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APPLICATION OF SOLAR THERMAL ENERGY TO DAIRY INDUSTRY

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1. INTRODUCTION

Considering the climate crises associated with the harmful gas emissions, the renewable energy technologies become one of the fastest developing sectors across the world. Solar energy as a well-established renewable energy has been used for space heating, domestic hot water and electricity generation. Much attention in the last years has been paid to scale it up to the industrial levels.

The potential industries considered for solar energy application are automobile, brewery, food, paper, pharmaceutical, textile, minerals, chemical, agriculture, leather, and fabricated metals. Common processes considered for integration of solar energy include water heating, drying, steam heating and washing [1]. Food industry is one of the most promising industry for the solar energy applications, particularly dairy industry, due to the thermal heating and cooling requirements [2, 3]. There are thirty - five solar thermal systems used in the dairy industry, of which nine are located in European countries like France, Greece, Italy and Netherland [2]. Three out of nine solar thermal systems use flat plate collectors to supply hot water for preheating and cleaning processes to meet temperature ranging from 20ºC to 80ºC while the rest use parabolic through collectors and Fresnel reflectors to supply steam at the temperature ranging from 140ºC to 200ºC and pressure from 4 to 12 bar [2]. Solar collectors, heat exchangers and water heating units are important components of the solar energy system that have been already used in pasteurisation process to meet operation temperatures ranging from 63 ºC to 72ºC [3].

Although the application of various solar thermal systems in diary industry have been reported in the literature, there is still lack of consensus on the use of the solar thermal equipment within the existing heating and cooling systems. This study is focused on the integration of an advanced solar thermal system to dairy industry processes. The objectives are to: (i) understand the thermal heating and cooling requirements (ii) simulate different integration scenarios for solar thermal systems applications (iii) assess the solar energy contribution to the system. A case study of a diary company located in Greece was considered.

2. SOLAR THERMAL INTEGRATION

Table 1 presents the types and properties of the solar thermal collectors. It can be seen that a number of solar collectors use temperature ranging from 30ºC to 500ºC, however the temperature requirements for the dairy processes are approximately ranging from 63ºC to 200ºC [2,3], which corresponds to the medium temperature range requirements as presented in Table 1. Considering the relatively high demand of energy needed for the dairy industry, parabolic trough and Fresnel reflectors seem more feasible options as they can operate with thermal oil and have axis tracking [Table 1]. The use of thermal oil along with one axis tracking creates flexibility in integration options and increases the system efficiency compared to the use of water/air with no tracking option [4].

Table 1: Temperature ranges for various solar collector types and associated heat transfer fluids (HTF) [5]

Temp (ºC)	Collector type	HTF	Possible application	Tracking	Absorber
30-80	Flat plate	Water or air	Low temperature	No	Flat
50-200	Evacuated tube	Water or air	Medium temperature	No	Flat

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60-240	Compound parabolic	Water or air	Medium temperature	No	Line focusing
60-350	Parabolic trough	Water, air, thermal oil	Medium temperature	1 axis	Line focusing
60-250	Fresnel reflectors	Water, air, thermal oil	Medium temperature	1 axis	Line focusing
100-500	Parabolic dish	Water, air, thermal oil	High temperature	2 axes	Point focusing

3. A CASE STUDY

A dairy company located in Greece was considered as a case study. The collected data include weather, floor plans, flow diagrams, production rate and energy consumption. Table 2 shows the quantity of the products like skimmed milk, yogurt and yogurt-based dressings produced during 2019. The main dairy production processes require temperatures between 5°C and 175°C for cooling and heating demands.

Table 2: The products and annual production rate of a dairy plant produced in 2019.

Product	(kg/year)
Milk	4,062,039
Yogurt	48,734
Dessert	343,737
Milk crème	314
Drinkable yogurt	3,483
Tzatziki	354

The steam production process uses two boilers with different capacities of 600 kW and 300 kW while the cooling system uses a central chiller with a capacity of 200 kW. The energy consumption for 2019 was found to be 118,601 m^3 for natural gas and 1,582,629 kWh for electricity.

