) cost US$ 18 –25 and with power ratings of 900–1200 W, and used on the average 20 min per cooking session for the foods considered in this study. Maintenance and repair cost is US$ 10–15 per year.	US$ 0.12 (based on residential electricity tariff in Ghana) [32]
3	Solar powered PSEC: Total cost of solar PV panel plus cooking pot with PCM – US$ 198. Maintenance and repair cost is US$ 16–20 per year.	Solar radiation is ***free***

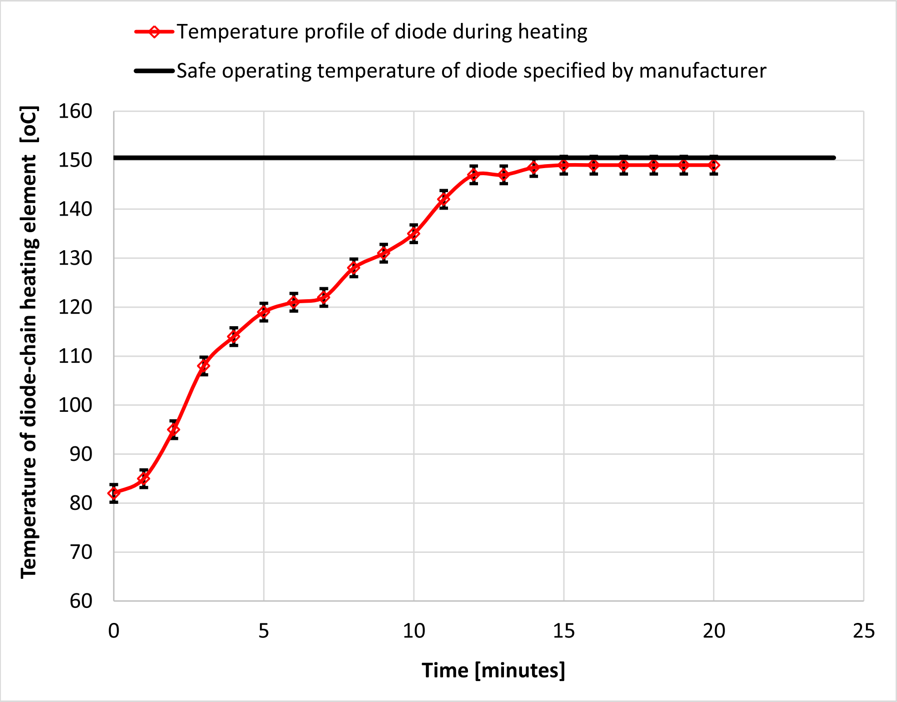


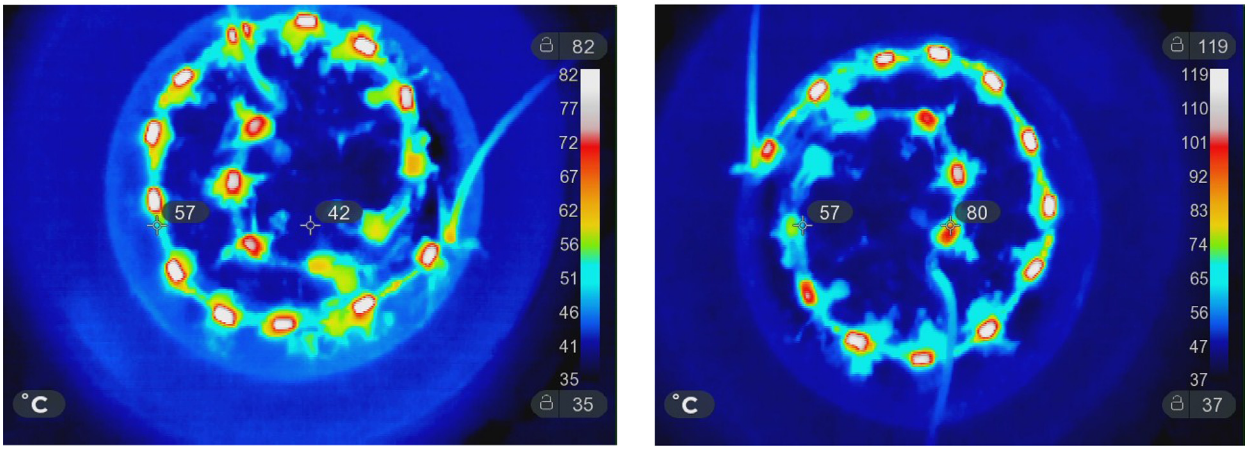
Fig. 4. Temperature profile of diode-chain heating element when supplied with PV electricity.

