ICCEE

Improving Cold Chain Energy Efficiency in food and beverage sector

Grant Agreement N° 847040



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Main report on supply chain energy impact analysis and best practices

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Project Coordinator: Simone Zanoni, University of Brescia, simone.zanoni@unibs.it

Authors: Simone Zanoni and Beatrice Marchi, UNIBS

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Project information

Project Title	Improving Cold Chain Energy Efficiency
Project Acronym	ICCEE
Project Number	847040
Project dates	September 2019 – August 2022
Abstract	The ICCEE (Improving Cold Chain Energy Efficiency) project will facilitate Small and Medium Enterprises (SMEs) in the cold chains of the food and beverage sector to undertake energy efficiency measures (EEMs) after carrying out supply chain energy audits. The focus on the cold chains of the sector is due to the significant energy requirements (refrigerated transport, processing and storage) with large potentials for savings. The implementation of the holistic approach, shifting from the single company perspective to the chain assessment, lead to increased opportunities for EEMs. To enable the update of EEMs, ICCEE will a) implement and apply an analytical energy efficiency tool to support and facilitate decision-making at different company organisational levels and b) launch a capacity building program towards staff and relevant stakeholders and a community dedicated to support a change in energy culture of the sector. The feasibility of EEMs will be evaluated by considering economic, environmental and social impacts encompassing their entire life cycle and the entire supply chain. Non-energy benefits and behavioural aspects will also be addressed and recommendations on financing schemes for SMEs will be assessed. The first part of the trainings will reach 300 companies through 20 national workshops thanks to the collaboration of associations in the consortium. 32 companies will be trained for the use of the tool in 4 EU workshops. At a final step, ICCEE will launch e-learning courses, which will be available also beyond the project's lifetime reaching at least additional 64 companies. ICCEE will introduce primary energy savings (118 GWh/year), increase invested capital in sustainable energy (64 million €), and reduce GHG emissions (40,376 tonCO2/year). Capacity building activities allow to increase stakeholders' knowledge and enhance their energy culture (2000 people). Outcomes from ICCEE will also support policymakers in defining tailored policies for the sector.

Rev.	Written by	Date	Checked by	Date
1.0	Simone Zanoni (UNIBS) Beatrice Marchi (UNIBS)	19/05/2020	Madeleine Alphen (ATEE)	25/05/2020
2.0	Simone Zanoni (UNIBS) Beatrice Marchi (UNIBS)	24/06/2020	Sibylle Brière (ATEE)	02/07/2020

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About

The project Improving Cold Chain Energy Efficiency (ICCEE) will accelerate turning energy efficiency opportunities of small and medium sized enterprises (SMEs) of the sector into actual investments and create a clear understanding of the opportunities offered by improving energy efficiency for companies' staff.

The specific objectives of ICCEE are:

1) Implement and apply an analytical energy efficiency tool to support and facilitate the decision-making processes of the companies in the supply chains in assessing their current energy performance of the supply chain,

2) Identify the energy saving potential of companies and support investments in viable energy efficiency improvement measures,

3) Create a capacity building programme and a community dedicated to support the change in the energy culture of organizations improving their energy performance through direct training and the development of an e-module.

ICCEE will make it easier for SMEs in the cold chains of the food and beverage sector to undertake energy efficiency measures (EEMs) after carrying out supply chain energy audits.

Focus on the cold chains was decided due to the significant energy requirements (refrigerated transport, processing and storage) of the sector, with large potential for savings. The cold supply chain is among the most energy-intensive systems within the food and beverage sector whilst there is limited understanding of its large energy efficiency potential and the economic advantages that can be obtained from energy saving measures.

The implementation of a holistic approach, shifting from the single company perspective to the chain assessment, leads to increased opportunities for EEMs.

ICCEE is coordinated by the University of Brescia with 12 partners: IEECP, FIRE (Federazione Italiana per l'uso razionale dell'energia), Adelphi Research Gemeinnützige, ATEE (Association Technique Energie Environnement), Fraunhofer, Riga Technical University, ESCAN, SPES GEIE, ECSLA, Chamber of Korinthia, University of Stuttgart, and Romalimenta.

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Foreword

The focus of the present report is on:

- the definition of the boundaries of the cold chains of the different products with details on the temperatures and actors characterizing the different stages involved in the production and supply of the goods;
- the development of a model supporting the energy consumptions analysis through the supply chain determined by the refrigeration requirements of both storage and transportation activities, and quality losses;
- the investigation of the main best practices among the energy efficiency measures for the improvement of the energy performance of the supply chain.

1. Supply chain definition

The supply chain is the series of processes involved in the production and supply of goods, from when raw materials are firstly made until final goods are bought or used (i.e., "from farm to fork"). These processes are managed by a set of companies operating with different purposes and at different stages, thus creating a network.

The "cold chain" refers to the various stages that a refrigerated product passes through. From the moment a fruit or vegetable is harvested, or an animal is slaughtered, the product starts to deteriorate. The deterioration of a product can be slowed by reducing the temperature at which it is stored.