Table 3 demonstrates the breakdown of energy consumption for different equipment used in the dairy plant at the maximum equipment capacity and average production rate. It can be seen that the maximum energy consumption of the dairy plant is 1241 kWh while the average production rate is 311 kWh.

Table 3: Energy consumption of a dairy plant at maximum capacity operation and at average production rate operation (calculated based on annual production in 2019).

Equipment	Source	Energy consumption at (kWh)	
		Max capacity	Average production rate
Boiler 1	NG	598	42
Boiler 2	NG	295	21
Main cooler	Electric	211	112
Milk tank cooler	Electric	18	18
Pump	Electric	19	19
Homogeniser	Electric	37	37
Centrifugal separator	Electric	21	21
Mixer	Electric	19	19
Fermentation tank	Electric	6	6
Refrigerator	Electric	11	11
CIP	Electric	6	6
Total		1241	311

Based on the data provided by the company on the existing thermal system, various solar thermal integration strategies were considered and the recommended option is presented in Figure 1. It can be seen that a solar thermal powered absorption chiller (h) is used to chill the coolant in parallel to the conventional chiller (a). Similarly, a solar powered steam drum (c) is used to produce steam for the system in parallel to the conventional boiler (d) and heat is transferred from the solar loop (green coloured loop) to the heating loop (red coloured loop) through a heat exchanger. The heat exchanger is not shown in the figure as it can be located inside or outside of the steam drum (c) depending on the size of the system. It can be seen that the thermal energy storage (g) is connected after the solar collectors (f) in series while heating and cooling demands (h and c) are connected in parallel to each other.

The main advantages of the recommended integration option are:

(i) flexibility on heat transfer fluid selection as the solar system is a close loop and do not mix with cooling or heating loops,

(ii) the solar powered cooling and heating equipment (h and c) are connected in parallel to conventional equipment (a and d) through separate feed outlets from the cold tank (b) and hot tank (e), respectively. Therefore, any problem/maintenance on conventional equipment does not affect the operation of solar equipment or vice versa

(iii) the plant has control to adjust the load between the conventional and solar energy (within the installed solar capacity).

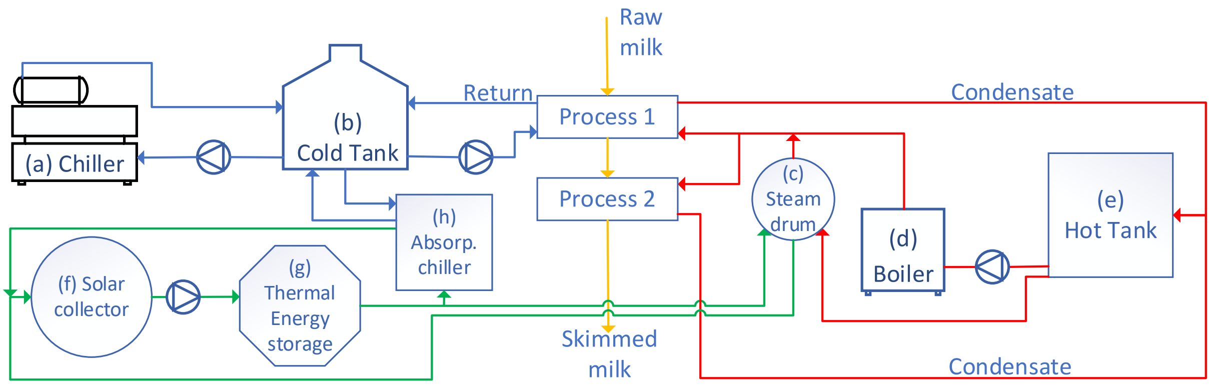

Figure 1: Basic schematic designed for the integration of solar technology in a dairy plant.

4. CONCLUSION

This study investigated the application of solar thermal energy in a dairy plant. The average energy production rate of a dairy plant was 311 kWh while the temperature requirement ranging from 5°C to 175°C for cooling and heating processes. Parabolic trough and Fresnel reflectors were suggested as the most applicable two solar collector options. A solar thermal integration scenario was developed and presented. The future work includes the simulation of the solar thermal energy integrated dairy processes using ASPEN Plus software.

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