Potential of Solar Energy in Food Process Heat Applications

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Abstract- *The food processing industry in India plays an important role in the country's economic development as a result of the vital linkages and synergies that it promotes between the industrial and the agricultural sector, the two most important sectors in the Indian economy. The Indian food processing industry has shown signs of potential for higher growth and profitability in the coming years. The global demand for energy is currently growing beyond the limits of installable generation capacity. To meet future energy demands efficiently, energy security and reliability must be improved and alternative energy sources must be investigated aggressively. An effective energy solution should be able to address long-term issues by utilizing alternative and renewable energy sources.*

I. INTRODUCTION

The food processing industry in India plays an important role in the country's economic development as a result of the vital linkages and synergies that it promotes between the industrial and the agricultural sector, the two most important sectors in the Indian economy. Presently, the world's second largest producer of food products second only to China, India has the potential of being the largest producer, there of surpassing China, given that India's food and agricultural sector contributes are around 26% of the country's annual GDP. The Indian food processing industry has shown signs of potential for higher growth and profitability in the coming years. According to an estimate, there will be a phenomenal deployment of capital, human resources, modern technology, and finance of over INR 140 billion in this industry in the next decade.

India is among the fastest growing dairy nations in the world. With increase in population, and enhancement in lifestyle of people, demand for the dairy and food products is increasing day by day. With increase in product demand, energy demand as well as well commercial energy consumption has been increasing at ~6 % during last two decades; India ranking 5th in the world. 49% of total energy is consumed in Industry. Import dependency at present, is 9 % for coal, 77 % for crude oil and petroleum product and 31 % for natural gas. (Desai and Zala, 2010) Today, major electricity generation takes place at central power stations which utilize coal, oil, water, gas or fossil nuclear materials as primary fuel sources. They are not renewable-limited-like every one earth has limitation to regenerate, less efficient (65-75%) and expensive. Renewable energy is that energy which comes from the natural energy flows on earth. Unlike conventional forms of energy, renewable energy will not get exhausted.

Renewable energy is also termed as "green energy", "clean energy", "sustainable energy" and "alternative energy" (Date, 2010). For production of energy we are using Petroleum (39%), Natural gas (23%), Coal (23%), Nuclear (8%), Renewable energy sources (8%) in different proportion. Different types of renewable energy are: Solar energy (1%); Wind energy (0.5%); Biomass energy (43%); Hydropower (50%); Geothermal (5%); The Sun is a reliable, non-polluting and inexhaustible source of energy, with overcome of all above shortfalls; it will never get exhausted ever. India lies in the sunny regions of the world. As concern to Indian scenario, we receive 5 to 7 kWh/m2 of solar energy for 300 to 330 days in a year, which is sufficient to set up 20 MW solar power plants per square kilo meter land area (BEE, 2010).

Solar energy is available abundantly in the country and can be used to good benefit in sweetmeat production. Ordinarily, insolation of around 600 W/m2 is not considered to be sufficient for attaining the required temperatures. With the help of concentrators, higher temperatures can be achieved and solar heating systems with concentrators can be effectively used in this particular industry. We can use solar energy in food operation like cooling, heating, lighting, pumping, drying, electrifying, steam generation, etc,.

The global demand for energy is currently growing beyond the limits of installable generation capacity. To meet future energy demands efficiently, energy security and reliability must be improved and alternative energy sources must be investigated aggressively. An effective energy solution should be able to address long-term issues by utilizing alternative and renewable energy sources. From the many available renewable sources of energy, solar energy is clearly a promising option as it is extensively available.The Sun is a sphere of intensely hot gaseous matter with a diameter of 1.39×109 m (Kreith and Kreider, 1978; Mani, 1980; Devabhaktuni et al., 2013). CO_2 induced global warming has become a pressing issue, and needs to be tackled. Efficient utilization of renewable energy resources, especially solar energy, is increasingly being considered as a promising solution to global warming and a means of achieving a sustainable development for human beings (Tian and Zhao, 2013). Achieving solutions to environmental problems that humanity faces today requires long-term potential actions for sustainable development. In this respect, renewable energy resources appear to be one of the most efficient and effective solutions (Bhattacharya and Jana, 2009, Rao and Parulekar, 2012).

II. SOLAR THERMAL ENERGY

Solar thermal systems are non-polluting and offer significant protection of the environment. The reduction of greenhouse gasses pollution is the main advantage of utilising solar energy. Therefore, solar thermal systems should be employed whenever possible in order to achieve a sustainable future (Kalogirou, 2004). The India Energy Portal estimates that around 12.5% of India’s land mass, or 413,000 km2, could be used for harnessing solar energy. This area could be further increased by the use of building-integrated PV. Though large-scale solar thermal collectors have not yet been deployed in India, one study has estimated that this technology alone could generate 11,000 TWh per year for India (Arora et al., 2010).

