Technomics of Renewable Energy Based Hybrid Community Cooking System

Vishnu Agarwal, Sudhir Jain

Abstract: ***International Energy Agency (IEA) carried out an energy survey of 5 top most nations between the years 2012-2017. In this survey IEA studied the world energy statistics and stated that 18% of the total energy consumption at home accounts for heating water for various purposes. The increasing gap between energy demand and its availability has envisaged the need for search of alternative sources of energy. Renewable energy sources can play a vital role in fulfilling the energy requirements of the people throughout the world. The majority of thermal energy and electric power is generated through non-renewable sources of energy like coal, gas and nuclear power, which are costly as well as degrade earth's atmosphere by greenhouse gas (GHG) emissions. Renewable energy sources derive their energy from the existing natural energy such as sun, wind, flowing water, biological processes, and geothermal heat which are almost free of charge. And using alternative renewable sources for generation of energy will save our earth and reduce the emission of greenhouse gases. Due to the increasing demand of energy, at times an individual renewable energy based system cannot fulfill the demand of required energy within the required time frame. If one system is insufficient to utilize this ample amount of radiations efficiently, one or more efficient systems can be connected in series for a single application. In other words hybrid systems can extract more energy from the renewable source compared to single system. In present work, a hybrid cooking system was designed by integrating solar water heater (SWH), heat pipe (HP), biogas and wood based boiler (auxiliary system) to decrease dependency on conventional energy sources like coal, LPG etc. At present, almost all community cooking systems use LPG as the prime energy source for cooking. This research work focused on transferring LPG based cooking system to renewable energy based hybrid cooking system. Heat required for boiling rice, pulses and green vegetables per day was calculated for 400 persons in community mess. As per the heat requirement a hybrid cooking system was designed and evaluated for its performance. An attempt was also made to reduce wood consumption in the boiler of hybrid cooking systems and to make the system efficient enough so that it can replace the conventional fuel (LPG) for cooking.***

Keywords: Hybrid cooking system, solar water heater and heat pipe set, biogas

I. INTRODUCTION

Energy is a contributing factor in the economic and social development of any country. Dependency on a certain type of energy is a huge impediment in the growth of any country. Sun is a huge and promising source of renewable energy. If optimum utilization of the solar radiations that strike on the earth's surface is done, the dependency on non-conventional sources of energy can be reduced to a large extent. Community cooking has gained much popularity these days because of its growing use in hospitals, colleges and industries etc. IEA studied the world energy statistics and stated that 18% of the total energy consumption at home accounts for heating water for various purposes and 7% of the total daily energy requirement was used for cooking food. Development of infrastructural facilities and systems that can make efficient and optimum utilization of solar radiations is the need of the hour. For this purpose, highly efficient solar radiation absorbing devices like solar water heater, heat pipes, concentrating solar water heater tower, parabolic water heater etc are required.

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Vishnu Agarwal, Department of Renewable energy engineering , college of technology and engineering , Udaipur, India

Dr Sudhir Jain , Department of Renewable energy engineering , college of technology and engineering , Udaipur, India

II. BACKGROUND

Selwente et al. [4] in their research based project utilized biogas as an alternative source of fuel, for water heating purpose in gas geyser instead of LPG.

Sabiha [3] reported the collector efficiency of different types of evacuated collectors and also focused on their performance, based on different working fluids as well. They also concluded that evacuated tube collectors were very efficient to be used at higher operating temperature.

Sharma [5] in their studies revealed that the evacuated tube collector consisted of many separate inner tubes filled with fluid and were covered by outer tubes. They concluded that the solar evacuated tubes showed more efficiency in converting sunlight into heat than the flat plate collectors.

Gawali [1] in their studies suggested a system which comprised of thermal energy storage tank in which solar thermal energy was stored in the form of sensible heat by using different types of oils. This arrangement helped to cook the food even during deficiency of solar radiations. The project dealt with performance analysis of system with different oils.

