Integration and Simulation of Solar Thermal Energy to dairy Processes

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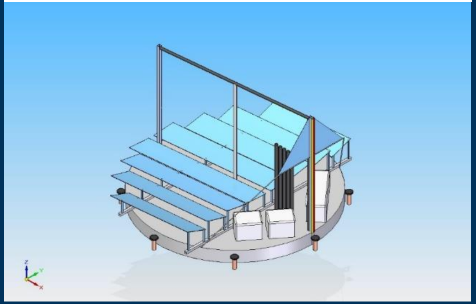


Outline

- Background
- Methodology
- Results and Discussion
- Conclusions and Future Work
- Acknowledgment
- References

The use of Solar Thermal Energy in Dairy Processes

SolarPACES
Solar Power & Chemical Energy Systems

- Solar Thermal Energy (STE) systems have recently shown a great potential to reduce fossil fuel use and CO_2 emission in the dairy industry[1]
- Currently, 33 STE systems are operating in the dairy industry, worldwide. Those systems:
  - use different collectors like flat plate, parabolic through and linear Fresnel
  - provide heat at the temperature range of 80 - 200°C and pressure of 4-12 bar
  - are integrated to processes like pasteurization - preheating - cleaning
- However, there are varios operational issues reported that affected their efficiencies, as follows:
  - shading on the solar collectors and the tracking system sensors
  - heat transfer fluid returning to the solar collector at variable temperatures effecting the control system
  - use of the same components like heat exchanger and pipes, etc to supply heat from the solar and conventional sources [2]

This can be prevented by a thorough pre-analysis of the <u>full dairy plant</u> and their loads, the proposed solar system, and the integration configuration before the installation of new STE systems to any inudstry.

Aims and Objectives

The aim of this study is to integrate and simulate a STE system for heating and cooling purposes that could be potentially used in a dairy industry. Two different scenarios will be developed and the most technically efficient solution will be investigated.

Objectives include:

- Analyse the existing thermal processes of a dairy industry and their current heating and cooling systems
- Use the results to simulate existing dairy processes for STE system integration
- Evaluate the most technically efficient solution that could be implemented in a dairy industry

Methodology

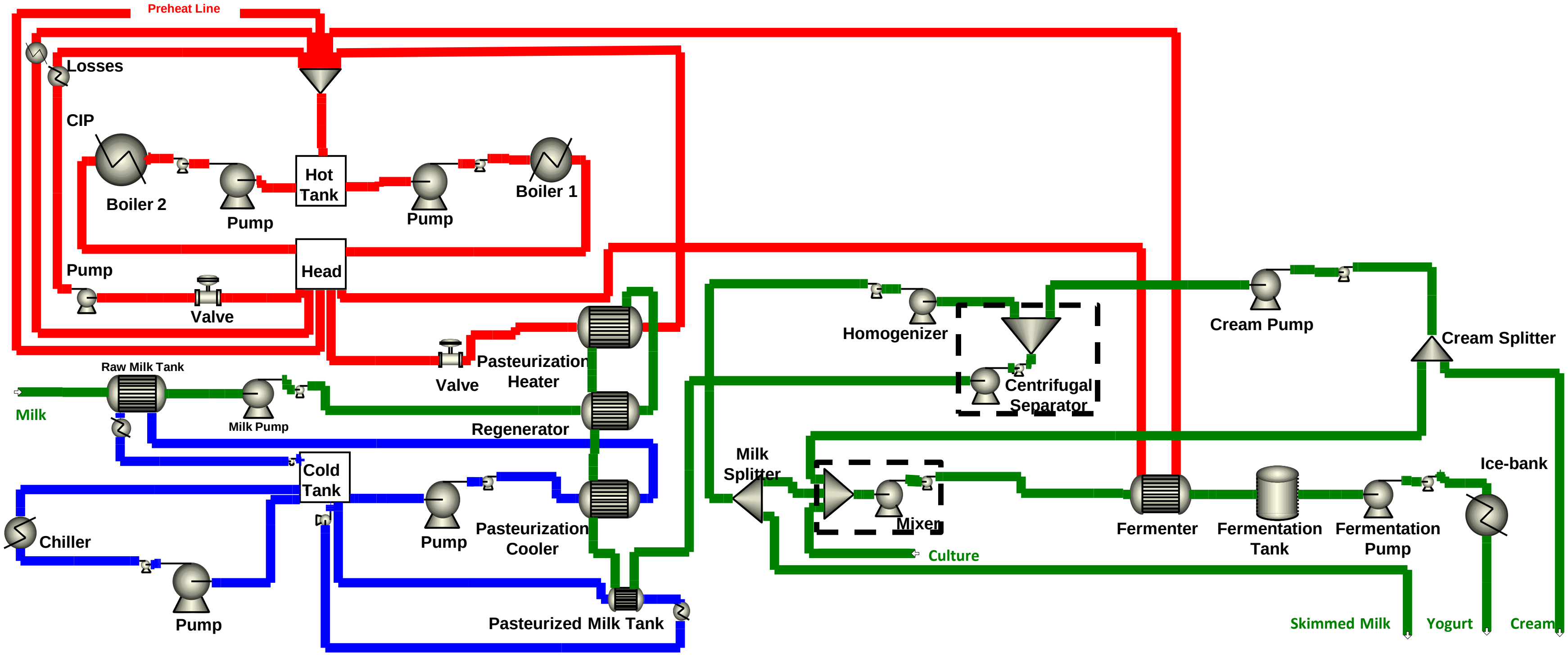
A case study of a dairy industry located in Greece (Latitude ≈ 38 N)

