CONCENTRATED PARABOLOID SOLAR COOKERS FOR QUANTITY COOKERY

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ABSTRACT

Several scientists have pointed out the relevance of alternate renewable sources of energy for combating 'Energy Crisis'. Among the renewable sources of energy, solar energy offers a practical solution for the energy problem which is clouding the prospects of mankind. Much of solar energy research in India is concentrated towards developing solar cookers for domestic use.

In this context we should concentrate our thoughts on utilizing solar energy for the cooking requirements at the large scale establishments for better future and energy security. For facilitating the quantity cookery in large establishments, CPSC are among the convenient, cost effective and operationally viable devices. In order to iron out all the queries such as the availability, cost-benefit ratio, the mode of installation, and the financial support given by the Government for installation, an explorative research study has been undertaken at Brahma Kumari Ashram at Mount Abu and Tirupathi Devasthanam at Andhra Pradesh, where the world's largest CPSCsystems have been installed. The findings of this study bring forth the importance of the CPSC for quantity cookery that could be one of the emerging ventures for meeting the energy demands of the country.

Key words: Energy crisis, Fossil fuels, Renewable energy, Solar energy, Concentrated Paraboloid Solar Cooker Quantity cookery

1. INTRODUCTION

Energy is regarded as a means to improve the quality of life and increase the productivity and employment, thereby dictating the regional, national and international policies and programmes. The energy needs of our country are increasing at a rapid rate, and indigenous energy resources are limited and may not be sufficient in the long run to sustain economic development. Enhancing the energy efficiency and minimizing the energy intensity of the economy should obviously constitute the basis of a timely energy strategy.

The energy crisis forces individuals, organization and governments to better utilize new and renewable sources of energy, which alone can meet the energy problem. Several strategies have been adopted to meet the situation such as energy conservation, use and application of renewable energy technologies. The appropriate proposition for the developing countries like India is to harness non-conventional renewable energies on a significant scale. Renewable energies are gaining importance against the conventional energy sources because conventional energy sources are embedded with several constraints like quantity and quality of reserve, logistics of transportation and environmental pollution. Among the renewable energy sources such as wind energy, solar energy, biomass and tidal energy, solar energy gains more prominence because other sources involve high technological development.

"Solar energy is the energy of the future, not just an alternative" was the message of the Second World conference on Solar Cookers. It further stated that this energy will soon achieve great economic importance, not only in third world countries which lack primary energy resources such as coal, gas and oil but also in the industrialized countries. Solar energy would be the best and ready alternative to conventional fuels if harnessed through solar cooking devices.

The rapid rise in population has resulted in constantly-increasing energy needs. In order to cope with the increasing needs of the people, a number of

infrastructural facilities are coming up such as educational institutions, restaurants, hospitals, roads, and transport facilities. Apart from these, migrations of people from rural and semi urban areas to towns and cities put more stress and evoke higher demand on available energy. Apart from these, the mushroom growth of educational institutions in the outskirts of the city with attached hostels and canteens also consume enormous quantities of fossil fuels for catering to the needs of the people.

Until recently thought has not been given to the enormous quantum of fossil fuels consumed for the quantity cookery in the hostels, canteens, temples, restaurants and such other similar places of mass cooking. If we look at the energy situation of our country, on one side is the shortage of fossil fuels, and on the other, the depletion of natural resources such as wood and other similar fuels is of major concern. It is high time to apply the viable renewable sources of energy on a wider scale to safeguard the future. In a number of applications, the solar cooking has been envisaged as one of the solutions to mitigate most of the population problems, though it has not been able to fully replace conventional fuels.

This prompted scientists to think about another form of solar cooker for larger groups of people. A CPSC (Scheffler) for cooking food, developed by scientists in Switzerland, was tested for its performance at Regional Test Centers (RTCs) for its suitability for Indian setup. The performance of this cooker was found to be highly satisfactory for cooking the complete meal for a community and conserving firewood, kerosene and liquefied petroleum gas. The technology finds great use in community kitchens in India. While solar cookers have not made their impact in individual homes in India, it is making waves in community kitchens. India has the distinction of having the world's two largest solar cooking systems. One is installed at Tirupati a popular place of pilgrimage in the State of Andhra Pradesh and the other is at Brahmakumari's Ashram at Mount Abu set with financial assistance from the German Government.

Realizing the potential of the concentrated paraboloid Scheffler type solar cooker in the area of quantity cooking and for promoting non-conventional energy sources the Ministry has come forward to give loans as well as 50 per cent subsidy to those who install this type of solar cookers. However, the incremental fuel equivalent that could be accrued through the installation of such solar cookers needs to be assessed. Unfortunately scientific, empirical experiments are meager in this direction (Ministry of Non-conventional Energy Sources, 2000).