Venden [7] in their paper discussed design calculations involved in the development of an energy efficient solar thermal system for generating steam at atmospheric pressure. They also included collector area calculation and number of evacuated tubes required. They also reported comparison of solar thermal system's performance with the conventionally used steam boilers in terms of fuel usage and carbon emissions.

Sharma [6] in their paper aimed to design horizontal fire tube two pass boiler for the commercial cooking of Indian food. The steam generation of this boiler was about 300 kg per hour. They concluded that this boiler could be used for commercial cooking of the Indian food in restaurants, food industries, dairies, etc.

Kariuki [2] in their work suggested that solar energy producers can increase their energy production by creating solar thermal hybrids and by using concentrating solar thermal hybrids in combination with other energy sources like coal, biomass, oil, gas, geothermal and others.

III. IMPORTANCE OF PROPOSED WORK

The purpose of this research work was to develop a hybrid cooking system that makes maximum utilization of renewable energy sources and reduces emissions of harmful gases to a minimum, thus protecting human health and environment. In this system, pressure cooking with high temperatures was used. By these methods, the cooking process took quarter of the time as compared to ordinary boiling. Present research paper focused on the integration of renewable energy systems to form a hybrid system for community cooking. Hybrid technology can contribute to significant reduction of fossil fuel consumption and reduce carbon emission suggested by Zhang et al. [8].

IV. EXPERIMENTAL DETAIL

A. *Techno-economic analysis of hybrid cooking system based on solar water heater, biogas, heat pipe and firewood*

Figure 1 shows the complete integration of heat converting devices like solar water heater, heat pipe system, biogas burner and wood based boiler. It is an efficient system for cooking in terms of consumption of wood and also serves as an alternate to conventional fuel (LPG) used for cooking. Water after being heated in solar water heater and heat pipe entered into boiler where it was further heated through biogas and wood. Due to this heating the temperature of water was raised up to 130°C at 2.7 bar pressure. Biogas was supplied constantly per hour to boiler for continuous addition of heat to the water in the boiler. Chemical energy of wood and biogas was converted in to heat energy inside the boiler and thus raised temperature of water from T_6 °C (water temperature at inlet of boiler) to T_7 °C (water temperature at outlet of boiler).

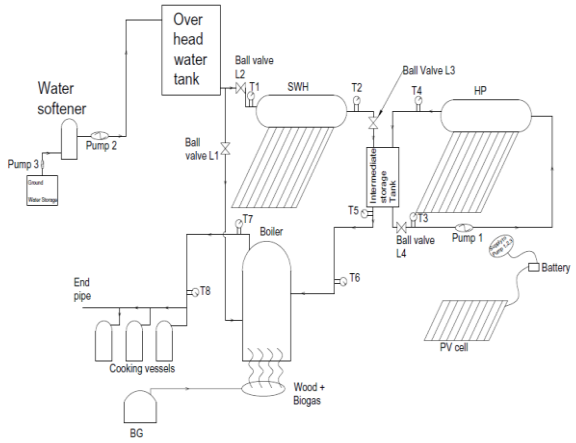

Figure: 1 Hybrid cooking system based on solar water heater, heat pipe, biogas and firewood.

V. RESULTS AND DISCUSSIONS

Table: 1 Heat gained by water through different devices /sources in the hybrid system

Time (hours)	Heat gained by water (kJ/h)			
	Solar water heater	Heat pipe	Biogas	Firewood
8:00	2,090	3,762	6,270	31,350
9:00	2,926	5,434	6,270	33,022
10:00	4,807	5,434	6,270	33,022
11:00	8,360	5,434	6,270	28,424
12:00	9,614	11,704	6,270	16,720
13:00	10,032	11,704	6,270	16,720
14:00	10,032	17,974	6,270	10,032
15:00	9,196	13,794	6,270	13,794
16:00	3,762	8,778	6,270	20,482

Table 1 indicates the value of heat gained by boiler feed water through different renewable energy device/sources like solar water heater, heat pipe, biogas and firewood. In this hybrid system average heat gained by water through solar water heater was 7MJ/h, average heat gained by water through heat pipes was 10MJ/h and average heat gained by water through biogas was 6.5MJ/h. Remaining heat was supplied by the burning of wood.