- A family owned dairy company
- Produces more than 2 million kg of dairy products annually
- Consumes around 49 thousands m^3 of Liquified petroleum gas (LPG) and 570 MWh of electricity per year
- Uses LPG for the heating system
- The processes require:
  - a heating system to provide heat at 180 ^oC
  - a cooling system to provide cooling at 0-4 ^oC

The Integrated Solar System

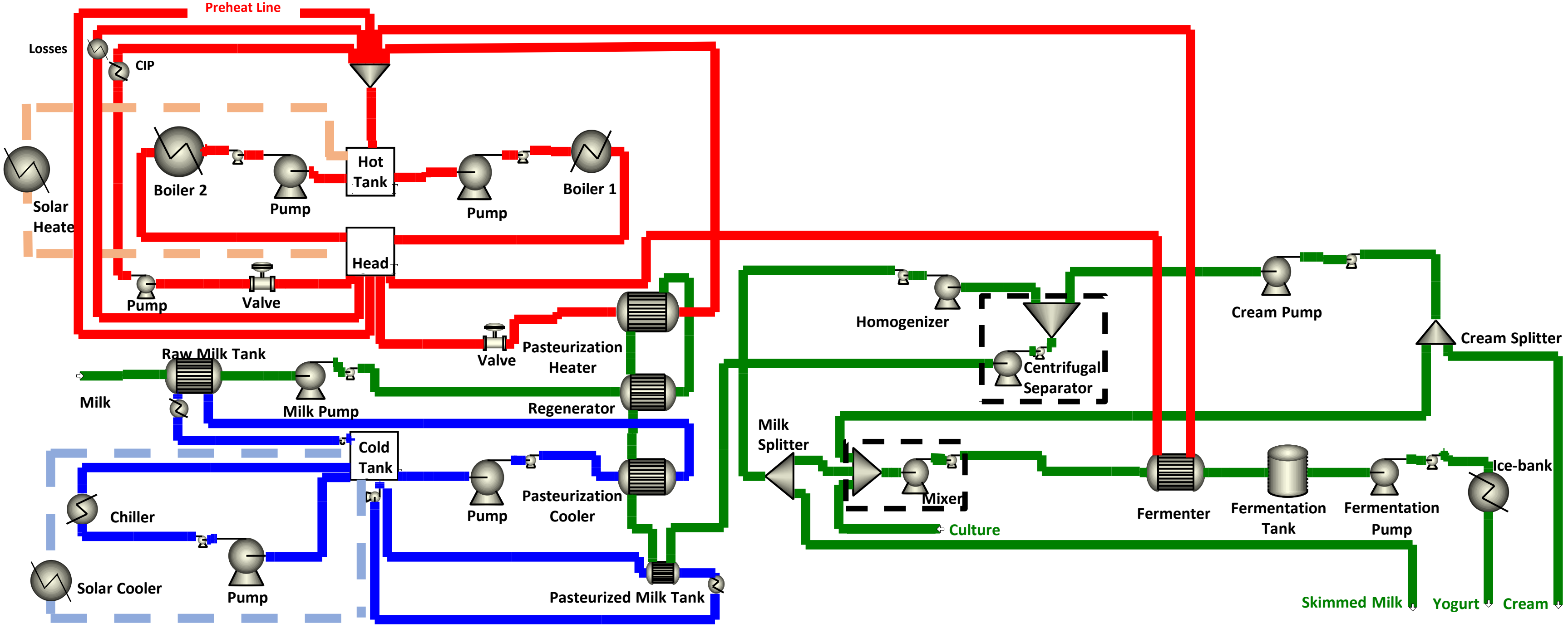
- The required data for the cooling and heating systems for production of milk, yogurt and cream are provided by a dairy company
- ASPEN Plus software (Aspen Technology Inc) is used to simulate the exiting plant for STE integration
- Two different scenarios are considered for simulation of the integrated STE to supply 32% of the total energy use[3]
- Solar contribution and energy savings are obtained from the simulation and used to evaluate the most efficient scenario
- Specific energy consumption of each product is calculated and critically evaluated

