

Planning of solar steam cooking system at SMVDU[†]

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Abstract: This paper presents the planning of the potential and feasibility of a complete Solar Solution for the mess at the Shri Mata Vaishno Devi University (SMVDU) campus. Since there is ample space near the mess, solar steam generating plants are proposed on the mess to reduce Liquefied Petroleum Gas (LPG) consumption substantially. Forty concentrators (sixteen square meters each) are proposed to be installed. The project's life is proposed to be twenty-five years with a capital cost of \$19.02 Thousand and additional operation and maintenance costs. The financial analysis shows that the total savings from the project are \$172.82 Thousand with a Cost-benefit Ratio of 6.40. The project's break even is approximated to be attained by the fortieth month of operation. Beyond the financial benefit, the project is proposed to have multiple other benefits to the institution. The benefits are that the use of fossil fuels (LPG) for cooking can be avoided by the installation of a thermal cooking system, it shall provide a better sustainability score in various rankings done worldwide for the university, the cost of tender of mess for future can be reduced drastically, the project will be brought up as a project that shall be displayed at every level in the Union Territory so that we shall promote the development of renewable energy uses.

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1. Introduction

India is in the sunlit region of the earth. The majority part of India daily receives 4–7 kWh/m² of solar radiation with 250–300 sunny days a year. Solar energy, felt by us as light and heat, can be used in two ways: the thermal way uses the heat for heating water, drying, cooking, power generation, and many other applications, whereas the second path, the photovoltaic way transforms the light in solar energy into electrical energy, which can be used for many purposes such as pumping, lighting, power supply and communications. Sun's energy has many benefits, making it an eye-catching and sustainable choice. These benefits include worldwide allocation, no-pollution nature and inexhaustible supply. India's average solar radiation intensity is 200 M W/km²[1].

Shri Mata Vaishno Devi University (SMVDU) is among the important institutes in higher education in engineering, management, arts, science and other areas. Since its founding, the university has played a major role in providing the country with educated personnel and know-how and pursuing research. SMVDU is located in Katra, a city in district Reasi in Jammu and Kashmir, India. The university is situated in the beautiful scenic view of the foothills of the Trikuta Mountains, where the holy shrine of Vaishno Devi is located. The university has an elevation of 875 metres from mean sea level.

The paper aims to show the feasibility and viability of solar cookers at the Shri Mata Vaishno Devi University Katra campus. The project includes installing solar steam cookers for all the campus messes to provide an alternative to the LPG currently used for cooking in all the messes. This little initiative would help our university reduce its carbon footprint and expenditure by reducing cooking costs by a big portion. It will be a big leap for our university toward a better future, and by doing so, we will also be pioneering the use of such technology in the union territory of Jammu and Kashmir.

2. Methods

When proposed, the project requires a basic analysis and action plan, which shall be defined under headings of energy consumption calculations, proposed system, location for installation and financial analysis.

2.1. Energy Consumption

The mess SMVDU uses commercial Liquefied Petroleum Gas (LPG) for all activities of cooking food. Data was collected from the mess of SMVDU about the consumption of LPG cylinders per day and students dining in the mess. The mess uses 19kg commercial cylinders. Here 19kg is the content of LPG in the cylinder. The details of occupants in various hostels and the daily consumption of 19kg commercial LPG cylinders are described in Table 1.

Table 1. Table showing daily consumption of LPG cylinders in various mess of SMVDU.

| Mess Name | Occupants | LPG cylinder consumption | Total cost of LPG consumption |
|---------------------------------------|-----------|--------------------------|-------------------------------|
| Vaishnavi | 220 | 2 | \$51.28 |
| Shivalik | 426 | 3 | \$76.92 |
| Vindhyachal | 290 | 3 | \$76.92 |
| Central | 300 | 2 | \$51.28 |
| Basohli | 560 | 3 | \$76.92 |
| Nilgiri | 311 | 2 | \$51.28 |
| Total cost of LPG consumption per day | | | \$384.6 |

A commercial LPG cylinder cost was \$25.64 in Jammu, Jammu and Kashmir, India, as of July 2022.