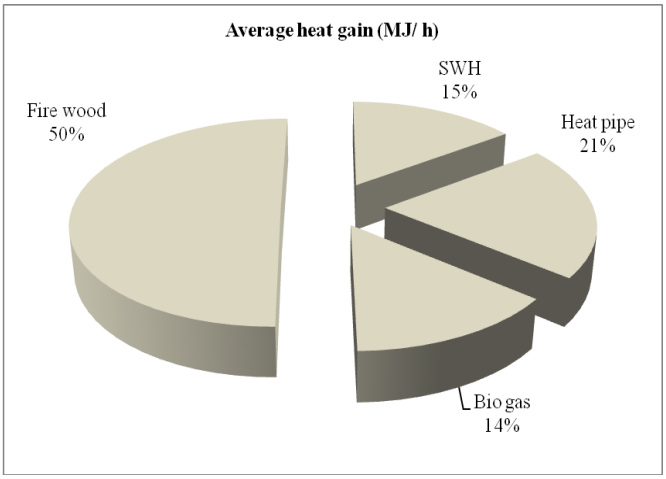

Figure 2 Heat gain by water through individual devices/sources of hybrid cooking system

Figure 2 is pictorial view of average heat gained by water through different renewable energy devices/resources. In this hybrid cooking system solar water heater contributed to 15% of the total heat supplied to boiler feed water, likewise heat pipes contributed to 21% and contribution of biogas was 14% of the total heat supplied to the boiler feed water. Remaining heat was supplied by burning of firewood in the boiler for heating up the boiler feed water to 130ºC and 2.7 bar pressure for steam cooking.

VI. CONCLUSIONS

This research work focused on heat energy gained by water through the different renewable energy based devices in the hybrid system. This system served the purpose of replacing LPG (conventional fuel) which was earlier used for boiling food articles. Heat energy required was calculated for boiling food articles such as rice, pulses and green vegetables for 400 persons per day, and was found of the order of 322MJ/day. In the analysis of hybrid cooking system, performance of each component was carefully evaluated in detail. The detail performance evaluation based study unveiled many factors and parameters that had remarkable impact on the application of hybrid community cooking system. Through the following facts success of this research was established-

Before introducing the hybrid community cooking system-

- The consumption of LPG was about 0.75 cylinders per day in boiling of the aforesaid food articles. Cost of LPG per cylinder (commercial) is Rs 1,165 and therefore the cost of boiling the food articles was Rs 875 per day.

After introduction of the hybrid cooking system-

- In hybrid cooking system wood consumption was 23 kg per day, therefore the running cost per day for this hybrid cooking system was noted down as Rs 230 (wood @ Rs10 per kg). The running cost per day was very low as compared to LPG based cooking system. (approximately 1/3rd of LPG based cooking system)
- Slurry produced at the outlet of biogas plant was used as organic manure for plants. This slurry was further sold and the returns yielded, contributed in payback period.
- The capital cost of the system was Rs 4,46,000. This hybrid cooking system had a payback period of 26 months and 18 days
- Benefit cost ratio calculated for this system was 1.35.
- Internal rate of return of hybrid system was 37%.

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AUTHORS PROFILE

Vishnu Agarwal, M.E (Thermal Engineering), Ph.D. Research scholar, Department of Renewable Energy Engineering, College of Technology and Engineering, Udaipur.

Dr. Sudhir Jain, Professor and Head, Department of Renewable **Energy Engineering, College of Technology and Engineering, Udaipur. He owes a rich experience of 33 years. His expertise lies in the field renewable energy.**