In order to iron out all the queries that are associated with reference to CPSC this explorative research has been undertaken with the following objectives:

- Studying the design features technical data, mode of installation, cost benefit ratio and the usage of the world's largest CPSC.
- Assessing the resource recovery through the installation of CPSC in an educational institution and a textile industry.

2. METHODS AND MATERIALS

The solar activists have turned their attention in developing CPSC for quantity cookery to meet the challenges of the energy crisis. In order to propagate this idea the Ministry of Non Convention Energy sources offers fifty percent subsidy towards the installation cost. The Brahmakumari Ashram at Mount Abu Rajasthan. The Thirupathi Devasthanam at Andhra Pradesh, Avinashilingam University and Prem Durai Exports of Tamil Nadu have been chosen for this study. In order to gather the information regarding the design selection, installation details used and fuel savings, prospects and problems accrued by using this cooker the investigator made a detailed research using a structured schedule. A personal visit was made by the investigator to Brahma kumari's Ashram at Mount Abu, Rajasthan to draw genuine and authentic information about the Scheffler model of solar cooker for steam cooking, the first of its kind in the world. The schedule was mailed to the authorities of Thirupathi Devasthanam, to collect the relevant data.

Field level cooking experiments were conducted at Avinashilingam Deemed University, Coimbatore and Prem Durai Exports, Tirupur, where there cookers were erected and used for their canteen requirement.

3. FINDINGS

3.1 Concentrated Paraboloid Solar Cooker at Mount Abu, Rajasthan

The Brahmakumari's Vishwa Vidhyalaya is an International Spiritual Education Institution, recognized by the UNO under class 1 status operating with its headquarters at Mount Abu, Rajasthan. The world's first largest solar steam cooking system is installed at their headquarters, Shantivan Complex, Abu Road, where more than 10,000 people daily visit, stay and have meals. The Institution has received the recognition of being the first largest solar steam cooking system. Hence India is the forerunner in holding the title as having the world's largest steam cooking system.

History of Installation:
The Brahmakumari organization received the information of installing the CPSC from a non-governmental organization, St. Xavier's Technical Training Institute, Ankleshwar, Gujarat. About 20-25 Scheffler concentrators were manufactured and installed by the said institute with the help of the German scientists Mr. Wolfgang Scheffler and Ms. Christine Lipoid.

As the institute wanted to utilize the abundant solar energy they bought the assistance of Ms. HTT GmbH of Germany, Mr. Wolfgang Scheffler the inventor and Mr. Joachim Pilz of Brahmakumari. They also approached GATE, a funding agency of the German government and received funds under a pilot project scheme to install the first solar steam cooking system with paraboloid concentrators. In 1996-1997 the Brahmakumaris first installed a solar steam cooking system to cook food for 1000 persons. They were highly satisfied with its functioning and efficiency and they ventured into a much larger system in 1999 at Shantivan Complex, Mount Abu. Through the operation, meals were prepared twice a day for 10,000 persons. A larger version of the CPSC was erected.

Technical Details:
The solar steam cooking system installed at Shantivan uses parabolic concentrators of large surface areas that focus solar energy to receivers that convert water in the pipes to steam. This system consists of 84 improved versions of parabolic concentrators, each occupying an area of 9.2 m^2 reflective surface. Each concentrate is fitted into a rotating support which itself rests on a stand. Reflective surface area is made of special white glasses imported from Germany with special reflective efficiency close to 94 percent. The design is such that one parabola reflects from higher position to the front side of the receiver and other parabola from lower position to the reflected sunlight from 84 concentrators are focused onto 42 (shell type) receivers of 35cm in diameter each made out of boiler grade steel. Each concentrated gives a maximum output of energy equivalent to 4kW at 1000 watts/ m^2. A maximum of 3500 kg steam can be generated per day.

The mirrors are arranged in accurate East-West alignment. Tracking of the concentrators is controlled by a semi-automatic centralized system by means of 6 winches, DC motors, an electronic timer and a small photovoltaic system. Every day in the evening the system has to by manually reset to the morning position.

Working Principle:
The system works on a thermosyphon principle. 2 concentrators focusing from the front and rear sides of the receiver heat treated water in the receiver. The hot water immediately flows through an integrated 2.5cm diameter stainless steel pipe. As this cycle repeats, steam starts generating and collecting in the top half of the header pipe. Here the header pipe itself works as a steam reservoir.