Power output from the PV panel

Fig. 6 shows the PV panel power output measured during the experiment from sunrise to sunset. The average values and statistical deviations (in error bars) were computed from the data measured for the 20 days experimentation of the PSEC.

From the results of Fig. 6, it is observed that the power output from the solar PV panel increases from sunrise at around 7 am, peaks between the hours of 12 noon and 1 pm and then decreases at sunset around 5 pm. Peak power output of 140 W was obtained in the experiment at around 12 noon, resulting in maximum power ratio of 0.93 (140 W/150 W). The maximum power ratio expresses the ratio of the peak power obtained by the PV panel on the field to the manufacturer's maximum rated power (in this case 150 Wp, see Table 3). Maximum power ratios greater than 0.7 are considered to be good system design [34].

The higher maximum power ratio of 0.93 obtained in this study can be attributed to the fact that the forward bias voltage characteristics of the diode-heating element facilitate the PSEC drawing current near maximum point at all times, compared to other heating elements such as resistance heaters [20]. The finding of this study therefore highlights that diodes used as heating elements for solar electric cookers maximize electrical power output from solar PV panels resulting in improved system performance.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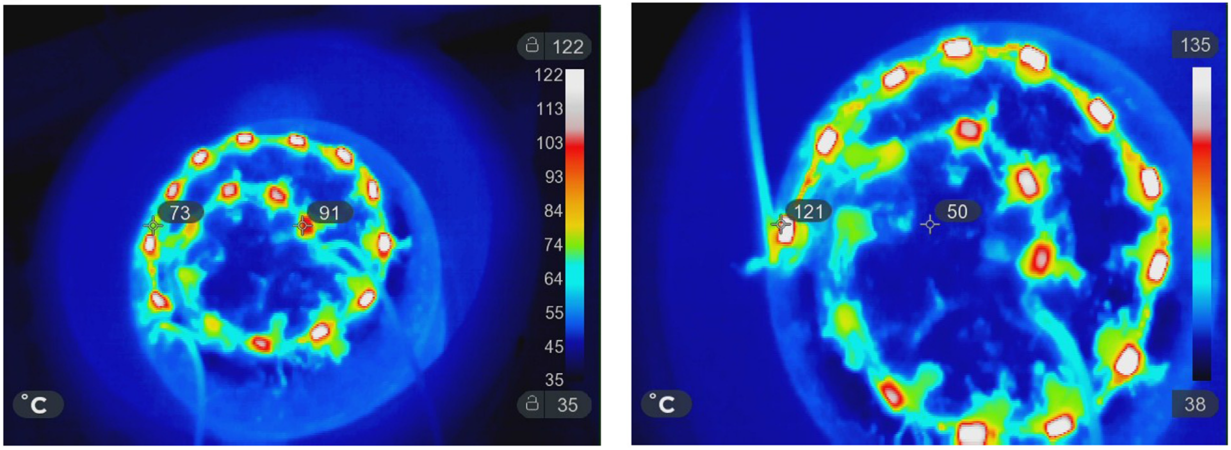
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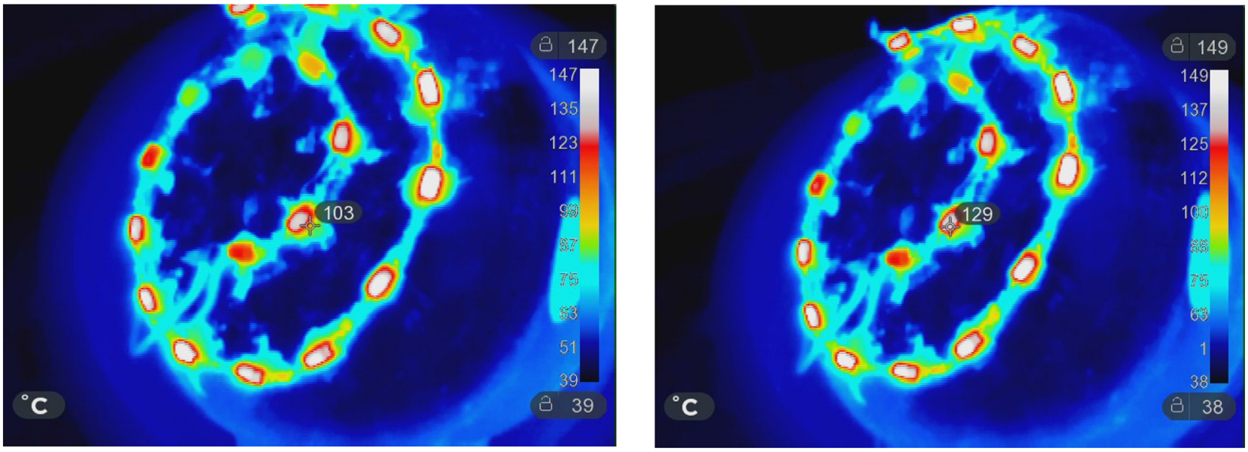
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Fig. 5. Temperature profile (contour) of diode heating element at different times.