Solar collectors and thermal energy storage components are the two kernel subsystems in solar thermal applications. Solar collectors need to have good opticalperformance (absorbing as much heat as possible), whilst the thermal storage subsystems require high thermal storage density (small volume and low construction cost), excellent heat transfer rate (absorb and release heat at the required speed) and good term durability (Winter, 1991).

III. SOLAR COLLECTORS

Solar energy collectors are special kind of heat exchangers that transform solar radiation energy to internal energy of the transport medium. The major component of any solar system is the solar collector. This is a device which absorbs the incoming solar radiation, converts it into heat, and transfers this heat to a fluid (usually air, water, or oil) flowing through the collector. The solar energy thus collected is carried from the circulating fluid either directly to the hot water or space conditioning equipment or to a thermal energy storage tank from which heat can be drawn for use at night and/or cloudy days. There are basically two types of solar collectors: Non-concentrating or flat plate type and concentrating (focusing) type solar collector (Kalogirou, 2004; Rai, 2011).

The solar energy collector, with its associate absorber, is the essential component of any system for the conversion of solar radiation energy into more usable form (e.g. heat and electricity). In the non-concentration type the collector area (i.e. area that intercept solar radiation) is the same as the absorber area (i.e. the area absorbing the radiation). On the other hand the concentrating collectors, the area intercepting the solar radiation is greater, sometimes hundred of times greater than the absorber area. Therefore much higher temperature can be obtained and utilised to generate medium pressure steam. For best efficiency, collectors should be mounted to face the Sun as it moves through the sky(Rai, 2011)

Principles of Conversion of Solar Radiation into Heat

Most of the energy we receive from the Sun comes in form of light, a shortwave radiation. When this radiation strikes on solid orliquid, it is absorbed and transformed into heat energy; the material become warm and stores the heat, conducts it to surrounding materials (air, water, other solids or liquids) or reradiate it to other material of low temperature. This re-radiation is a long wave radiation. The fundamental process now in general use for heat conversion is the green-house effect. Glass easily transmits short-wave radiation, which means that it poses little interference to incoming solar radiation, but it is very poor transmitter of long wave radiation. Hence the energy gets accumulated in the collector (Sukhatme, 1996).

Flat-Plate Collectors

When the temperatures below about 90oC are adequate, as they are for space and service water heating flat plate collectors, which are of the non-concentrating type, are particularly convenient. They are made in rectangular panels, from about 1.7 to 2.9 sq. m. in area, and are relatively simple to construct and erect. Flat plate can collect and absorb both direct and diffuse solar radiation; they are consequently partially effective even on cloudy days when there is no direct radiation. Flare plate solar collectors may be divided into two main classification based on the type of heat transfer fluid used(Sukhatme, 1996).

a. Flat-plate liquid collector
b. Flat-plate air collector or solar air heaters

The principal difference between two types is the design of the passages for the heat transfer fluids. Liquid heating collectors are used for heating water and non-freezing aqueous solutions and occasionally for non-aqueous heat transfer fluids. Air and gas heating collectors are employed as solar air heaters(Alghoul, 2005).

The majority of the flat-plate collector has five main components;

1. Transparent covers which may be one or more sheets of toughen glass or UV stabilised radiation transmitting plastic film or sheet.
2. Tubes, fins, passages or channels are integral with the collector absorber plate or connected to it, which carry the water, air or other fluid.
3. The absorber plate, normally metallic or with a black, surface, although a wide variety of other materials can be used with air heaters.
4. Insulation, which should be provided at the back and sides to minimise the heat losses. Standard insulating materials such as fibre glass or styro-foam are used for this purpose.
5. The casing or container which encloses the other components and protects them from the weather.

Concentrating Collectors

Concentrating (Focusing) collector is device to collect solar energy with high intensity of solar radiation on the energy absorbing surface. These collectors are special form of flat-plate collectors modified by introducing a reflecting or refractingsurface (concentrator) between the solar radiations and the absorber (Rai, 2005).They use different arrangements of mirror and lenses to concentrate the Sun's rays.Thus the radiation ranges from low values (1.5 to 2) to high values (10,000). Thus fluid can be heated to temperature of 500oC or more (Jayakumar, 2009).As per the number of concentrating collector geometries, the main types of concentrating collectors are;

a. Parabolic trough collector
b. Mirror strip reflector
c. Fresnel lens collector
d. Flat-plate collector with adjustable mirrors
e. Compound parabolic concentrators

