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STAND-ALONE PARABOLIC SOLAR COOKERS AND RURAL INDUSTRIALISATION IN SOUTH AFRICA

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ABSTRACT

Lack of infrastructural facilities, empowerment, hunger and malnutrition are some of the major challenges facing the rural communities in Southern region of Africa, while the latter two often so because of the choices of whether to buy food or to buy the expensive cooking fuel or other family needs with the insufficient available income; inadequate infrastructures on the other hand has led to rural-urban migration boom amounting to an increase of over 62 percentage of the urban population over the last 15 years thereby adding to the urban unemployment problems in Southern Africa. For this purpose developing and promoting affordable solar cooking/heating system that can use the free available energy of the sun for Southern African condition is of utmost importance. Since Parabolic solar cookers are known to be most effective in terms of heat production, this paper thus looks into how the parabolic solar cooking system capable of working during the day and night or when there is no radiation can be used to fight the major challenges facing the rural areas in the southern Africa which are deforestation, hunger and poverty among others and how it can be used to develop local industries (Bread, Brownies, Pancake and Post-harvest) in Southern Africa.
Keywords: Southern Africa; Parabolic solar cookers; Hunger and Poverty; local industries.

INTRODUCTION

Various research has shown that 47% world population live in rural areas and they are poor with fewer resources, they lack gainful employment and awareness of their world. (Grundy, 1995). In search of a realistic solution to ensure food security and global equality (Jerneck and Olsson, 2013)world bodies like the World Food Programme (WFP), FAO, United Nations (UN) and the International Fund for Agricultural Development (IFAD); have continue to pull prodigious resources together to lead a realistic development in agriculture, rural development and sustainable development (Misselhorn, 2005)

Cooking with the sun, although not a new or novel idea (Wentzel and Pouris, 2007), it can serve as a realistic solution to the afore mentioned challenges. Solar cooking can also be said to be one of the most prominent way forward to meet the challenges of energy demands (Yettou et al., 2014), as well as inequality in our world; it also offers an alternative and an environmentally friendly energy supply for cooking especially in rural households and can also be used for local industrialisation if the heat generated is chsnnekled and used foe other processes like food processing, post-harvest management and food storage (Mawire et al., 2010).

There is a wide range of definition that exist for the term "rural industrialization"; for the scope of this paper we will define it as an self-reliant entrepreneurship springing up at local or village level which involves the development of social amenities and growth variety of human pursuits such as, business, industry, agriculture, etc. and acts as a potent factor for economic development.

This paper thus presents how the use of a parabolic cooker as a heat generating system can be used to initiate rural industrialisation by developing local industries such as food processing and post harvest management equipments.

NOMENCLATURE

V_1	[l]	Initial volume of oil
V_2	[l]	Final volume of oil
β	[-]	Volumetric expansivity coefficient of oil
T	[°C]	Temperature
P	[N/m^2]	Pressure
ρ	[kg/m^3]	Density
g	[m/s^2]	Acceleration due to gravity

CHALLENGES OF LIVING IN A RURAL COMMUNITY

Majority of the agricultural and farming activities are in Africa are done in the rural areas, while the processing industries on the other hand are sited in the cities. This has led to an increasing gap in the different living standard between the people in urban and rural societies as well as the sudden boom in the urbanization over the last decade can be attributed to this fact (Jerneck and Olsson, 2013, Rogers et al., 2012).

The human population of southern and eastern Africa according to is estimated at about 400 million (IFAD, 1995-2014), more than three-quarter of the poor people in Africa are known to be living in rural areas and they all live on small scale agriculture for food and making a living, despite this, "*the support and the development assistance to agriculture is decreasing and in Sub-Saharan Africa more than 218 million people live in extreme poverty*" (IFAD, 1995-2014). The incidence of poverty in Sub-Saharan Africa is increasing faster than the population. Overall, the pace of poverty reduction in most of Africa has slowed since the 1970s (Grundy, 1995, Sanger, 2014)

The problem of safe water, sanitation and hygiene is still a major challenge facing Africa despite all the on-going efforts.

