XIII JORNADA DE JÓVENES INVESTIGADORES/AS DEL I3A

Instituto Universitario de Investigación en Ingeniería de Aragón
Universidad Zaragoza

Techno-economic assessment of a solar-driven polygeneration system for agri-food industries

ARIF, M. N.; PINA, E. A.; SERRA, L. M. and LÁZARO, A.

Thermal Engineering and Energy Systems Group (GITSE), Aragón Institute of Engineering Research (I3A), Department of Mechanical Engineering, University of Zaragoza, Spain

email : marif@unizar.es

INTRODUCTION

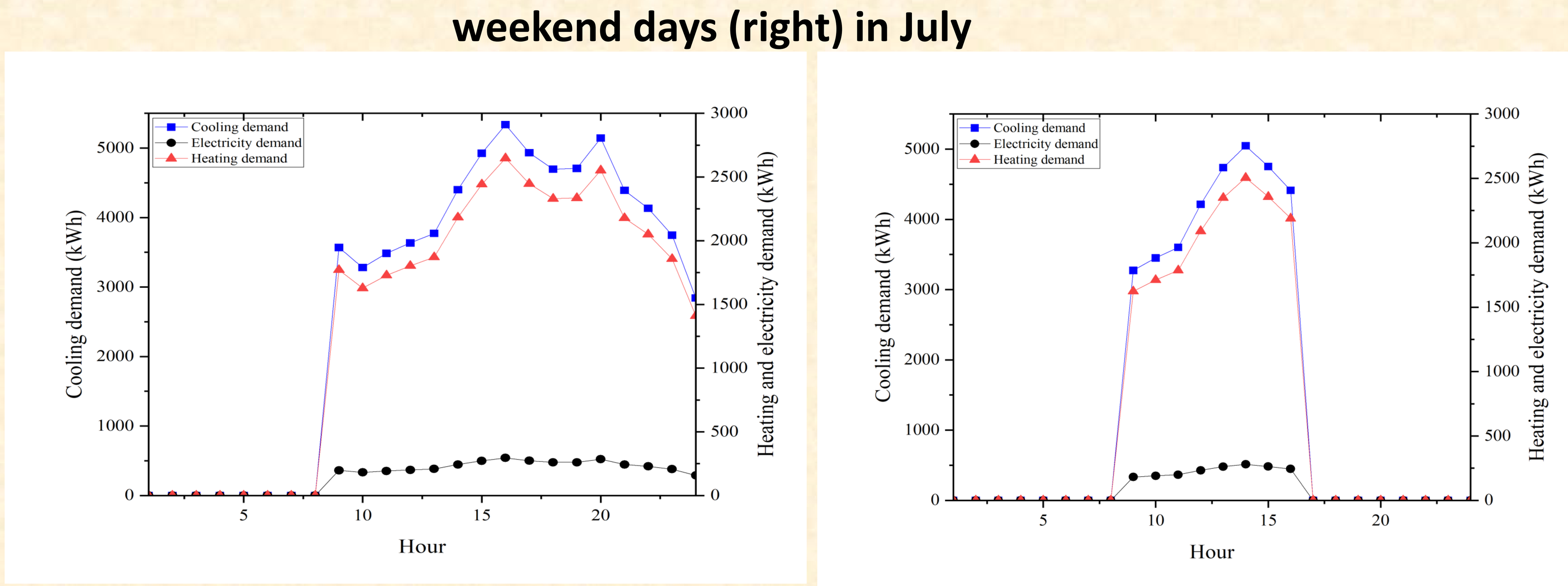
The performance of an optimized solar-driven polygeneration system for a dairy industry located in Tauste, Spain, is examined by integrating different technologies to produce heating, cooling and electricity. The considered technologies in the studied system include parabolic trough collectors, Organic Rankine Cycle, auxiliary boiler, mechanical chiller and thermal energy storage. The system is connected to the electrical grid selling the surplus of electricity produced and purchasing the required electricity, when needed. The techno-economic performance of the proposed system, as well as its environmental benefits, were carried out by properly examining its physical behavior throughout the year.

