Renewable Horizons: Solar Power and Dairy Industry in India

Abstract

Renewable energy is energy obtained from sources that are essentially inexhaustible such as wind power, solar power, geothermal energy, tidal power, bio-energy and hydropower. It is also known as non-conventional energy.Harnessing renewable energy offers numerous environmental benefits, including mitigating climate change, reducing air pollution, conserving natural resources, and enhancing energy security by diversifying energy sources.Solar resources are available in every country and both Solar Photovoltaic (SPV) and Concentrating Solar Power (CSP) technologies can be used to convert solar resource into electricity. SPV can use both direct and diffuse sunlight to generate power, while CSP relies on direct sunlight, restricting its deployment to areas with high Direct Normal Irradiance (DNI). Mandatory demand supported with higher subsidies for green technologies will positively attracts dairies towards use of solar energy. In many villages, power cut hinders the reception of milk from milk producers as electronic weighing system and milk testing instruments require uninterrupted power supply.solar-powered dairy operations offer resilience against power outages and fluctuating energy costs, empowering farmers with greater control over their operations. As the Indian dairy industry embraces solar power, it not only secures a greener future but also fosters economic growth and energy access in rural communities, marking a significant stride towards sustainability and self-sufficiency.

Keywords: Renewable energy, rural communities, Solar Photovoltaic, non-conventional energy

Introduction

The twenty first century is forming into the perfect energy storm. Rising energy prices, diminishing energy availability and growing environmental concerns are quickly changing the global energy panorama (Foster *et al*., 2010). The Paris Agreement establishes a mechanism to limit global temperature rise to “well below2°C”, and ideally to 1.5°C, compared to pre-industrial levels. To meet the agreement's climate goals, a significant restructuring of the global energy environment is required (IRENA, 2019).

Renewable energy refers to energy derived from naturally replenishing resources that are virtually inexhaustible on a human timescale. These resources include sunlight, wind, water (hydropower), geothermal heat, and biomass (organic matter such as plants and waste). Unlike fossil fuels, which are finite and produce harmful emissions when burned, renewable energy sources are sustainable and emit minimal or no greenhouse gases during energy production. Harnessing renewable energy offers numerous environmental benefits, including mitigating climate change, reducing air pollution, conserving natural resources, and enhancing energy security by diversifying energy sources. Additionally, renewable energy technologies continue to advance, becoming increasingly cost-effective and accessible, driving the global transition towards a cleaner, more sustainable energy future.

In the dairy industry, renewable energy finds diverse applications, enhancing sustainability and efficiency. Farms integrate solar panels and wind turbines to generate electricity, powering essential operations like milk cooling and equipment usage. Anaerobic digestion systems convert organic waste, such as manure, into biogas for electricity and heat, alongside producing organic fertilizers. Biomass heating systems provide renewable heat for farm buildings and facilities, reducing reliance on fossil fuels. Effluent treatment processes benefit from renewable technologies like solar-powered pumps, lowering energy consumption and costs. Additionally, the adoption of electric or biofuel-powered vehicles in transportation reduces greenhouse gas emissions, contributing to a greener dairy supply chain. By embracing renewable energy, the dairy industry not only reduces its environmental footprint but also enhances its resilience and sustainability for the future.

Renewable energy in India: Potential and thrust

Renewable energy is energy obtained from sources that are essentially inexhaustible such as wind power, solar power, geothermal energy, tidal power, bio-energy and hydropower. It is also known as non-conventional energy. There is a huge potential for tapping energy from various renewable energy sources i.e., solar, wind, biomass, small hydro, bagasse and cogeneration. The total potential for renewable power generation in the country as on 31st March, 2020 is estimated at 1097.46 GW which includes solar power of 748.99 GW (68.24%) and other renewables of 348.47 GW (31.76%). Further, the geographic distribution of the estimated potential of renewable power shows that Rajasthan has the highest share of about 15 per cent (162.22 GW). This is followed by Gujarat with 11 per cent share (122.08 GW) (MOSPI, 2021). Majority of the region in Gujarat has the potential to generate energy with magnitude ranging from 700,000 kWh to 730,000 kWh.