IV. SOLAR COLLECTOR APPLICATIONS

- Solar water heating systems
- Solar space heating and cooling
- Solar refrigeration
- Industrial process heat
- Solar desalination systems
- Solar thermal power systems
- Solar furnaces
- Solar chemistry applications

Nandi (2009) studied utilization of solar Thermal Energy in Food Processing Industry of sweetmeat products. On sunny days, when average solar radiation is 600W/m², the temperature rises above 150°C in the collector tube. Bhatewara (2012) analysed Application of Solar Thermal in Dairy Industry for various unit operations like cooling, washing, cleaning, pasteurization, sterilization, evaporation and spray drying. There are several potential fields of application of solar thermal energy in the temperature range of 60°C to 180 °C, like heat production for industrial processes in the food, textile, wine and chemical industries, solar cooling and air conditioning, solar drying and seawater desalination, thermal detoxification of drinking water, and small power generation and water pumping through medium temperature Rankine cycle systems (Bhave, 2012).

For almost 20 years, Brahma Kumari's and its sister organization, the World Renewal Spiritual Trust (WRST), a recognized scientific and industrial research organization in India, have been conducting training, research and development in renewable energy technologies. 'India One', a 1 MW solar thermal power plant situated near the Brahma Kumari'sShantivan Campus in Abu Road, Rajasthan, India, is due to be completed in 2016. This innovative project uses 770 newly developed 60m2 parabolic dishes and features thermal storage for continuous operation. The plant will generate enough heat and power for a campus of 25,000 people and is a milestone for decentralized and clean power generation in India.

Clique Solar, India's first solar boiler company, installs world's 1stlarge concentrated solar thermal (CST) system for providing Thermal energy in hotels at ITC, The Maurya Hotel, New Delhi.This installation has been operational for over a year now and it saves ITC an equivalent of almost 40,000-42,000 litres of fossil fuel (furnace oil) per annum, which amounts to a reduction in CO2 emissions by almost 110 - 130 tons per annum.

Muni Seva Ashram, Goraj is an active agent in the drive for sustainable development, wherein the use of resources meets human needs while preserving the environment. The Ashram had made a sustained effort to use modern technologies to reduce the use of conventional resources. Some of the Ashram's efforts towards promoting the use of renewable energy are: Heating Water - Solar flat plate collectors are used to heat 31,000 liters of water that is used everyday at the Ashram's kitchens, guest houses, and hospitals. Cooking -Scheffler dishes of 10m2 each and solar cooker are utilized for cooking food for around 600 students.

Photovoltaic Systems -Since grid power was not available when Green Campus was being built, a 13KW solar power plant was installed to meet the lighting and ventilation demands of the schools and hostels.Air-Conditioning -A system of 100 Schefflerdishes of 12.5m2 each meets 100 of the 600 Ton Refrigeration (TR) required by the two hospitals in the Ashram. This is the first solar air-conditioning system of its kind in India.

The Solar Steam Cooking System at Tirumala, Andhra Pradesh definitely finds a mention among the most noteworthy initiatives in solar energy as it is the largest of its kind in the world. Tirumala Tirupathi Devasthanam (TTD) in Andhra Pradesh is one of the most popular pilgrimage places in India. The temple authorities provide food for huge number of devotees' everyday at the temple. However, they had to contend with the problem of fuel shortage and electricity in this process. The solar steam cooking system installed in 2002, by the Tirumala Tirupathi Devasthanam (TTD) at Tirumala in Andhra Pradesh has the ability to prepare food for 15,000 people/day. This ingenious system uses automatic tracking solar dish concentrators that convert water into high-pressure steam. The system designed to produce over 4000 kgs of steam/day at 180oC and 10 kg/sq cm is adequate to cook two meals for approximately 15,000 persons. The system can save around 1,18,000 litres of diesel per year, valued at Rs 2.3 million. The total cost of the solar cooking system was about Rs. 110 million and was installed by M/s Gadhia Solar Energy Systems, Valsad under a demonstration scheme of MNES with 50% financial support.

In 2002, The solar steam cooking system installed at Sai Sansthan, Shirdi has 40 parabolic concentrators/ dishes (Scheffler dishes) placed on the terrace of Sai Prasad Building. Water coming from the steam headers placed above the header centers is received from bottom of the receiver, gets heated up to due to heat generated (about 550oC) due to concentration of solar rays on the receivers and get pushed up via top pipe of receiver into the header. They have installed hot- water-systems at its dharmashalas / dormitories, providing staying facilities for devotees.In the Sulabh Sauchalaya complex located in its premises, to night-soil-biogas plant is installed to generate gas from human excreta, which is used to operate generators to produce electricity for the complex. The Sansthan has also installed solar streetlights in its pumping complex.