RURAL INDUSTRIALISATION IN SOUTHERN AFRICA

Emphasis on the reasons for and causes of bias society in which the poor remains poor and are locked up in the rural communities and why rural-urban migration has been on the rise has been treated with details in literatures (Lipton, 1977) therefore we will rather dwell more on how rural development can be achieved in southern Africa through industrialisation generated from the use of the use of the parabolic cooker.

(Potts, 2012, Siamwalla and Valdés, 1980, von Braun, 2010, Duncan, 1998, Paumgarten and Shackleton, 2009) have shown in literatures that rural industrialization is paramount to any emerging economy like that of South Africa and can instantly lead to the following advantages:

- Small scale industries do not need large initial capital investment
- The available local resources can serve as direct raw materials for the developed industries
- Rural industrialization will reduce the high rise in rural urban migration.
- It leads to job creation
- Food creation

STAND ALONE PARABOLIC COOKERS REMEDY

(Yettou et al., 2014) in their work divided solar cookers into *"box-type cookers, concentrating-type cookers and non-focussing type cookers and within these three main categories are included cookers with direct or indirect heat transferring modes cookers with or without storage, and cookers with tracking or non-tracking systems*". The solar cookers reffered to as the direct types in the above make use of the direct normal irradiation (DNI) from sun directly fro cooking while the Indirect on the other hand uses heat transfer fluid to transfer the heat from the heat receivwer to the cooking unit. (Yettou et al., 2014, Muthusivagami et al., 2010). The different types of designs described here can have a one or two axis tracking system incorporated into their design to follow the sun; different papers exist on the reviews of these different types of cookers.

The Parabolic cookers, especially the ones with storage had been shown to be effective and can cook when there is no sunshine and thus had been chosen to be used. Hazardous living conditions, insecurity, ill-health, poverty, food insecurity and social conflicts within and between ethnical groups could derive their sources from the global inequality which is also a major cause of both under consumption and over consumption (Jerneck and Olsson, 2013, Rogers et al., 2012) can be averted if the heat generated from parabolic system technology is used to develop the local

OVERVIEW

The aim of the system discussed here is to develop a cooking system that uses solar energy for cooking and can also store up heat energy so it can be useful when there is no sunshine and in the evening hours. Southern Africa receives more than 2500 hours of Sunshine per year and an average of 4.5 – 6.5 kWh/m^2 per day insolation (Department of Energy, 2011) making this project realistic. The desired system would eliminate wood stove cooking in sub Saharan Africa and must be solar powered and should be generate and hold an energy of 4 Kw/hr for between 16-18 hours. The expected heat output should be 200°C; it must be smoke free and must reduce deforestation. The maximum cost for a family size should be $200 and the community size to be $2000. This project is executed using available and cheap standard material in South Africa, therefore might vary in other African countries to make it more localised.

THEORIES

DESIGN DETAILS

A photo voltaic (PV) panel is attached to provide electricity for the whole system. The power generated through from the PV is then used to drive the pump in the system. An expansion tank is introduced into the system to accommodate the oil expansion, and also serve as the pump container as shown in figure 1. It is a simple box and the oil expansion is determined using temperature differences and the oil properties in the volumetric expansion equation:

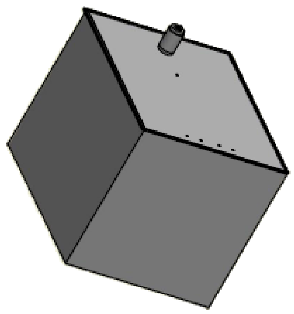
$$V_2 = V_1 + (1 + \beta \Delta T)$$

The table 1 below shows the oil expansion rate using the initial ambient temperature as the lower limit temperature and the iterating it to the an upper limit temperature of 300℃, a temperature far higher than the maximum expected temperature the oil would reach during usage, the following table was generated.