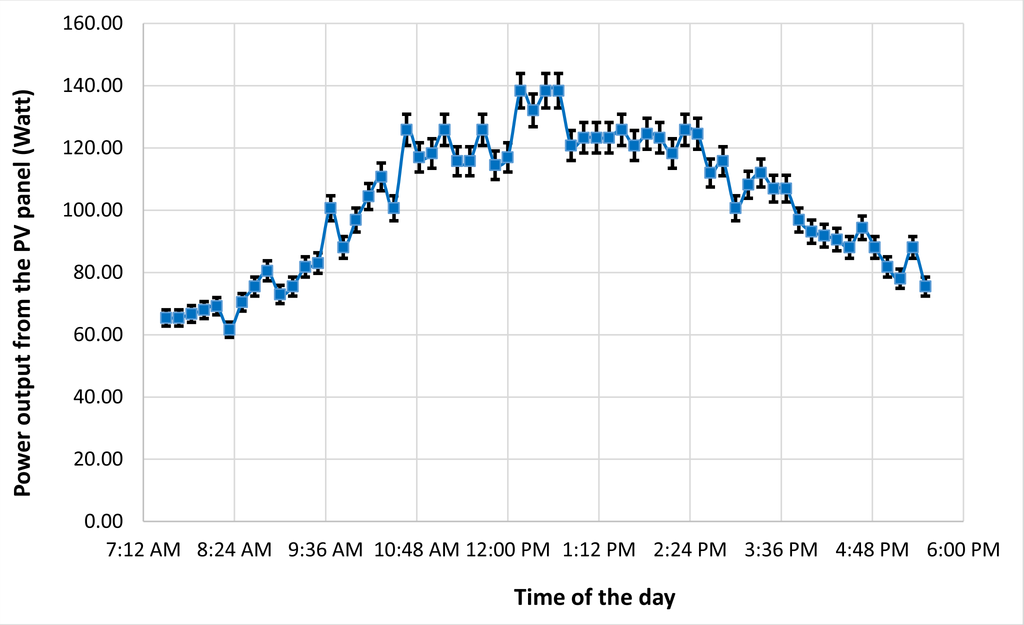

Fig. 6. Solar PV power output.