ENERGY DEMANDS

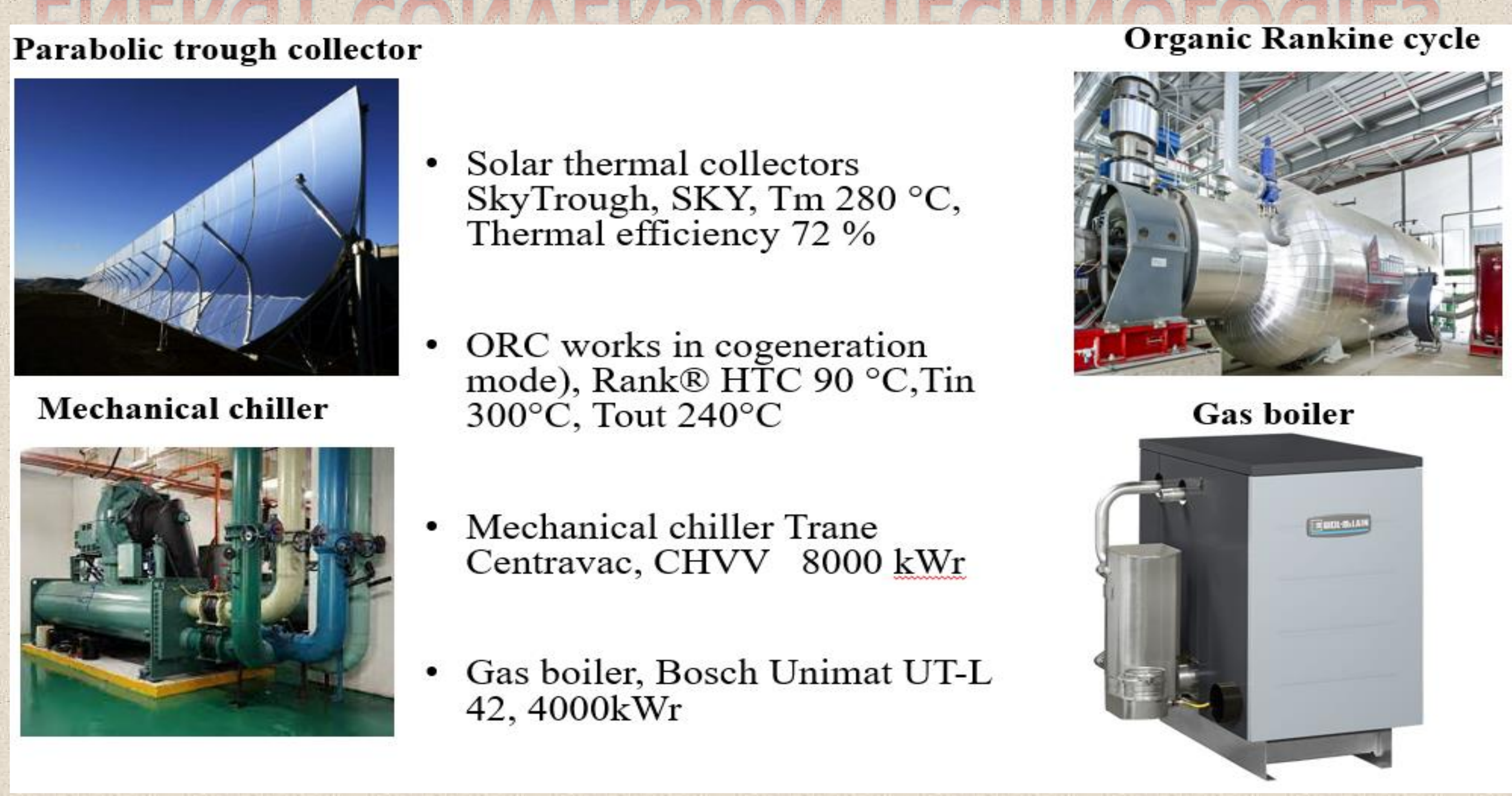
- The dairy industry plant is open 16 hours per day for weekdays and 8 hours per day for weekends. The required temperature for hot water is 90^{o}C, and chilled water is 7^{o}C.

