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Original article

Financial viability of solar industrial process heating and cost of carbon mitigation: A case of dairy industry in India

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ABSTRACT

Dairy industry in India has a substantial demand for process heating at temperatures that can be provided with solar collectors. However, the acceptance and dissemination of solar industrial process heating systems would also be affected by their financial attractiveness for the users. Another attractive feature of SIPH systems is their ability to mitigate environmental emissions. Results of a financial viability analysis including estimation of cost of mitigating carbon emissions with use of SIPH in dairy industry in India are presented in this paper. Seven locations in India with dairy plants have been selected and annual useful thermal energy output of SIPH systems at these locations has been estimated. Further, levelized unit cost of useful thermal energy (LCUTE) delivered by the SIPH systems is estimated and a comparison with the existing process heating options being used in the dairy industry in India have been made. Other measures of financial viability such as discounted payback period, net present value and internal rate of return for an investment in SIPH systems in dairy plants have also been estimated. Finally, the cost of carbon mitigation with use of SIPH in dairy industry in India has been estimated. Results presents that in terms of LCUTE solar industrial of process heating systems doesn't seems financially viable. Moreover, payback period of the SIPH systems are very higher thus lower value of NPV and IRR, therefore, their use does not seem to be much attractive. Also the cost of carbon emissions likely to be mitigated with use of SIPH is on higher side. Therefore, In view of the long term economic and environmental benefits of using SIPH in dairy industry there is a need of marginal support to ensure their financial viability as compared to fossil fuel based systems, the government may consider providing suitable incentives for the same.

Introduction

India produced 132 million tonnes of milk in the year 2012–13 and out of this around 26 million tonnes (approximately 20%) was routed through 1065 milk processing plants with reported installed capacity of 37 million tonnes per annum [21,17]. In a typical milk processing plant, a major fraction (70%) of energy use is essential for process heating (50–200 °C) [22,10,14]. Most of the process heating demand in the dairy industry in India is met with fossil fuels based process heating systems mainly (furnace oil, light diesel oil (LDO), low Sulphur heavy stock (LSHS), natural gas and high speed diesel HSD, coal etc.) [3,11]. With the use of state of art solar collector technologies it is possible to supply thermal energy at temperatures ((50–200 °C) required by the dairy industry [4,23,24]. A significant potential (6.5 PJ) of solar based process heating has also been estimated for dairy Industry in India [26].It has also been observed that most of the locations with dairy plants in India have considerable availability of Direct Normal Irradiance (DNI). Thus, it can be inferred that the India has substantial solar resource availability for promoting use of solar industrial process heating in dairy industry. Moreover, to promote the harnessing of solar energy for industrial process heating, the Government of India has implemented a UNDP-GEF supported project [31].

Large potential as well as integration capability of solar industrial process heating in the dairy industry in India notwithstanding, it's actual penetration in the field would essentially depend upon the financial viability of SIPH systems for the potential user as against the existing options such as those based on fossil fuels. Environmental sustainability is also a deciding factor for the same. Carbon mitigation potential of solar process heating in industries has been estimated in several studies [25,11,26,27]. Though only a few studies exclusively deals with detailed financial viability assessment of SIPH systems [2,12,13,15,28], several of the studies dealing with design and performance evaluation often present relevant results on one or more measures of economic performance [1,4,19,20,9]. Commonly reported measures for economic evaluation or appraisal of the SIPH systems for use in different industries include payback period, net present value and

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Nomenclature

ACC	annualized capital cost
ACOM	annual cost of operation and maintenance of solar industrial process heating (SIPH) system
ASC_f	area of solar collector field
AUTED	annual useful thermal energy delivered
$C_{o,}$	capital cost of process heating system
CF_f	carbon fraction in the fuel
CV_f	calorific value of the fuel
CUF	capacity utilization factor of milk processing plants in the country
d	discount rate
DNI_d	design value of direct normal irradiance
DPP	discounted payback period
E_o	embodied carbon emissions with the SIPH system.
F_{CO}	fraction of carbon oxidized on burning of fossil fuel in the boiler
HSD	high speed diesel
IRR	internal rate of return
LDO	light diesel oil
LSHS	low sulphur heavy stock
LCUTE	levelized cost of useful thermal energy delivered
NPV	net present value
n	useful life of process heating system
η_f	efficiency of fuel utilization in the boiler
η_{siph}	efficiency of solar industrial process heating system
PHR_h	hourly process heating requirement
S	salvage value of SIPH system after completion of useful life
SIPH	solar industrial process heating
UCUTE	unit cost of useful thermal energy delivered
UP_f	unit price of fuel
α	rate of annual escalation in the operation and maintenance cost of SIPH system
β	rate of annual degradation in the performance of SIPH system
£	rate of annual escalation in the prices of fossil fuels