Temperature profiles of PCM and cooking medium

The temperature profiles for PCM and the cooking medium monitored with the K-type thermocouple during the experiments are shown in Fig. 7. Cooking was done in 2 different stages/periods, that is the stage of charging the PCM (between 0 and 90 min) and the stage when the PCM is fully charged (between 110 and 160 min).

From the result of Fig. 7, the temperature of the PCM increases from 28 °C (at the start of the experiment) to about 118 °C (its melting temperature) within a period of 90 min. This period is called the charging phase. After reaching the melting temperature and beyond, the PCM is said to be charged [35]. During the charging and charged state, heat is transferred from the PCM to the cooking medium to cook the food. The result shows that the PSEC has average cooking time of about 95 min and 50 min during the period of charging and when the PCM is charged, respectively. The cooking times (95 min and 50 min) obtained in this study using the PSEC is relatively shorter than cooking time reported in literature for other cooking technologies such as solar thermal cookers [36,37].

Efficiency of the PSEC

The overall efficiency of the solar cooker was computed using the thermodynamic analysis as presented in Eq. (9). Information presented in Tables 2 and 3, in addition to the average solar irradiance measured at the site ($G = 700$ W/m^2), the average change in temperature ($\Delta T = 75$ °C) in cooking the food and the average cooking time ($\Delta t = 95$ min) were used to compute the efficiency of the PSEC. The efficiency of the solar cooker developed in this study is found to be 56.2%. Table 5 compares the efficiency of the PSEC with other cooking technologies reported in literature.

From available literature, the highest efficiency of a solar cooker is 46.3% for a hybrid solar cooker [39]. The relatively higher efficiency of the PSEC (56.2%) which is a solar electric cooking technology is as a result of the use of diode chain which is able to match the heating element to the PV characteristics to operate at the maximum power point, as also reported in the work of [20].

Comparative financial analysis of the PSEC with other cooking technologies

To evaluate the financial sustainability of the PSEC as good cooking technology, comparative financial analysis was conducted with the PSEC against cooking with grid electricity and with solid-fuel (charcoal). Charcoal is the most used solid fuel for cooking in Ghanaian homes with over 60% share [45]. Data obtained from field study (presented in Table 4) in terms of the cost for cooking per day was used for the financial analysis.

Fig. 8 shows comparative financial analysis for the PSEC and the other two cooking technologies, over a 10-year period. In computing the cost of charcoal and electricity for cooking over the 10 years period, the annual average cost growth rate reported in Ghana Energy Statistic Report was used [45].