	Annual demand , MWh	Peak demand, kW
Electricity	2328	723
Heating	11376	3533
Cooling	22932	7124

Hourly cooling, heating and electricity demands of the dairy industry for working days (left) and weekend days (right) in July



ENERGY CONVERSION TECHNOLOGIES

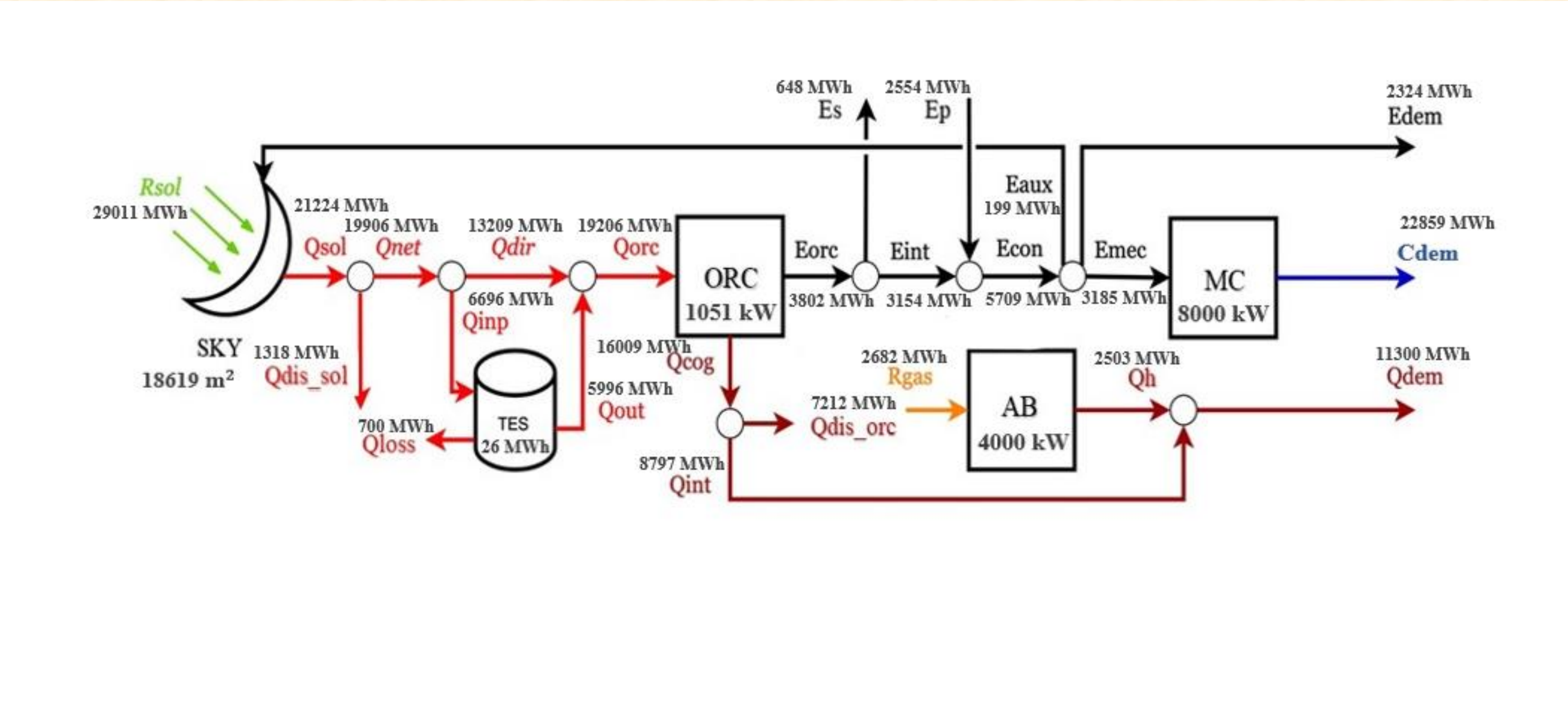


TECHNICAL SPECIFICATIONS

Technologies	Sky Trough (SKY)	Organic Rankine Cycle (ORC)	Mechanical chiller (MC)	Auxiliary boiler (AB)	Thermal energy storage (TES)
Unit Investment cost	400 €/m^2	2100 €/kW	140 €/kW	90 €/kW	65 €/kWh
Carbon emissions	126 kgCO$_2$/m^2	190 kgCO$_2$/kWh	72 kgCO$_2$/kW	10 kgCO$_2$/kW	210 kgCO$_2$/kWh

Solar system
Average electricity cost = 0.210 €/kWh
Natural gas cost = 0.11 €/kWh