As the whole system works on a thermosyphon principle there is no need for a separate or any circulation pump. This increases efficiency and there is no interruption from power cuts.

The system is modular in design. Each module consists of 14 parabolic concentrators focusing on 7 receivers. Steam collected in the 6 steam reservoirs from all 6 modules are interconnected to a common steam drum from where steam is carried by insulated pipes to the kitchen.

Feed Water and Backup System:
A water softening system is incorporated to treat water for steam generation to avoid formation of any scales in the header pipe and receivers. Steam traps and a pressure reducer station ensure good quality steam.

In case of lower solar radiation or extra demand, a high effluent diesel fueled backup system provides steam. The combination of solar cooker with this conventional backup system provide, round the clock, steam on demand.

System Safety:
The system is protected against excess pressure by safety valves and an automatic shutdown mechanism. The status of the whole system is monitored by temperature and pressure meters and a computerized 6 channel data logger.

Though the system is designed for 20,000 meals per day, so far it has provided steam to cook 33,500 meals during peak solar radiation periods, and it seems its maximum capability can still be stretched. In between the gatherings, the output and the sorting capability of the system was excellent so that even at 4:00 AM sufficient steam for tea preparation for 15,000 people was available. During such periods the backup system could be switched off completely.

Cost Analysis:
The capital outlay for the installation of Concentrated Paraboloid Solar Cookers in Mount Abu is shown in Table 1.

TABLE 1 : COST ANALYSIS

Components	Material	Total Cost (Rs.)	percentage
- Stand	Iron	8,40,000	14
-Rotating Support	Iron	21,00,000	35
- Insulation	LRB mattress	1,54,000	2.158
-Aluminum Sheet	Aluminum (28 mts x6)	1,00,000	1.6
- Header pipe	Mild steel (28 mts)	6,00,000	10
- Receiver	Mild steel (7 in no.)	35,000	0.58
-Stainless steel pipe	Stainless steel	55,200	0.92
- Reflectors	German glass (145 in No.)	21,00,000	35
Labour cost		15,000	0.25

A huge capital outlay of Rs.60 lakhs was spent for the installation of the CPSC at Mount Abu., Of this a large portion, 21 lakhs, was spent on the rotating support and reflectors because of the high cost of the quality iron and the imported reflectors. A lesser amount, about Rs.15, 000, was spent towards the labor charges, since major work had been achieved through involvement of their own organization members and trained technicians.

Table 2 indicates the quantum of fuel saved through the use of the CPSC.

TABLE 2: QUANTUM OF FUEL SAVED

Monthly and Year	No. of Days System Operated	No. of Hours System Operated	Quantum of Fuel Saved Diesel (lts)
September 2002	30	240	8436
October 2002	31	224	6722
November 2002	30	268	7856
December 2002	31	209	6543
January 2003	31	254	7588
February 2003	28	192	5846
March 2003	31	278	8364
April 2003	30	158	4620
May 2003	31	132	3933
June 2003	30	153	4835

The quantum of fuel saved is directly proportional to the number of hours of usage of the system. Thus a total of 64,743 litres of diesel was saved through this installation of CPSC in one year. However in certain months, we could observe that even though the number of hours the system operated was long, the quantum of fuel saved was less. This can be attributed to the type of dishes prepared and the vegetables used for preparing meals. If one institution could save so much of fuel through the installation it is easy to infer how much fossil fuel can be conserved in a year if all such institutions adopt this technology.

Time Taken to Cook Selected Food Items:

All kinds of root vegetables, leafy vegetables and other vegetables were cooked through the steam cooking and served to the people (Table 3).

TABLE 3 TIME TAKEN TO COOK SELECTED FOOD ITEMS

Food items	Quantity	Time (minutes)
Rice (Kg)	700	12
Dhal (litres)	120	30
Vegetables (kg)	890	25
Kadhi (litres)	95	30
Tea (litres)	900	25
Milk (litres)	200	25
Coffee (litres)	300	25

The investigator observed the feasibility and effectiveness of the CPSC in preparing meals for more than 10,000 persons per day at Mount Abu. Due to the tapping of concentrated rays of the system, the steam generation was hastened and thus the preparation time was less. Hence the authorities could serve hot meals to any number of devotees assembled for spiritual discourses.