India's Intended Nationally Determined Contributions (INDCs) target to achieve about 40 per cent cumulative electric power installed capacity from non-fossil fuel-based energy resources (UNFCCC, 2020; NISE, 2019) and to reduce the emission intensity of its Gross Domestic Product (GDP) by 33 to 35 per cent from 2005 level by 2030. With this objective, National Solar mission (NSM) Phase-II aims for achieving significantly tall targets of 175 Giga watt (GW) by 2022 (MNRE, 2020) comprising of 100 GW solar, 60 GW wind, 10 GW small hydropower, and 5 GW biomass-based power projects. Of the 100 GW solar energy target by 2022, 40 GW has been targeted through grid-connected rooftop solar (BEE, 2018). The government is also aiming for 450 GW power from renewables by 2030 (Prakas*et al.,* 2020; BEE, 2018). Various mechanisms to encourage the use of renewable energy in the country includes Renewable Purchase Obligation (RPO), Renewable Energy Certificate (REC), Power Purchase Agreement (PPA) and Feed-in Tariff and a tax of US$1 per metric ton on domestic and imported coal used for power generation (Khare *et al*.,2013). Gujarat solar energy is only affected during parts of July and August due to the monsoon effect (Harinarayana and Kashyap, 2014). The dominance of solar energy especially PV among renewable energy technologies is owed mostly to its noiselessness, non-toxic emission, relatively simple operation and maintenance (Singh and Pal, 2020; Moosavian*et al*., 2013).

Solar energy

Electromagnetic waves are the primary means by which solar energy is transported to the Earth. It is by far the largest carbon-free energy source on the planet. It strikes the Earth in one hour (4.3×10^{20} J) is more than all the energy consumed on the planet in a year (4.1×10^{20} J). The solar radiation reaching the earth's surface predominantly consists of infrared (52 to 55%), visible (42 to 43%), and ultraviolet (3 to 5%) radiation (Duffie and Beckman, 2013). At the upper atmosphere, the Earth gets 174 petawatts (PW) of solar radiation (insolation). The rest is absorbed by clouds, oceans, and land masses, with approximately 30 per cent reflected back to space (Seetharaman, 2021). The amount of solar radiation that reaches any given location is dependent on several factors including the geographic location, time of day, season, landscape and local weather. Because the earth is round, the sun strikes the surface at different angles ranging from 0° (just above the horizon) to 90°(directly overhead). When the sun's rays are vertical, the earth's surface gets maximum energy. The more slanted the sun's rays are, the longer they travel through the atmosphere, becoming more scattered and diffuse (BEE, 2018). The value of the solar constant varies from day-to-day depending on the actual distance from the sun. The present accepted value of solar constant derived from space-based measurements is 1360.8 ± 0.5 W/m^2 (Tyagi, 2009; NASA, 2008). Solar resources are available in every country and both Solar Photovoltaic (SPV) and Concentrating Solar Power (CSP) technologies can be used to convert solar resource into electricity. SPV can use both direct and diffuse sunlight to generate power, while CSP relies on direct sunlight, restricting its deployment to areas with high Direct Normal Irradiance (DNI).

Solar energy potential and status in India

Since, India is situated on the sunny belt in the north of equator, the scope for generating power and thermal applications using solar energy is huge. Most parts of the country receive a daily solar irradiance of 4–7 kWh per square metre per day (kWh/m^2/day) and sunshine of about 6–8 h a day, averaging to about 2300 to 3200 h per year (Sharma *et al*., 2012). The country receives enough solar energy to generate more than 500,000 TWh per year of electricity, assuming 10 per cent conversion efficiency for PV modules (Muneer and Munawwar, 2005). Based upon the availability of solar radiation and land, National Institute of Solar Energy (NISE) assessed the country's solar potential of about 748.99 GWp assuming 3 per cent of the waste land area to be covered by SPV modules (BEE, 2018). Though Rajasthan (with a solar irradiance of about 5.5–6.8 kWh/m^2/day) gets the highest solar radiation globally, northern Gujarat (more than 5.5 kWh/m^2/day), parts of Ladakh, parts of Andhra Pradesh, Maharashtra and Madhya Pradesh also receive fairly high radiation (Dawn *et al*. 2016) as compared to many parts of the world (Bhushan *et al*., 2014; Sharma and Harinarayana, 2013; Goswami, 2012). It is estimated that India can achieve complete energy security by 2031 even if 1 per cent of the total land area is used for solar energy (Goswami, 2012). International Energy Agency forecasts that solar energy could be the world's biggest source of electricity by 2050 (Bagher *et al*., 2015). Recently, India achieved 5th global position in solar power deployment by surpassing Italy (MNRE, 2019).