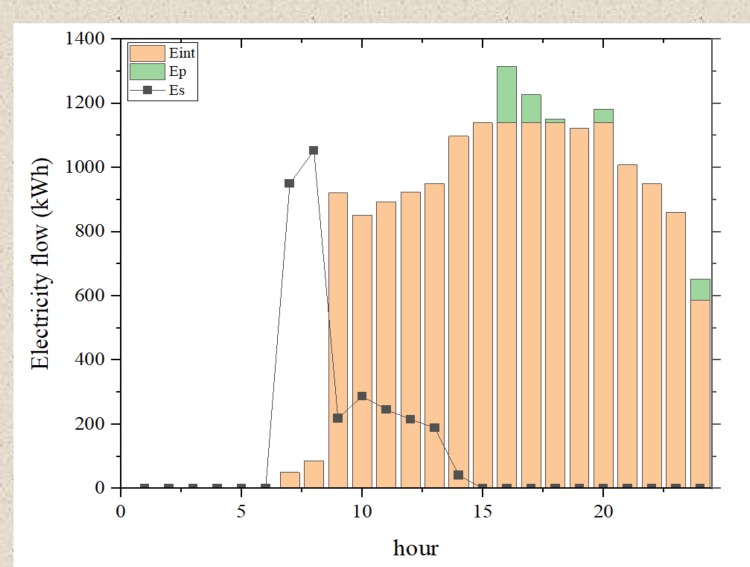
SOLAR SYSTEM MODEL

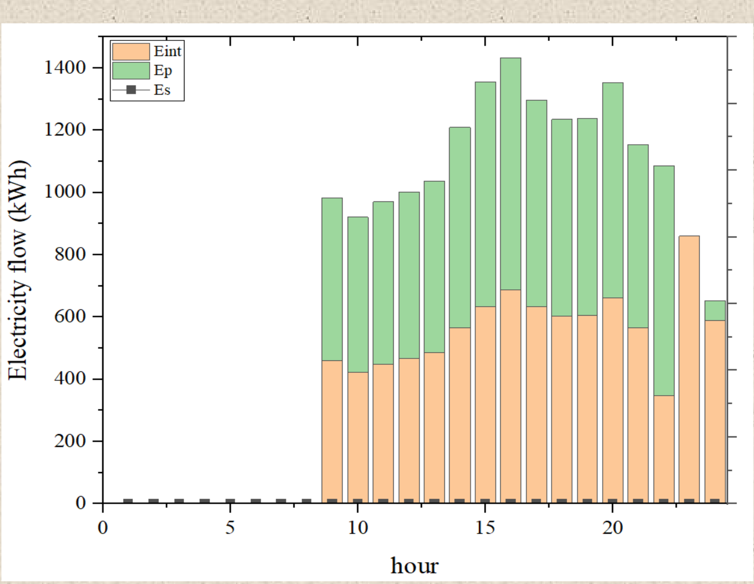


SYSTEM OPERATION

- The solar collector produces high-temperature heat at an average temperature of 280 °C to drive the ORC, which operates in cogeneration mode producing electricity (for the electricity demands and the mechanical chiller) and heat.
- Excess solar heat can be stored in the TES unit or dissipated to the environment.
- The pre-design of the the system has been made through a mixed-integer linear programing (MILP) model which has been developed by using LINGO software to minimize the total annual cost of the system.
- The model determines the capacities of SKY, TES and ORC. The installed capacities of MC (8000 kW) and AB (4000 kW) are fixed and have been sized to provide the energy demands when the solar system is not operative.
- The total annual cost is calculated as the sum of the annual investment cost and the annual operation cost of the system. The objective function is subject to restrictions like capacity limits, production constraints and energy balances.

HOURLY ELECTRICITY FLOWS ON WORKING DAYS IN JULY (LEFT) AND DECEMBER (RIGHT)





CONCLUSIONS

- The study analysed the performance of SDPS for a dairy industry located in Tauste, Zaragoza, Spain.
- The optimization results showed that the proposed SDPS has a solar fraction of 63.3% with a lower cost (close to 30%) and lower greenhouse gas (GHG) emissions (close to 70%) as compared to the conventional energy supply system.

ACKNOWLEDGEMENTS

This work has been partially funded by the research projects PID2020-15500RB-I00, MCIN/ AEI/10.13039/501100011033,/10.13039/501100011033, and by the European Union "NextGenerationEU"/PRTR" PID 2020-15500RB-I00, TED2021-131061B–C31, the Government of Aragon (Ref: T55-23R) and the European Regional Development Fund (ERDF). Eduardo Pina acknowledges thanks the Ministry of Science, Innovation and Universities of Spain and the European Union "NextGenerationEU".

Instituto Universitario de Investigación en Ingeniería de Aragón
Universidad Zaragoza

GITSE Thermal Engineering and Energy Systems
Aragón Institute of Engineering Research
University Zaragoza