Table 1: Oil Volumetric expansion

Initial volume(l)	Final Volume (l)	Maximum Expansion (l)
5	5.825	0.825
10	11.65	1.65
15	17.475	2.475
20	23.3	3.3
25	29.125	4.125
30	34.95	4.95
35	40.775	5.775
40	46.6	6.6
45	52.425	7.425
50	58.25	8.25

The coefficient of volumetric expansion of oil is taken to be 0.0006/℃ as given in the used shell oil technical data sheet. The maximum expansion volume for a 50 litre storage system is 8.25 litres as shown in the table, thus an expansion box of higher volumetric capacity was designed. The oil is then pumped using a gear pump which is attached to the cover of the tank as shown in figure 2 and seats inside the expansion tank to prevent hot oil leakage after been used over years.



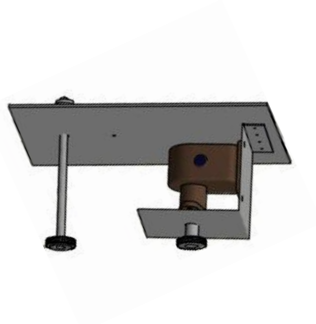


Figure 1 Expansion tank **Figure 2** Pump on tank cover

The fluid is then transferred to the receiver on the dish and it is heated to its maximum temperature depending on some variable such as flow rate, the amount of solar rays reflected, the emissivity and the absorptivity etc. The heated fluid then goes down into the storage tank and this is insulated to keep the hot throughout the usable period. The fluid transfer pressure is determined using the standard Bernoulli's equation.

$$P + \frac{1}{2}\rho V^2 + \rho g h = constant$$

The heated oil in the storage can now be transferred to the cooking section. The design of the cooking section is dependent on the intended use of the parabolic solar cooker either for regular cooking or industrial usage. Details of these are discussed in the result section as well as the modifications and Impact on rural areas section.

LOCALISATION OF TYPES

The system under consideration is a parabolic solar reflector-concentrator and cavity heat receiver, sun tracking control system and a pump to be powered by electricity supply from a photovoltaic panel without the need to be connected to the grid. The design consists of three sub-systems: collection, storage and output as shown in Figure 3. The set-up also includes thermal heat storage system making it possible for the system to work during the day and night or when there is no radiation. The heat transfer fluid to be used for the system is the Shell HTF S2X. The heat storage tank is an insulated tripod based tank. High temperature flexible pipes will be used to transfer heat throughout the system.
The figure 3 below shows the flow of the heat transfer fluid in the system.