internal rate of return that are usually estimated on the basis of net fuel savings likely to accrue with the installation of SIPH systems. As an example investigation of the economic viability of solar hot water systems for soft drinks and vegetable oil industry in Khartoum (Sudan) was carried out [12]. The results presented that the solar energy systems have significant potential in industrial processes and substantial life-cycle savings can be achieved. In different case studies carried out in Greece [13], economic evaluation of solar industrial process heating systems with conventional fossil fuel based systems have been made. In this analysis, all existing SIPH systems have been studied and eight successful applications of solar thermal systems in the industry in Greece have been identified. The outcomes of the study revealed that due to increase in the price of liquid fuels, solar process heating systems in industrial applications shall become cost effective. Similarly the case studies on the adoption of SIPH in the industries in Turkey and Pakistan confirmed economically viability of SIPH for low temperature (60–80 °C) requirements [19,20]. For example, in the case study for the textile industry in Turkey a payback period of less than 3 years has been estimated. All these studies were focused on the case of a specific industry or production unit. However, performance of an SIPH system depends on several parameters such as the design value of available insolation and its availability, climatic conditions at the location of use, performance characteristics of solar collector used and thermal load with required operating conditions of process heating (delivery

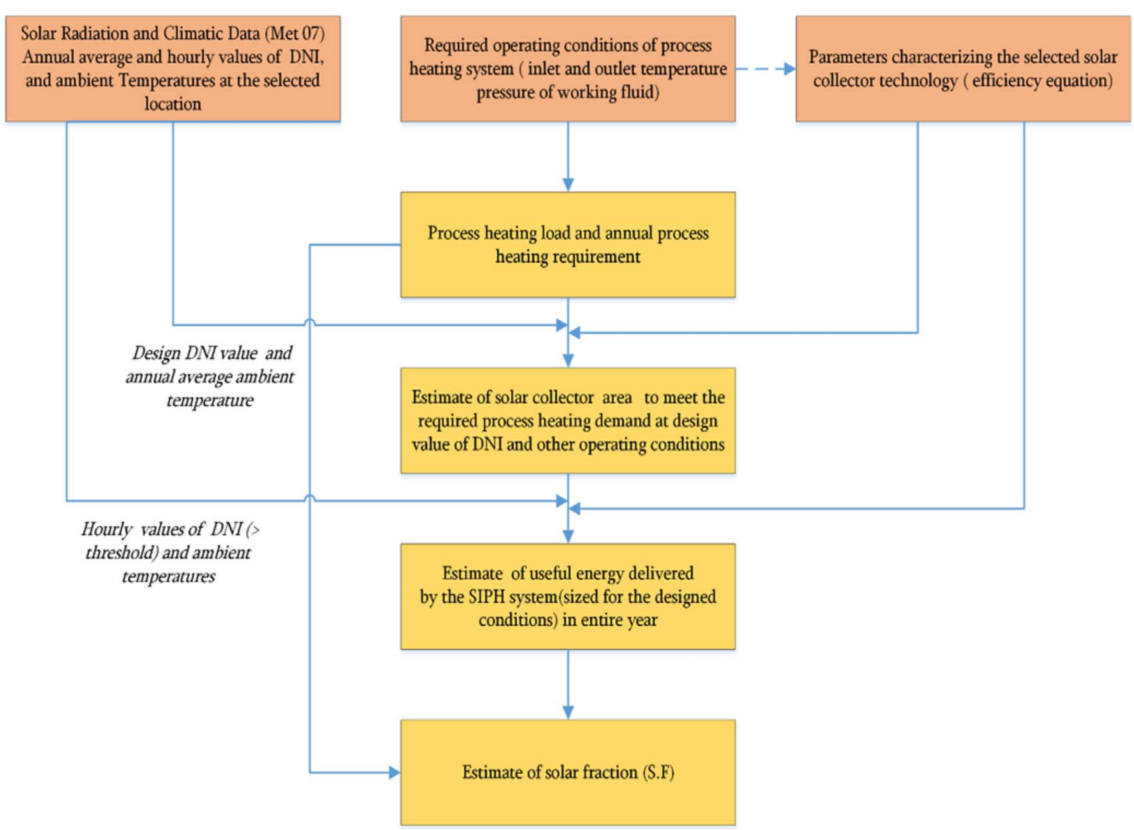

Fig. 1. A schematic of the methodology adopted for performance estimation of SIPH systems.