Simulation of the Dairy processes



Existing Heating Line (Steam) | Existing Cooling Line (Water Glycose) | Production Line (Milk)

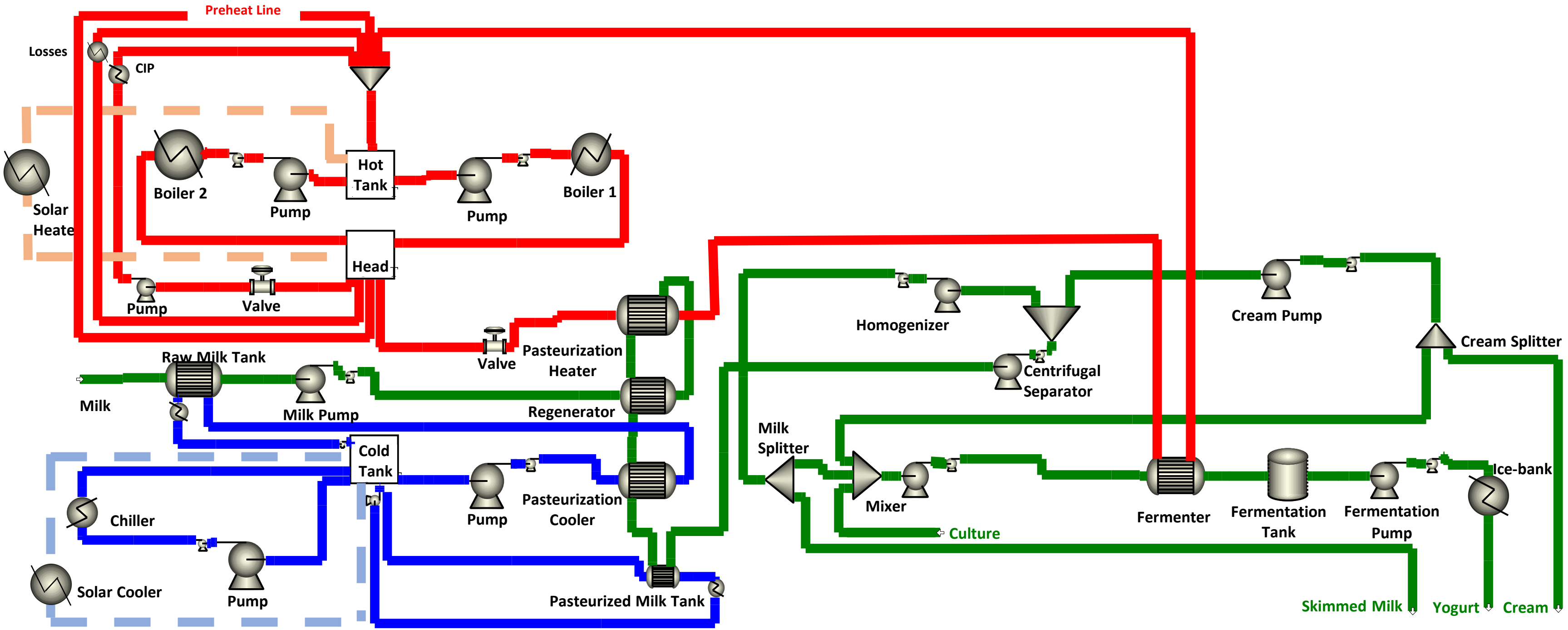
Scenario One
STE Integration for direct heating and cooling
Pasteurizer and fermenter connected in parallel