3.2 Concentrated Paraboloid Solar Cookers at Tirupathi

The Tirumala Tirupathi Devasthanam at Tirumala in Andhra Pradesh installed the world's largest solar steam cooking system in September 2002. This system was inaugurated by Honourable Chief Minister of Andhra Pradesh 'Chandra Babu Naidu' on the terrace of Annadanam complex of Tirumalai Tirupathi Devasthanam. One of a total of six systems sanctioned by Ministry of Non-Conventional Energy Sources to date, the world's largest system for cooking application was installed at Tirupathi by M/s. Gadhia Solar Energy Systems, Valsad Gujarat, India.

The solar steam generating system comprises of automatically traced paraboloid concentrators, a steam header assembled with receivers, steam pipelines, feed water piping, steel structures and civil works, instrumentation like pressure gauges and temperature indicators, steam separators, steam traps, etc. It is generally hooked up with a conventional steam generating system boiler working on diesel so as make the system reliable under all climate conditions. The system has a capacity to prepare food for 15000 persons twice a day. The system employs automatic tracking

solar dish concentrators, which convert water into high pressure steam. The steam thus generated is being used for cooking purpose in the kitchen of the Tirumala Tirupathi Devasthanam. The system has been designed to generate over 4000 kg of steam per day at 180^0C and 10 kg/Cm^2 which is sufficient to cook two meals for around 15,000 persons. It is modular, consisting of 106 automatically tracked parabolic concentrators arranged in series and parallel combinations, each of 9.2 m^2 reflector area. Each unit of concentrator is connected to a central steam pipe line going to the kitchen. The system is made of indigenous components and the reflectors of acrylic mirrors having reflectivity over 75 per cent. The system is functioning satisfactorily since 1994 and is expected to save around 1,18,000 litres of diesel per year.

Cost Benefit Ratio:

Total cost spent on the installation of the system
= Rs. 109.00 lakhs
Total fuel saved per year
= 1,18000 litres of diesel
Cost of the fuel (Diesel) per litre = Rs. 24/-
Total cost of the fuel per year
= Rs. 24 x 1,18000 litres
= Rs. 28,32000/-
Cost of the maintenance = Rs. 15,000/ year
Net saving = Rs. 28,17000/-
Pay back period = approximately 4 years

The payback period of the system after availing the financial support from the Ministry of Non Conventional Energy Sources may vary from 3 to 5 years depending on the size of the system.

3.3 Resource Recovery – A Case Study of the Educational Institution/Industry

The resource recovery in Avinashilingam Deemed University and Textile Industry through the use of CPSC was calculated by recording quantum of fuel saved per month and through assessing the fuel equivalent saved and analyzing the ratio of cost-benefit. The data obtained indicates that on an average 1420 kg of firewood and 87 litres of kerosene was saved after installation of the cooker in the Textile Industry. A sum of Rs. 25.560 spent towards firewood and Rs. 870 spent towards kerosene were saved in Textile Industry. Due to installation of CPSC in the University on an average of 31.25 of liquefied petroleum gas could be saved per month.

The fossil fuel equivalent that could be saved through the use of renewable energy has been computed by Mr. Myles. Table 4 gives the fuel equivalent saved through the use of CPSC in the two institutions.

TABLE 4: FUEL EQUIVALENT SAVED

Type of fuel	Fuel equivalent saved / month	
	University	Textile Industry
LPG (kg)	31.25	475.5
Butane (kg)	26.88	408.9
Kerosene (lts)	38.75	86.70
Gasoline (lts)	50.00	760.8
Firewood (kg)	216.9	3300
Charcoal (kg)	87.50	1331
Cow dung (kg)	768.75	11,697
Electricity (kWh)	293.75	4469

Thus the erection of CPSC bringsforth considerable savings in fossil fuel.

4. RECOMMENDATIONS

The findings of the study indicate that through the use of nature's gift of solar energy for quantity cookery, a large quantum of fossil fuel and huge sum of money could be recovered within a period of 5 years. Thus these recommendations are framed:

- Universities, colleges, hospitals, hostels, hotels, canteens, and temples must come forward to install the CPSC in order to save fossil fuels.
- Mass communication media such as print, audiovisuals, and film shows must give wider publicity to the solar cookers and take this concept to the people.
- Awareness should be given to the personnel about the CPSC by explaining its multiple benefits.
- The productive youth in the rural areas should be channeled towards setting up local industries for manufacturing the solar cooker units, thus avoiding transportation cost.

5. CONCLUSION

In conclusion, CPSC fulfill the criteria for practical applications: being technically feasible, eco-friendly, customer oriented, and locally available, and saving fossil fuels and providing more employment opportunities. If such technology is adopted on a large scale, the energy crisis can be solved in our country, a decisive step towards becoming a developed nation.

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