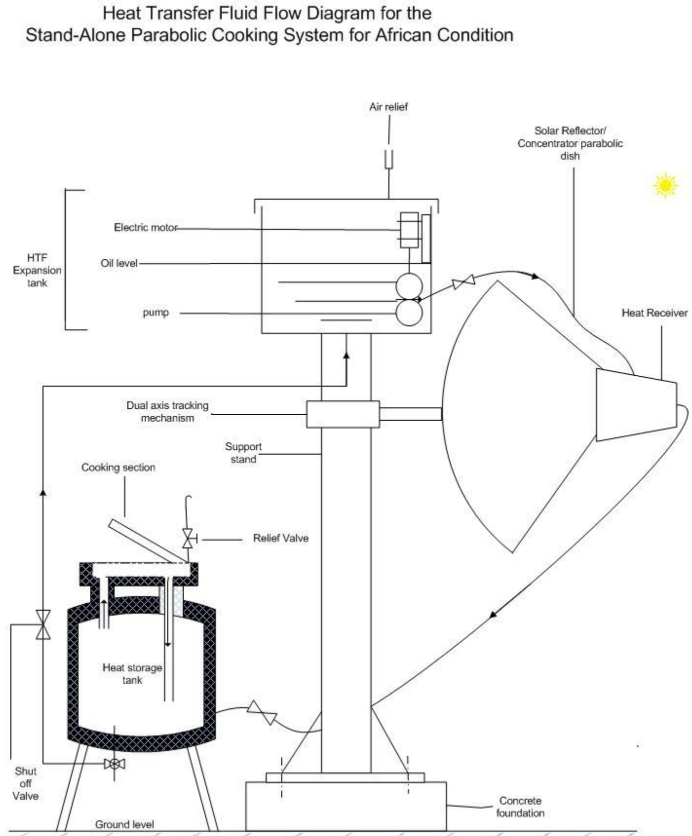


Figure 3 The heat fluid flow diagram for the Parabolic Solar cooker

The expansion tank in the figure 1 above perform dual function, firstly as an expansion tank and secondly as a spill catch for any leakage that might occur after years of pump usage.
The stand-alone parabolic cooker would be used by people who have access to adequate sunshine and can perform cooking both in the day when there is sunshine and also in the night.

RESULTS AND MODIFICATIONS

In order to attain thermal equilibrium in short time, the cooking surface is modified to be a coiled cupper tube and then hot oil is passed through the copper tubing; an output temperature of 250 °C at the cooking section was achieved. When compared with just a flat plate head, the time to reach thermal equilibrium is far shorter. The storage tank was also insulated with fibre glass and wrapped to prevent heat loss to the atmosphere. This allows the storage system to be able to supply heat for several hours during no sunshine or at night. The cooking section allows heated oil to rise up while the cold oil goes back to the tank which is then recycled.

The stable end heat generated allows for the modification of the cooking section to suit different uses as shown in the next section.

MODIFICATION AND IMPACT ON RURAL AREAS

The cooking section of the parabolic cookers can be modified to perform the following functions:

- Water pasteurization

- Solar Oven for Industrial Bread Making, Brownies and other heat based industries
- Industrial Agricultural Food processing that requires high temperature
- Meal cooking for Individuals, Family/Institutional/ Community Cooking
- Braai, meat/fish roasting and general cooking

WATER PASTEURISATION

Globally, water-borne related diseases are the second highest causal of deaths in children under the age of five (5) ranked just behind the deaths from acute respiratory infections (Gleick, 2002). Safe water is far from being accessible to dwellers of rural community in Africa while the inadequate available ones in its cities are fast deteriorating.

Heating contaminated water to 65°C kills all germs or infectious organisms as well as the contaminating bodies (CIOCHETTI and METCALF, 1983), therefore the cooking section can be developed to act as solar water heater to communities of family in need of water pasteurization.

INDUSTRIAL DEVELOPMENT

Most baking and pastry making processes are accomplished under 250°C (Mondal and Datta, 2008, Zhang and Datta, 2006) and with these cooking system used directly as an oven these industries can be setup. This will automatically provide an employment for the teeming populace of the village and will reduce the overdependence on the supplies from the cities.

EDUCATIONAL DEVELOPMENT

In South Africa, the National school nutrition programme enhances school learning through provision of healthy food. The food is prepare using electricity or coal where there is no access to the grid (Department, 2009). Using this parabolic cooking system will reduce the cost incurred in purchasing cooking fuel/coal or the load on the national grid. It also preserves the natural taste of the food. The cost incurred during food cooking which would have been averted by using the cooking over time can be therefore be used for educational development.

COOKING BREAKTHROUGH

When used as a home unit, the system can also serve as life saviour for women who walk hundred miles to gather firewood used for cooking. It will save unnecessary stress and injuries to health which could have resulted from cooking with firewood (Otte, 2013). The system can be used for cooking community festive feasts. Institutions like hospitals, refugee camps, prisons and military can also use the solar cooking system for various specific purposes.

CONCLUSIONS

It can be seen from this paper that the stand-alone parabolic cooker can be used as a means of fighting water borne diseases, hunger, malnutrition, poverty and inadequate rural industrialization challenges among others; since the system will not just make cooking easy but also boost the economic activity of the rural areas.

Since the set up was done in South which have similar weather condition to all other Southern Africa countries in terms of direct solar irradiation, it is therefore expected that government, bodies and aid groups will adopt the use of this system and use it for rural industrialization in the southern Africa.

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