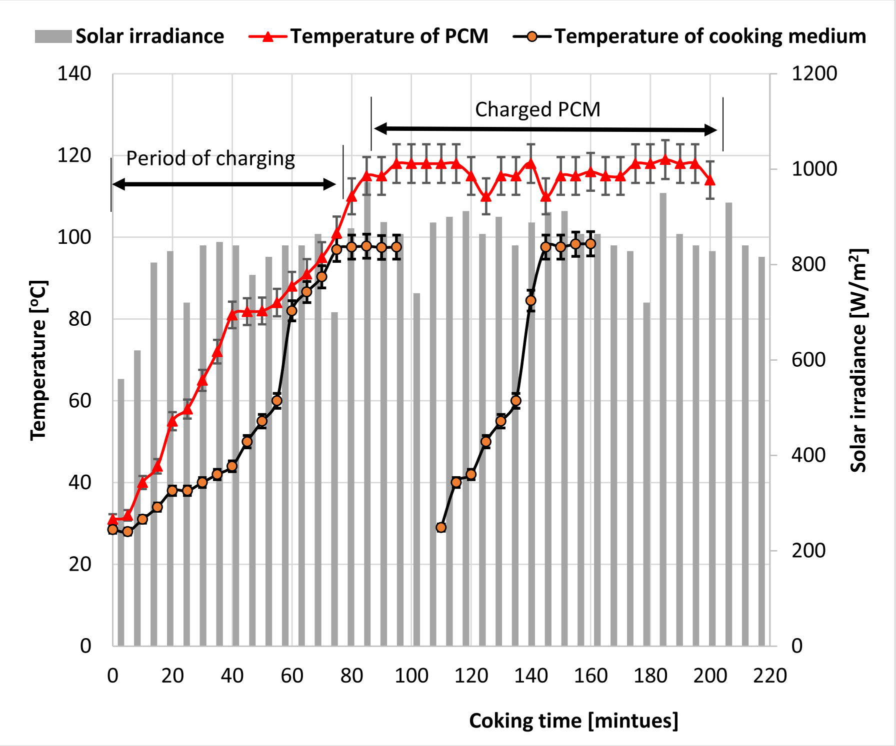

Fig. 7. Temperature profile of PCM and cooking medium.

Table 5
Efficiency of PSEC compared with other cooking technologies.

Study conducted	Efficiency
Current study on PSEC	56.2%
Solar cooker with tracking-type bottom reflector: An experimental thermal performance evaluation of a new design.	12.5% [38]
Design, development and testing of small-scale hybrid solar cooker.	38.1–46.3% [39]
Experimental determination of energy and exergy efficiency of solar parabolic-cooker.	9.2% [40]
Experimental and numerical investigation of solar flat plate cooking unit for domestic applications.	9% [41]
Box type solar cookers with sensible thermal energy storage medium: A comparative experimental investigation and thermodynamic analysis	28% for Bayburt stone solar cooker, and 22.25% for conventional solar cooker [42]
Design, development and testing of a double reflector hot box solar cooker with a transparent insulation material.	30.5% [43]
Efficiency of a solar cooker in Pakistan's Quetta Region	29.81% [44]

From the result of Fig. 8, it is observed that initial cost of the PSEC is about 11 times higher than the coal-pot cooking technology (using charcoal fuel) or the hot-plate cooking technology (using grid electricity). However, at the end of the analysis period (10 years in this study), the cumulative costs of cooking with charcoal and grid electricity are 2.8 and 2.1 times higher than cooking with PSEC. From Fig. 8, simple pay-back periods of 3 years and 4.5 years are realized for the PSEC compared with cooking with charcoal and grid electricity, respectively.

The finding of this study has revealed that there is potential cost savings of US$ 575 and US$ 365 for using the PSEC as a cooking technology compared with charcoal and grid electricity, respectively, for a 10-year period. This result demonstrates that efficient solar cooking technology such as PSEC is a potentially transformative alternative for cooking in African homes and with significant sizeable market, as also reported in the study of [46]. The only barrier to realizing this opportunity in African homes in order to transition them from very polluting cooking fuel such as charcoal/biomass to more environmentally clean cooking technology (PSEC) is **cost**. Innovative financing options including "pay and use", "pay-as-you-go", etc., [47,48], would have to be explored by developmental partners and governments within the region to support the global energy transformation agenda as far as clean cooking in SSA is concerned.