2.2. Proposed System- Solar Steam Cooking System

The Solar Steam Cooking system was developed to give an eco-friendly option to the rising energy requirements of community kitchens in India. Till March 2022, the Government was also giving several subsidies to enhance and promote the use of such systems[2]. The solar steam cooking system is extremely useful for the mess of schools, institutions, ashrams, hospitals, and armed and police forces. The technology deploys the concept of concentrating sun rays on a smaller area to achieve high-range temperatures, allowing faster cooking. This section discusses the technical details and the expected benefits of installing a solar steam generation system in Shri Mata Vaishno Devi University's messes. The principle behind the solar steam cooking system is shown in Figure 1.

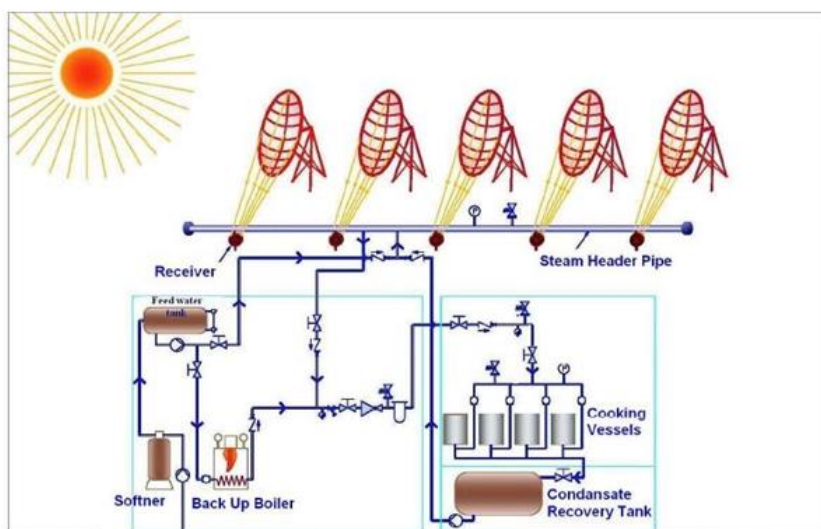


Figure 1: Basic principle of the solar steam cooking system[3]

The cooker concentrates sunlight in a smaller area using concentrators of parabolic shapes to change the water to steam of superheated nature. These concentrators are set up in a set of two (facing South & North) to combine into an array or a series. The set of two concentrators focuses heat on the receivers from both sides. Because of concentrated heat, these receivers contain water converted into superheated steam with pressure in the 12 to 16 bars range and accumulates in the Steam Header, as shown in Figure 1. The high pressure of steam is dropped to a safe approved limit of 1 to 1.2 bar in pressure reducing station. This reduced pressure steam is then transported to the adequate capacity steam cooking vessel. Normally rice is prepared within 8 - 9 min. Dal is cooked within 9 to 12 min., Potato/vegetables are cooked within 4 to 6 m. The variation in quantity does not affect the time required to cook. This steam can prepare Idly, Dhokla, Paratha, Tea, Coffee and boiling water[4].

In addition, the payback they give on the environment, the proposed systems is advantageous in many other ways as well:

- It is a non-direct system with steam generated outside the cooking area and brought into the kitchen via piping; hence, the existing kitchen structure can be used with minimum modifications.
- The cooking is done in the existing kitchen, with only the apparatus outside, so standing in the sun is unnecessary.
- Align the dish in the morning, and the system automatically tracks the sun
- The higher ranges of temperatures produced by this technology result in faster cooking than other solar cooking technologies.
- Easy to move and clean
- Durable and safe operation.
- Useful time is from one hour after sunrise to one hour before sunset
- Useful for urban, rural, and tribal areas in community kitchens, hostels, hotels, and remote camps.

The proposed cooking system has components as stated: a set of two parabolic focusing dishes, the receiver, the steam header pipe, tracking, timer, wire rope, gearbox and pulley for daily east-west tracking, seasonal adjustment devices, steam cooking vessels, and pressurized reducing valve station. Table 2 shows the proposed number and size of concentrators for various mess of SMVDU University.