Existing Heating Line (Steam) — Existing Cooling Line (Water Glycose) — Production Line (Milk)

STE heating system integration (Steam) — STE cooling system integration (Water Glycose)

Scenario Two
STE integration for direct heating and cooling
Pasteurizer and fermenter connected in series



Existing Heating Line (Steam) | Existing Cooling Line (Water Glycose) | Production Line (Milk)

STE heating system integration (Steam) | STE cooling system integration (Water Glycose)

Results & Discussion

Maximum Production Rate Steady State Operation [kW]			
	Existing System	**Scenario 1**	**Scenario 2**
Electric Load [kW_e]	142.8	142.8	142.8
Conventional heating [kW_{th}]	641.4	401.7	220.9
Solar thermal heating [kW_{th}]	0.0	242.5	133.3
Conventional cooling [kW_e]	206.2	128.6	112.1
Solar thermal cooling [kW_{th}]	0.0	77.0	93.4
Solar contribution (%)	**0%**	**32%**	**32%**
Total Capacity - Solar System [kW_{th}]	0.0	319.4	226.6
Total Capacity - Conventional Systems [kW]	**847.7**	**530.3**	**332.9**
Total Energy Consumption [kW]	990.4	992.5	702.3

		Current System	**Scenario 1**	**Scenario 2**	**Literature**
Specific Energy Consumption [MJ/kg]	**Milk**	0.339	0.324	0.218	0.3-0.8 [4]
	Yogurt	0.659	0.658	0.576	0.47-1.2 [4]
	Cream	0.390	0.389	0.268	0.18-1.0 [4]

Conclusion & Future Work

- A STE system was integrated to a dairy industry using ASPEN Plus software.
- Two integration scenarios of the STE system were developed as a direct heating and cooling systems
- In both cases the solar system was set to supply 32% of the industries load to meet EU's 2030 climate & energy framework target.
- Results showed that scenario two was more energy efficient compared to scenario one
- The specific energy per kg of milk, yogurt and cream produced was found to be 0.22, 0.58 and 0.27, respectively, for scenario one which was consistent with the literature

Future work

- Consider more STE integration scenarios
- Access economic and environmental aspects

References

1 Lauterbach C, Schmitt B, Jordan U, Vajen K. The potential of solar heat for industrial processes in Germany. Renewable and Sustainable Energy Reviews [Internet]. 2012 [cited 16 September 2021];16(7):5121-30. Available from: https://doi.org/10.1016/j.rser.2012.04.032

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4 Carlsson-Kanyama, A. and Faist, M. (2000). Energy use in the food sector: adata survey. Swedish Environmental Protection Agency. http://citeseerx.ist.psu.edu/viewdoc/download?rep=rep1&type=pdf&doi=10.1.1.205.8375

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Thank you for your attention!
Any questions