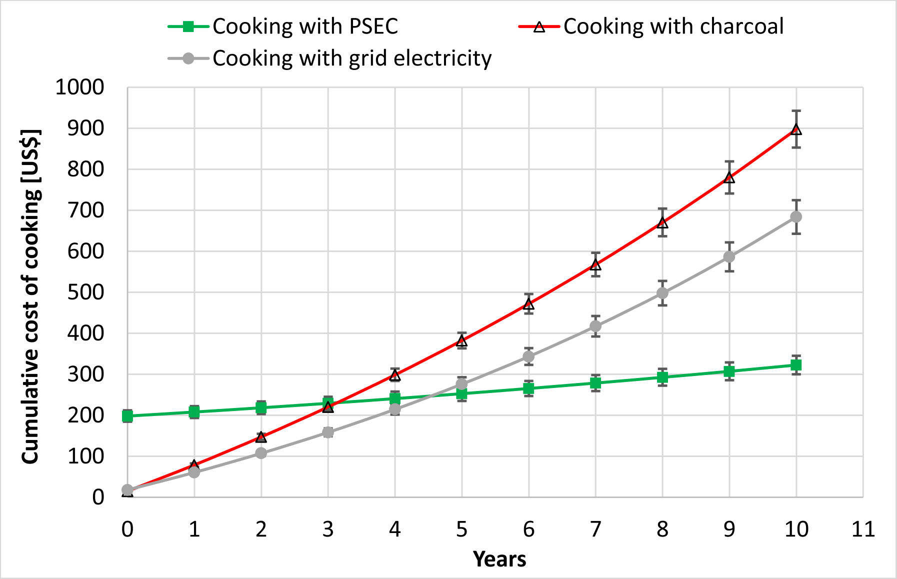

Fig. 8. Comparative financial analysis of cooking with PSEC and other technologies.

Conclusion and policy recommendations

In this study, technical and financial analyses have been conducted on a pressurized solar electric cooker (PSEC) as a viable cooking technology for use in energy deprived communities such as in SSA. From the study result, the following conclusions are made:

i The PSEC integrated with PCM has higher cooking power resulting in shorter cooking time compared with other solar cooking technologies. When the PCM was charged, the cooking time of the PSEC was less than an hour.
ii The PSEC was able to charge the PCM to reach its melting temperature, thereby providing continuous source of heat for cooking under fluctuating solar irradiations during the experiment.
iii Financial analysis over a 10-year period revealed that the PSEC has potential cost savings of US$ 575 and US$ 365, compared to cooking with charcoal and grid electricity, respectively.

Policy recommendations for SSA countries

Cooking is the highest source of GHG emissions in many African homes. This is largely due to inefficient cooking technologies using polluting fuels (charcoal and wood-fuels), with negative environmental and health impacts (especially for women and children). The African Union's Agenda 2063 establishes the links between sustainable energy supply, industrialization, development and environmental sustainability. However, Africa is far behind in modern energy cooking services. Only 16% of the population in SSA have access to modern energy cooking services [49]. The continuous use of charcoal and wood-fuels for cooking is increasingly depleting the African forest, making the continent more vulnerable to climate change. Interventions to reduce GHG emissions from polluting cooking fuels feature as one of the main areas for nationally determined contributions (NDCs) towards climate change mitigation and adaptation in the region. Solar PV electric cooking (eCook) presents opportunity to decarbonize cooking in African homes. The main challenge to realize this opportunity is the initial capital cost, despite its cheaper life-cycle cost. Some possible policy recommendations to overcome the high initial capital cost can be for SSA countries to support local production of the solar PV eCook on mass quantities- to benefit from economy of scale. Further, national programmes within SSA countries, which provide subsidy for end-users to patronize environmentally-friendly cooking technologies such as PSEC can be a game changer for the sub-region. Additionally, international development cooperation programmes with agencies such as GIZ, UNIDO, SNV Netherlands, and grants from climate-related funds such as the Green Climate Fund (GCF) can help to drastically reduce initial cost of solar PV electric cookers to enable market penetration in SSA. Finally, energy service companies (ESCOs) in SSA can facilitate market penetration of solar PV electric cooking technologies by supporting innovative financing schemes such as “pay and use”, “pay-as-you-go”, build-operate-transfer (BOT), etc.

Further studies

In this paper, results have been presented on the developed PSEC for cooking rice, which is a common staple food in African homes. An attempt was made to use the PSEC to fry fish and other foods but it was not successful. Temperature of about 190 °C, which is required for frying foods could not be achieved by the PSEC due to the limiting melting temperature of the PCM of 120 °C. Further studies to explore different PCMs with higher melting temperatures are therefore recommended.

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