Grid parity of solar energy in India

Grid parity refers to the point at which the cost of generating PV electricity equals the cost of buying it from the grid. Presently, solar tariff in India is very competitive and has achieved grid parity (MNRE, 2021; BEE, 2018). The cost decline experienced by PV technology during the last decades (Masson *et al*., 2016) has allowed it to reach grid parity in many countries (Solar Photovoltaics, 2011). It suggests that PV technology is set to play an increasingly relevant role in the process of decarbonizing the energy system (IEA, 2015). It is expected that though the landed cost of conventional electricity to consumers will increase at a rate of 4 per cent and 5.5 per cent per annum in the base case and in an aggressive case respectively, solar power prices are expected to decline at the rate of 5–7 per cent per annum (Khare *et al*., 2013).

Application of Solar Energy in Dairy Sector

The whole dairy value chain is energy-intensive, from village-level milk pooling sites to product transportation. Extensive use of solar energy in dairy value chain can significantly reduce operational cost and ensure usage of clean energy (Indo-German Energy Forum, 2020). Solar energy can be the best option as India has an abundance of sunshine with a good intensity. Solar energy finds various applications in dairy processing operations like heating, steam generation, cooling, lighting, drying, etc. (Sain *et al.*, 2020).

Indian dairy industry consists of over 1,200 large, medium and small dairy plants. The dairy industry is dominated by the co-operative sector with 60 per cent of the installed processing capacity in this sector. Nearly 30 per cent of overall manufacturing cost is spent on purchase of furnace oil, electricity, which is substantial. Typical dairy plants derive about 70 per cent of their energy requirements in the form of thermal energy and the remaining 30 per cent is consumed in the form of electricity (Saur Energy, 2019). Refrigeration systems consume about 50 to 60 per cent of total electrical power consumption in dairy industries. A range of technologies and processes for the commercial application of renewable energy in milk cooling facilities are being developed. Additional work is needed to enhance the efficiency and effectiveness of these technologies and to reduce their costs (Moffat *et al*., 2016).

Podjanaaree and Saraboon (2019) presented dairy farm model with low-cost alternative energy. It was reported that the energy cost for dairy farming approximately ranges between 20 to 25 per cent of total cost depending on the size of dairy farm. Furthermore, the installed SPV at the farm was able to reduce about 78-100 per cent of electrical energy from the grid. Hence, the farmers are able to reduce their energy use and in turn increase their profit margins.In another study, Sidney *et al*. (2020) designed a standalone solar power system to power a milk chiller with 200 W DC compressors using the PVsyst software for different climatic zones in India. The software was used to determine the least number of PV panels and batteries, as well as a method for getting yearly solar fraction values for five different climatic zones in India. From the experiment, it was found that the required number of PV panels got reduced from 4 to 2 panels when considering the maximum power point for a typical summer day. The custom-built milk chiller was able to chill down the milk from 37°C to 4°C within 2 hours on all days using cold energy from the ice bank tank.

Foster *et al*., (2017) evaluated performance of the photovoltaics refrigeration technology (PV-SMART) coupled with direct drive for off-grid milk cooling. The PV chillers were powered directly by a DC compressor, which chilled ice stored in the refrigeration unit's walls. This eliminated the need for electro-chemical batteries and successfully chills milk to 10°C in 2 hours and 4°C by morning preventing bacteriological growth. Whereas, De Blas *et al*. (2003) studied milk cooling module powered by SPV.The characteristics and operating conditions of a refrigeration unit designed to chill a daily milk production of 150 litres were investigated. The facility was a stand-alone, direct-coupled system where 20 photovoltaic modules, 120 Wp each, power two permanent magnet, direct current motors of 24 V, 650 W. Each motor powered a separate cooling system compressor, allowing the equipment to be operated with one or two motors and varied PV module interconnections, depending on the available irradiance level and the system's thermodynamic condition. The photovoltaic energy obtained during daylight hours was stored in the form of sensible and latent heat of frozen water in a tank surrounding a milk container. Thermodynamic analysis of the system showed that the autonomy of the system is 2.5 consecutive cloudy days if the available stored ice energy is 80 per cent of the nominal capacity of the water/ice tank. Results of the refrigeration efficiency were similar to those obtained by other commercial refrigeration facilities powered by a photovoltaic array, including batteries.

