ICCEE
Improving Cold Chain Energy Efficiency in food and beverage sector

BEST PRACTICES – ENERGY GENERATION
FACTSHEET

Energy storage systems

The sustainability and high performance of the refrigerated space used for the preservation of the food products is an essential part of conservation techniques that reduce the environmental impact. The concept encompasses a variety of techniques including electrical (EES) and thermal energy storage (TES) systems, which recently gathered a large interest among the energy market.
By using EES and TES as part of an integrated system, overall efficiency can be improved resulting in less energy expenditure. They have a key role in increasing the hosting capacity of renewables overcoming their main drawbacks (i.e. intermittency and uncertainty).
These solutions decrease energy consumption, reduce carbon emissions, and saves money. They also lead to increased share of self-consumption and improved reliability.

'Reaching the energy independence'

TRL 9

Main NEBs (other benefits)

Reduced carbon emissions
Increased host capacity of RES
Increased self-consumption
Improved reliability

Description

In recent years, Distributed Generation (DG) from Renewable Energy Sources (RESs) equipped with Energy Storage System (ESS) has received an increased attention due to the growing pressure towards a more sustainable and decarbonized energy system. ESS solutions are recognized as a key technology for overcoming, or at least mitigating, the main drawbacks of renewable energy caused by its intermittency and uncertainty since they allow to store energy and release it when needed. These devices can also increase the hosting capacity of RESs, the reliability of distribution systems, and share of self-consumption of energy prosumers.

What is the improvement focus?

Energy storage systems are deployed to overcome the mismatch between demand and supply of electrical or thermal energy and thus they are important for the integration of renewable energy sources.
The most promising ESSs for the cold chains are electrochemical (e.g., batteries) and thermal energy storage systems. If the system includes a battery, the operating voltage of the PV module will be controlled by the voltage of the battery. The battery will also serve as a buffer, making it possible to store the electricity generated by the PV panels for later periods. However, the addition of a battery increases the cost and complexity of the system and reduces its steady-state efficiency. In addition, electrical storage may not be needed in a solar refrigeration system as thermal storage (e.g. ice or other low-temperature storage mediums) may

be more efficient and less expensive [1].

Benefits

Energy storage technologies can support energy security and climate change goals by providing valuable services in developed and developing energy systems. A systems approach to energy system design will lead to more integrated and optimised energy systems. Energy storage technologies can help to better integrate electricity and heat systems and can play a crucial role in energy system decarbonisation by [2]:

- improving energy system resource use efficiency
- helping to integrate higher levels of variable renewable resources and end-use sector electrification
- supporting greater production of energy where it is consumed
- increasing energy access
- improving electricity grid stability, flexibility, reliability and resilience.

From the viewpoint of companies, ESS can be used for time shifting and peak shaving purposes leading to relevant cost savings, and as an emergency power supply.

ESSs allow to shift refrigeration loads from peak to low consumption periods, increasing the self-consumption share and reducing the environmental impacts and economic costs due to the lower purchase of energy generated from fossil fuels

Electrical Energy Storage

The main applications of EESs (i.e., load shifting and peak shaving) allow to shift refrigeration loads from peak to low consumption periods, increasing the self-consumption share and, consequently, reducing the environmental impacts and economic costs due to the lower purchase of energy generated from fossil fuels [3]. However, the benefits introduced, and the return of the investment are strictly dependent on the electricity tariff [4]. Despite the growing maturity and availability, the improved reliability, and the more cost- competitiveness, the diffusion of these new technologies has still to overcome the resistance of several barriers to become fully spread solutions, such as the lack of knowledge and awareness and other social, organizational or political factors [5].

Thermal Energy Storage

Thermal energy storage (TES) is a highly effective way of reducing the 24/7 energy consumption of the cold chain. TES acts like a battery for refrigeration systems, using phase change material (PCM) to store thermal energy in the form of cold for future use. TES modules containing PCM are placed above the storage racking so that they are above the product and are also placed inside the air stream of the evaporator fans. This allows heat to flow via convection to the TES when the air units are off. Once the ES reach their thermal capacity absorbing heat, the air flow from the evaporator fans can efficiently and directly cool the calls back to the solid state. The PCM in the TES system provide latent heat capacity to the refrigerated environment, allowing the TES to absorb a large amount of thermal energy from the surrounding environment while remaining at the same temperature. This allows the refrigerated environment to maintain a cold operating temperature for an extended time period without running the mechanical systems.
For example, during off-peak hours, a facility’s existing refrigeration equipment freezes the PCM. During peak hours, a facility can dramatically reduce the mechanical run time of its costly refrigeration systems and rely on the PCM to stabilize room temperatures and ensure food quality is not compromised. During these extended periods, the PCM absorbs up to 85 percent of all heat infiltration in the freezer, maintains 38 percent more stable temperatures to ensure food quality and safety, and helps avoid up to 90 percent of peak period consumption. Additionally, TES can integrate with renewable power sources like solar to reduce overnight grid power up to 95%. This helps facilities further reduce their grid-based energy consumption and contribute to corporate sustainability and renewable energy goals, a win for the planet and the bottom line.

