'Solar thermal energy makes it possible to produce cold from hot.'

Food and Beverage sector

TRL 6/7 to 9

Alternative refrigeration technologies (solar cooling)

Under the pressure of environmental protection and to help reducing the usage of fossil fuel, the refrigeration driven by solar energy has become one of the promising approaches to reduce or partially replace conventional refrigeration systems. The technology is almost mature to compete with conventional cooling equipment but remains highly dependent on climatic conditions.

Solar cooling can be obtained by various technologies. The two main commercial options are:

- photovoltaic driven vapour compression chillers
- heat driven cooling machines fed by solar collectors

Main NEBs (Other Benefits)

Energy substitution
Decarbonised energy used

Solar electric refrigeration

Solar cooling systems can be classified into two main categories according to the energy used to drive them: solar thermal cooling systems and solar electric cooling systems.

In solar electric cooling systems, electrical energy that is provided by solar photovoltaic (PV) panels is used to drive a conventional electric vapor compressor air-conditioning system. Both types of solar cooling can be used in industrial and domestic refrigeration and air-conditioning processes, with up to 95% saving in electricity.

In solar thermal cooling systems, the cooling process is driven by solar collectors collecting solar energy and converting it into thermal energy and uses this energy to drive thermal cooling systems such as absorption, adsorption, and desiccant cycles.

Electricity-driven solar refrigeration systems

In general, solar electrical cooling systems consist of two parts: photovoltaic panel and electrical refrigeration device.

Photovoltaic cells transform light into electricity through photoelectric effect. The power generated by solar photovoltaic panel is supplied either to the vapor compression systems, thermoelectrical system, or Stirling cycle.

This solution is quite easy to implement and can feed other energy uses in Zuzwil (Switzerland), a supermarket chain has operated Switzerland's first "positive" energy supermarket since November 2015. A success made possible by the design of the store and the installation of solar panels on the roof.

In the first full year of operation, 113% of the energy needed for this 995 m² supermarket was produced by solar panels installed on the roof.

This supermarket consumes around 40% of the electricity daily produced on its roof and injects the rest into the grid. Conversely, it draws current from the Swiss electricity network when solar power is not enough, especially in winter and at night.

Solar thermal cooling systems

Solar thermal systems use solar heat rather than solar electricity to produce refrigeration effect.

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A solar collector provides heat to the "heat engine" or "thermal compressor" in a heat-driven refrigeration machine. The efficiency of a solar collector is primarily determined by its working temperature. At a higher working temperature, the collector losses more heat to ambient and delivers less heat. On the other hand, the heat engine of thermal compressor generally works more efficiently with a higher temperature. A solar thermal system is designed in consideration of these two opposing trends.

Different technologies of solar thermal refrigeration exist:

- **Thermo-mechanical refrigeration:** a heat engine converts solar heat to mechanical work, which in turn drives a mechanical compressor of a vapour compression refrigeration machine. This system is likely more expensive than a solar electric refrigeration system.

- **Sorption refrigeration:** uses physical or chemical attraction between a pair of substances to produce refrigeration effect. A sorption system has a unique capability of transforming thermal energy directly into cooling power. Among the pair of substances, the substance with lower boiling temperature is called sorbate (plays the role of refrigerant) and the other is called sorbent.

The sorption systems can be subdivided into different technologies bases on different physical principles: absorption systems and physical or chemical adsorption systems.

- **Desiccant cooling** (or open sorption cooling): in a liquid desiccant cooling system, the liquid desiccant circulates between an absorber and a regenerator in the same way as in an absorption system. Desiccant dehumidification offers a more efficient humidity control than the other technologies. When there is a large ventilation or dehumidification demand, solar-driven desiccant dehumidification can be a very good option.

Conclusions on solar refrigeration

A variety of options are available to convert solar energy into refrigeration. Although their level of maturity varies significantly and their average cost is higher than "classic" refrigeration solutions, those systems present a real interest to decarbonise the energy used for cold production.

Lots of applications are already commercialised such as solar cold rooms or solar refrigeration food trucks.

It is to be noted that, before choosing a solar refrigeration technology, an alternative cold production unit or significant storage capacities have to be anticipated, as those systems highly depend on climatic conditions.

Opportunities and barriers to implementation

Opportunities	*Barriers*
Energy substitution using solar energy instead of fossil fuel	More expensive than conventional refrigeration process
Electricity saving compared to conventional technology	Depend on climatic conditions
Decrease electricity consumptions cost	Level of maturity varied
Panels easy to implement	Need to an alternative cold production in case of bad weather
	Low energy storage capacities

References

[1] Solar cooling technologies, S. Ajib and A. Alahmer

[2] Solar refrigeration options – a state of the art review, D.S Kim and C.A. Infante Ferreira

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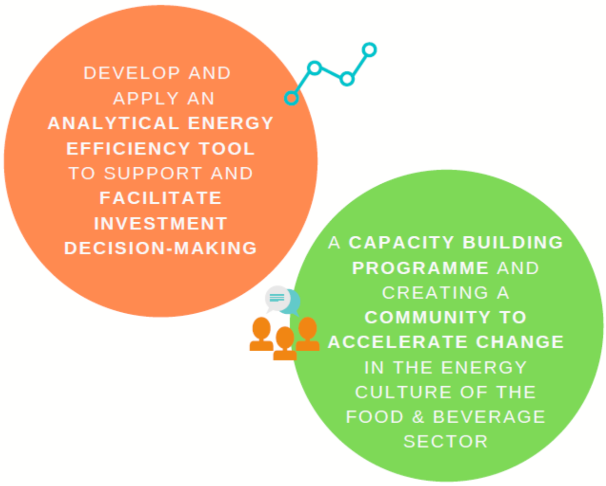
Improving Cold Chain Energy Efficiency in food and beverage sector

About ICCEE

The project ICCEE, www.iccee.eu, funded by the EU programme Horizon 2020, aims at improving energy efficiency in the cold chain of the food & beverage sector and making it easier for the sector to:

- undertake energy efficiency measures across the entire supply chain and
- accelerate the implementation of energy audit results.

ICCEE follows a holistic approach that moves from a single company perspective to the assessment of the entire cold supply chain. Existing financing schemes for SMEs will be assessed: the optimal ones will support the implementation of energy efficiency measures. ICCEE objectives build on 2 pillars:



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