Table 2: Proposed number and size of concentrators for various mess of SMVDU

| No. of Persons | Total Parabolas/ Dish area | ShadowFree Space | Tentative Cost of Solar Concentrator |
|--|--|---------------------|---|
| Up to 350 (Vaishnavi, Vidyachal, Nilgiri & Central Mess) | 6 X 16 m ² = 96m ² | 210 m ² | \$25587.74 |
| 351 to 550 (Shivalik & Basohli Mess) | 8 X 16 m ² = 128 m ² | 280 m ² | \$35335.46 |

2.3. Location for Installation

While surveying the area for installation, the following requirements are to be satisfied:

- There should be no shadow causing structures and erections in the vicinity of the system.
- An ample ground area or roof area getting direct sunlight must be available. In the mess of SMVDU, the roofs are either slanting or occupied by solar panels.
- Hence the system must face south to the maximum possible extent.
- The flat area on ground was identified.
- Since the university is having a good green landscape, the shadow due to trees is taken into consideration. [5].

Considering the points mentioned above, a survey was conducted of the possible empty areas near the messes that could be used to install solar concentrators to generate steam to meet the required steam for cooking.

2.4. Financial Analysis

19kg LPG cylinders are used in a mess for preparing food. Taking the pessimistic analysis, it was assumed that the solar steam cooking system should save half of the LPG cylinders under use; the net LPG savings per day per bhawan mess are as shown in Table 3:

Table 3: Cost saving and total cost of solar concentrator for various mess

| Mess | Number of Cylinders used | Number of cylinders saved | Cost Saved per day | Tentative Cost of Solar Concentrator |
|--------------|-----------------------------|------------------------------|-----------------------|---|
| Vaishnavi | 2 | 1 | \$25.22 | \$25200.00 |
| Shivalik | 3 | 1.5 | \$37.84 | \$34800.00 |
| Vindhyanchal | 3 | 1.5 | \$37.84 | \$25200.00 |
| Central | 2 | 1 | \$25.22 | \$25200.00 |
| Basohli | 3 | 1.5 | \$37.84 | \$34800.00 |
| Nilgiri | 2 | 1 | \$25.22 | \$25200.00 |

The cost of commercial LPG cylinders was \$25.64 in Jammu, Jammu and Kashmir, India, as of July 2022.

2.4.1. Break-Even Analysis:

| | | |
|--|---|------------|
| The total cost saved from all the mess per day | = | \$189.18 |
| The total cost saved per month | = | \$5675.40 |
| Capital Cost of Project | = | \$17040.00 |
| Setup cost/ civil works to be done (at10 % of capital) | = | \$1704.00 |
| Total tentative cost of project | = | \$18744.00 |
| The interest rate applicable on capital cost | = | 9.5% |
| Monthly maintenance cost (at 1%of capital cost annually) | = | \$156.20 |

The break-even is achieved on the 40th month of the installation, and the break-even analysis for the system is shown in Figure 2.