Cryogenic Energy Storage

The need to increase energy system flexibility, alongside the need to lower fossil fuel use in the food sector, and the importance of refrigeration infrastructure presents an opportunity for Liquid Air Energy Storage (LAES) [6].
Amongst the numerous methods to store energy, Cryogenic Energy Storage (CES) is a known, but still

rather undeveloped and unexploited thermal energy storage principle, which is coming again in favour due to its attractive features and advantages [7]. At low power demand, CES systems use electricity from RES or the grid to liquefy air (as a mixture or separate nitrogen, oxygen and argon) and to store the liquefied cryogen in a large insulated vessel at very low (cryogenic) temperatures. It can be recalled that, at atmospheric pressure, liquid nitrogen (constituting approx. 78% of the air content) has a boiling point of -195.8 °C, while liquid oxygen (approx. 21% of the air content) boils at -183 °C. The latent heat of vaporization is 200 kJ/kg for N_2 and 213 kJ/kg for O_2. In several applications, a sensible heat of up to 160 kJ/kg can also be exploited.
CES is a promising technology enabling on-site storage of RES energy during periods of high generation and its use at peak grid demand. Thus, CES acts as grid energy storage, whereas at peak demands liquid cryogen is boiled (with an over 700-fold expansion in volume) to drive a turbine and to restore electricity to the grid.
Hence, the principle of Cryogenic Energy Storage (CES) is simple and logical:

- During periods of low-power demand and low energy price, a cryogenic gas is liquefied and stored in a well-insulated vessel (charging period).
- During times of high-power consumption and high energy price, the liquefied cryogen is pumped and expanded to drive a generator of power which is restored to the electrical grid (discharging period).

To date, CES applications have been rather limited by the poor round-trip efficiency (ratio between energies retrieved from and spent for energy storage) due to unrecovered energy losses. In fact, the liquefaction of a unit mass of cryogen currently consumes much more energy than its evaporation can deliver.
The CryoHub[1] project recently investigated the potential of large-scale cryogenic energy storage at refrigerated warehouses and food factories, thereby capturing and utilising the vast amount of cryogenic cold released when boiling the stored liquid cryogen (in combination with RES integration and waste heat recovery). This extra cooling potential eases the functioning of existing refrigeration plants by providing substantial part of the refrigeration capacity needed to maintain the desired low temperatures in storage warehouses for chilled or frozen foods.
Furthermore, integrating CES into food processing or preservation facilities is a novel and attractive means for fostering the growth of the RES sector, revealing also a substantial potential to improve efficiency [7].

[1] CryoHub “Cryogenic Energy Storage for Renewable Refrigeration and Power Supply” (2015) Horizon 2020 Project No. 691761

Opportunities and barriers to implementation

Opportunities	*Barriers*
Reduced energy bill	Investment cost
Reduced carbon emissions	
Increased host capacity of RES	
Increased self-consumption	

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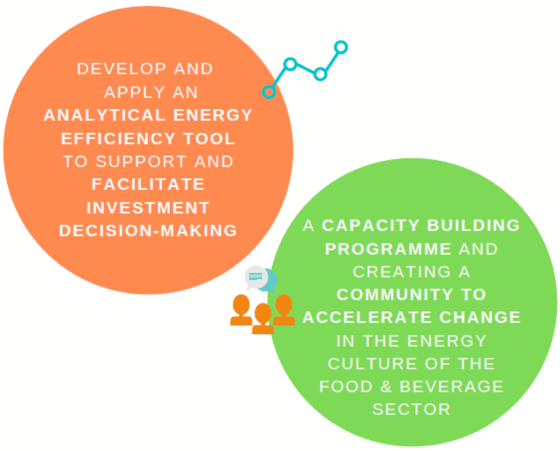
About ICCEE

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
- to 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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