Kasera*et al*., 2021 evaluated the performance of a solar DC milk refrigerator using Refrigerant R290. Performance parameters i.e., Cooling capacity, Coefficient of performance and Solar coefficient of performance and energy consumption were investigated for the different room temperature using variable speed mode for 14 kg of milk. It was discovered that when the temperature rises, the cooling capacity diminishes. Power consumption increases as temperature increases. COP of the system decreases with increasing temperature as expected. COP was found in the range of 0.61 to 0.23. The higher temperature of condenser was also a reason for low COP at high room temperature. It was concluded that such type of system can be successfully applied for remote areas where electricity is not available and suitable speed can be applied as per the power availability. Desai (2011) evaluated the performance of solar based milk cooling system in terms of actual COP, refrigeration effect produced, work of compression and energy requirement. The solar intensity was recorded and it was found that it increases gradually from morning to about 13:00 h and subsequently reduces in the afternoon period. The electrical energy consumption of the BMC obtained under different loading conditions ranged from 0.58 to 0.64 kWh with agitation and 0.65 to 0.69 kWh without agitation. Also, BMC at optimum cooling load gave higher COP_{act} as compared to part load. Khan *et al*., 2020 used variable refrigerant flow technology to produce an enhanced solar milk chilling system. The improved design of a solar chilling system consisted of a chilling tank (200 L capacity) coupled with one ton of refrigeration unit powered by PV panels (2 kWp) and VRF technology to make system more energy efficient by reducing the torque load. Experiments were implemented to minimize the raw milk temperature from 30°C to 4°C using different batch sizes (50, 100, 150, and 200 L). The comparative power required to run various types of different compressors viz., reciprocating, rotary with capacitor and rotary with VRF were found to be 1.8 kW, 1.2 kW and 0.8 kW respectively whereas the torque loads for each compressor type were 3.3 kW, 1.6 kW, and 0 kW respectively. It was reported that around one ton of refrigeration unit is sufficient to chill 200 L of milk at 4°C within less than two hours.

The government is actively contemplating a solar scheme for the dairy industry, which would subsidize the installation of solar technologies. Ministry of New and Renewable Energy (MNRE),United Nations Development Plan (UNDP) and National Dairy Development Board (NDDB) are actively trying to implement green energy solution in dairy industry (Saur

Energy, 2019). Hence, mandatory demand supported with higher subsidies for green technologies will positively attracts dairies towards use of solar energy.In many villages, power cut hinders the reception of milk from milk producers as electronic weighing system and milk testing instruments require uninterrupted power supply. The innovative technologies available for the use of solar energy for heating requirements and generation of electrical power is not fully exploited yet in dairy sector. Many developed countries, where even sun rays are only available for a few months in a year are also using solar energy, at farm and processing facilities. India has ample opportunities to expand the use of solar energy (Bhadania, 2017). Hence, solar energy is turning out to be the innovation that lowers costs, adds income and future-proofs the business in dairy sector.

Conclusion

Renewable horizons are illuminating the future of the dairy industry in India, with solar power emerging as a transformative force. India, with its abundant sunlight, is witnessing a surge in solar installations across dairy farms, promising sustainability and energy independence. Solar panels adorn rooftops and open spaces, harnessing the sun's energy to power crucial dairy operations, from milk chilling to water pumping and milking machinery. This shift towards solar energy not only reduces reliance on traditional grid electricity but also mitigates greenhouse gas emissions, contributing to India's ambitious renewable energy targets. Moreover, solar-powered dairy operations offer resilience against power outages and fluctuating energy costs, empowering farmers with greater control over their operations. As the Indian dairy industry embraces solar power, it not only secures a greener future but also fosters economic growth and energy access in rural communities, marking a significant stride towards sustainability and self-sufficiency.

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