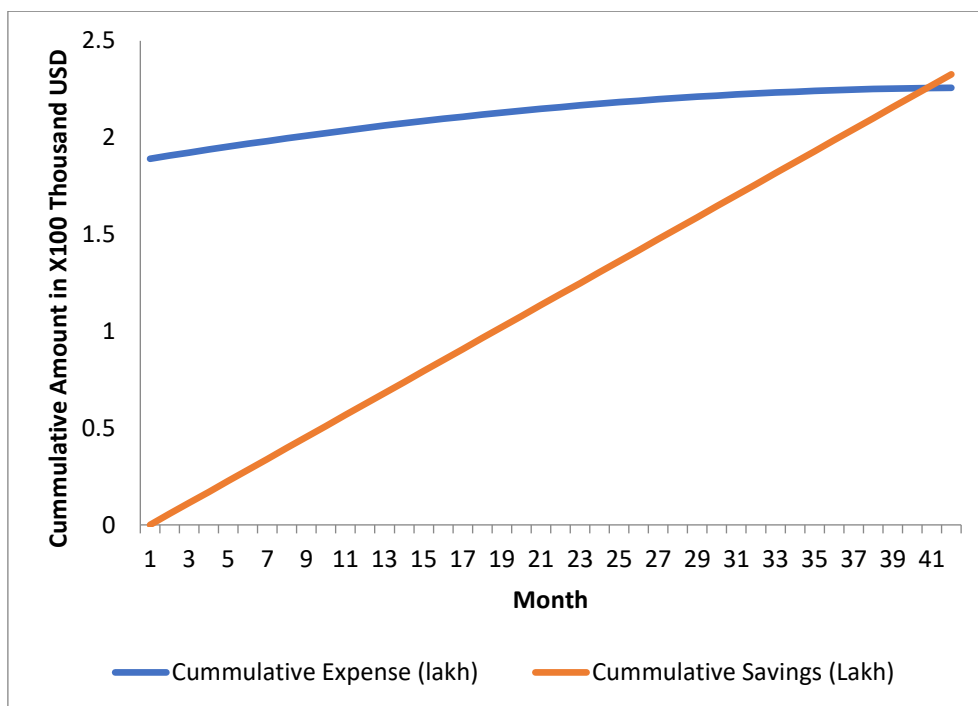


Figure 2: Break-Even Analysis of the solar steam cooking system for SMVDU Mess

3. Result and Discussions

The solar steam cooking system is a realizable option for large-scale cooking. Though this system completely depends on the availability of solar irradiance, this has been considered considering 300 days of operation in a year. The system shall start working when sunlight is available. It might be possible that the system is inoperable during breakfast or dinner time. However, since food like boiling potatoes and cooking cereals and rice can be done whenever the system is available, most tasks can be managed by a good shifting of cooking schedules. If shifting the cooking schedule is not possible for specific reasons, LPG cylinders are always available at the disposal of the mess. Nevertheless, from the perspective of moving towards a greener future, independence from conventional fossil fuels is necessary, and the solar steam cooking system for SMVDU mess is a viable and doable option.

Further, from the perspective of the financial analysis of the project, we note that the project's life is 25 years, and the cost of buying and setting up a project is \$187440.00. This cost shall accumulate interest of \$31800.00 at 9.5% over 25 years. Further, the 1% operation and maintenance cost for 25 years shall accumulate to \$46860.00. Hence the total cost university shall pay for 25 years shall be \$266100.00.

The university shall save the money from the LPG cylinders not used over 25 years, which would give an accumulated savings of \$1702620.00 over its period of operation. This brings out the project's benefit-to-cost ratio (BCR) to 6.40. This BCR is an excellent result, and it is recommended that the university must opt for solar steam cooking systems.

It is assumed that only half of the cylinders are saved daily, but the system shall save much more than the projected savings. It might save up to 75-80% based on the usage and dishes to be prepared in the mess. Also, the increase in the cost of LPG cylinders has not been considered. This shows that the approach has been pessimistic while planning the solar steam cooking system. This is done to counterbalance the vacation period when not all mess is preparing food.

4. Conclusion

The system is proposed to save to 7.5 cylinders per day. Saving, as stated, signifies that the solar steam cooking system can save a large amount of LPG cylinders. If all the community mess around India deploys the stated system, it shall save a great amount of LPG. The saved LPG can be provided to homes that cannot get the LPG for cooking. Further, it shall reduce the dependence on fossil fuels. Since an ample amount of LPG shall be available, the price of LPG can also go down.

Although this system requires some maintenance, an annual maintenance contract can easily take care of it. With its tracking feature, this system can use much solar energy and thus is highly efficient. Although the mirrors' efficiency and receivers degrade with time, they can be remedied with a proper maintenance contract. Overall, with good savings possible, the system is highly feasible. It will be financially viable and provide a better sustainability score in various rankings done worldwide; the cost of tender of mess for the future can be reduced drastically. The project has a cost-benefit ratio of 6.4, meaning there will be six times the university expenses and this project can be brought up and displayed at every level as a big step toward the development of renewable energy.

5. Acknowledgement

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References

1. <https://www.iitr.ac.in/departments/AH/uploads/File/Internship/Solarification/Introduction.pdf> (Accessed on 12 June 2022)
2. http://ahec.org.in/internship/solarification/solar_steam_cooking_system.pdf(Accessed on 15 June 2022)
3. Tobeishat, Reema. (2018). Sustainable Built Environment (SDBE 504) Final Report Atmospheric Pollution Figures 'Household Air Pollution (Traditional Cook Stove) in India'.
4. <https://www.iitr.ac.in/departments/AH/uploads/File/Internship/Solarification/technology.pdf> (Accessed on 12 June 2022)
5. <https://www.iitr.ac.in/departments/AH/uploads/File/Internship/Solarification/Strategy.pdf> (Accessed on 12 June 2022)