A study identifying the most promising industrial sectors for solar applications has already been completed and the electroplating, food processing, pulp and paper, pharmaceutical and textile sectors have shown great promise for solar technology applications.

V. ECONOMICS AND FUTURE PROSPECTUS OF SOLAR ENERGY IN INDIA

India has tremendous scope of generating solar energy. It was estimated that the cost of Solar Thermal system for heating 100 litres water/ day from 60 to 120oC temperature is Rs.22,000/- which saves about 2200 units of electricity annually with payback period range from 3 to 5 years. Also helps in preventing emission of 1.5 tons of CO2 annually. The operation and maintenance cost is negligible (Jayakumar, 2009). Parabolic trough collectors (PTC) can effectively produce heat at temperatures between 50oC and 4,00oC. PTC installed at sweetmeat food industry for steam generation at 180oC. Cost of solar system is Rs. 35000 which saves electricity about 8.8kWhr per day. The payback period is 4 years with interest rate of return is 9.3% (Nandi, 2009). On installation of solar water heater, the feed water of the Boiler raised to 67 °C from 27 °C. An average 3000 lit of feed water being utilized per day saves around 120000 kCal/day thermal load, which amounts to 4774.20 lit of Furnace oil saved per annum. The Total investment was of Rs. 3.82 Lakhs and the cost savings was of Rs.1.57 Lakhs in the same year (Anon 2010). Solar concentrating collectors can be retrofitted to the existing boiler or heater system in the industry, substituting the use of furnace oil or electricity used for the heating application partially or fully. The 160 m2paraboloid concentrating dish based system installed at Mahanand Dairy, Latur by Clique Consultants Pvt. Ltd., Mumbai. This system generates hot water at 180oC and 18 bar pressure, to be used for milk pasteurization. It saves 70 – 90 liters of furnace oil on a clear sunny day (Bhave, 2012).

Concentrating Solar Power (CSP) technologies use systems of mirrored concentrators to focus direct beam solar radiation to receivers that convert the energy to high temperature for power generation. Typically, this heat is transformed to mechanical energy through a steam turbine and then to electricity.With about 300 clear, sunny days in a year, India's theoretically calculated solar energy incidence on its land area alone, is about 5,000 trillion kilowatt-hours per year.The solar energy available in a year exceeds the possible energy output of all fossil fuel energy reserves in India (Nangia et al., 2014). The daily average solar power plant generation capacityover India is 0.25 kWh per m2 of used land area, which is equivalent to about 1,500–2,000 peak (rated) capacity operating hours in a year with the available commercially-proven technologies. On 16 May 2011, India's first 5 MW of installed capacity solar power project was registered under the Clean Development Mechanism. The project is in Sivagangai Village, Sivaganga district, Tamil Nadu (Chinnammai, 2013).

States like Andhra Pradesh, Bihar, Gujarat, Haryana, Madhya Pradesh, Maharashtra, Orissa, Punjab, and West Bengal Have great potential for tapping solar energy due to their location.In January 2015, the Indian government significantly expanded its solar plans, targeting US$100 billion of investment and 100 GW of solar capacity by 2022. Government-funded solar electricity in India was approximately 6.4 MW per year as of 2005. India is ranked number one in terms of solar electricity production per watt installed, with an insolation of 1,700 to 1,900 kilowatt hours per kilowatt peak (kWh/KWp). 25.1 MW was added in 2010 and 468.3 MW in 2011. As of 31 August 2015, the installed grid connected solar power capacity is 4,229.36 MW, and India expects to install an additional 10,000 MW by 2017, and a total of 100,000 MW by 2022. The Jawaharlal Nehru National Solar Mission aims at development and deployment of solar energy technologies in the country to achieve parity with grid power tariff by 2022 (Srivastava and Srivastava, 2013).

VI. CONCLUSION

Solar energy is clearly a promising option as it is extensively available. Solar power, especially as it reaches more competitive levels with other energy sources in terms of cost, may serve to sustain the lives of millions of underprivileged people in developing countries. Furthermore, solar energy devices can benefit the environment and economy of developing countries.Solar thermal systems harness solar energy by utilising solar radiations to generate heat- as hot water, hot air, steam etc. that can be deployed for meeting numerous applications in different sectors such as power generation on a large scale, space heating, space cooling, community cooking, process heating etc. These applications make use of solar energy collectors as heat exchangers that transform solar radiation energy to internal energy of the transport medium (or heat transfer fluid, usually air, water, or oil). The solar energy thus collected is carried from the circulating fluid either directly to the hot water or space conditioning equipment, or to a thermal energy storage tank from which heat can be drawn for use at night and/or cloudy days. Solar energy collectors can be used in a wide variety of systems, could provide significant environmental and financial benefits, and should be used whenever possible.

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