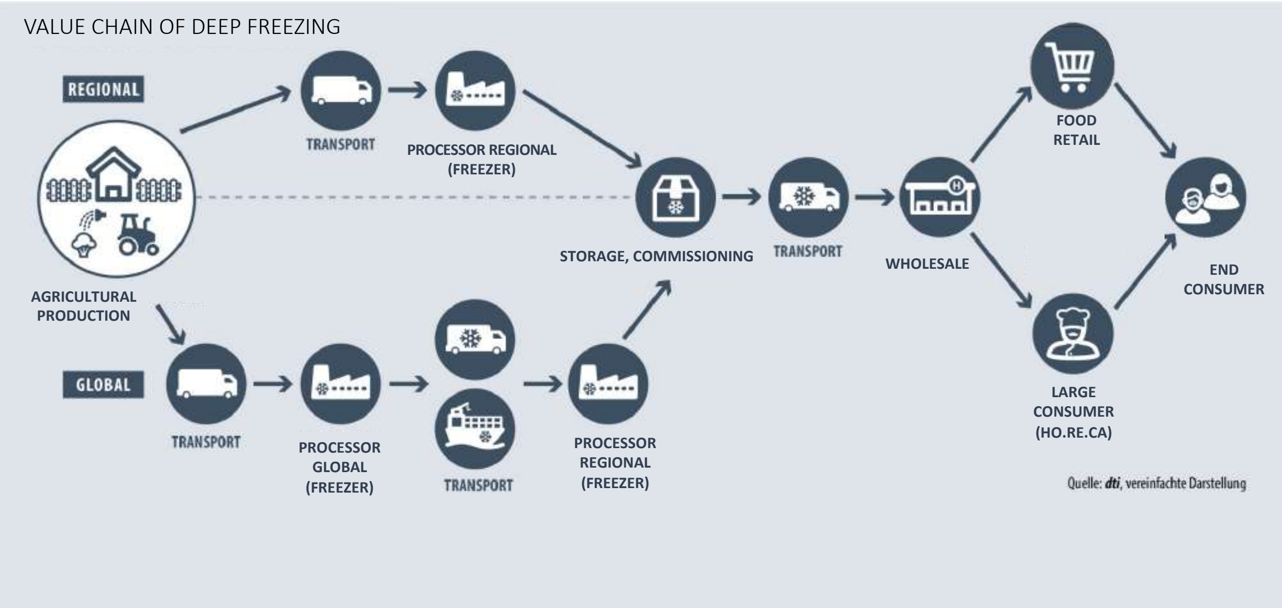

Figure 1. Value chain of deep freezing [1]

The focus of ICCEE project is on Small and Medium Enterprises (SMEs) operating in cold chains of the food and beverage sector. Nevertheless, supply chains can also include large companies, which may drive other partners' (e.g., raw material suppliers, retailers, …) focus on energy efficiency solutions/technologies/strategies.

The focus will be on the stages with temperature control requirements, hence the stages of the supply chain that will be taken into account strictly depend on the specific category of product concerned. In particular, the energy performance of the logistic activities (e.g., refrigerated transport, cold warehouses) will be the main focus of the assessment, since

[1] https://www.tiefkuehlkost.de/tk-fuer-alle/nachhaltigkeit-qualitaet/nachhaltigkeit-tk/tk-kette

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energy consumptions of production processes are dependent on the specific product considered.

2. Temperature requirements

In the table below, the maximum temperature levels at all process steps for different products categories, defined through Regulations, characterizing the different stages and activities of the supply chains considered and determining the required refrigeration loads are shown.

Category	Product	Supplier	Transport	Producer		Transport	Retailer
		Storage		RM storage	FP storage		Storage
Beverages	Smoothies from frozen raw materials	-18 °C (± 3°C during transportation)			+4 °C		
	Fresh orange juice	+8 °C			+4 °C		
Dairy	Cow's fresh milk	+8 °C if daily collection otherwise 6 °C	+10 °C	+8 °C if daily collection otherwise 6 °C	+4 °C		
	Seasoned cheese	+6 °C	+12 °C	+6 °C	Ambient temperature		
Sea Fish	Fresh fish	0 °C					
	Frozen fish	-18 °C (± 3°C)					
Fruit and vegetables	Fresh green peas	+ 8°C			+ 6°C		
	Frozen green peas	+8 °C			-18 °C (± 3°C during transportation, ± 6°C in display cabinets)		
Meat	Prepared beef meat		+7 °C		2 °C for minced meat and + 4 °C for meat preparations		
	Frozen beef meat		+7 °C		-18 °C		

Regulation (EC) 853/2004; Council Directive 21 December 1988 (89/108/EEC); Italian Decree; ATP Agreement; German standard (DIN 10508)

Table 1. Temperature requirements for different stages in supply chains

3. Model definition

The model developed is mainly defined by three sub-models: (i) energy requirement in storage activities, (ii) energy requirements in transport activities, and (iii) time-temperature effects on the food quality and consequent energy consumption. The aim deals with the minimization of the overall specific energy consumption.

The model will also allow to compare the energy performance of the optimal management, defined in the following inventory model, and the actual management of the supply chain. Specifically, the optimal inventory management deals with the minimization of the storage time of the lot at each stage avoiding any inefficiencies (e.g., waiting time for unloading activities of vehicles).

3.1. Storage activities

The specific energy consumption of a warehouse can be defined as follows:

$$SEC\ (\frac{kWh}{m^3 year}) = \frac{energy\ use\ (kWh/year)}{warehouse\ size\ (m^3)} \quad (1)$$

It should be noted that the annual energy use is given by the contribution of different energy carriers for refrigeration purposes, such as electricity, natural gas, diesel, etc., since the production processes are out of the scope of this study. These contributions are normalized in equivalent energy use through the related kWh conversion factors.

The SEC of the storage activities per unit of product, however, is related to the space utilization of the product, i.e. $\alpha\ (kg/m^3)$, and the storage time, $\tau\ (year)$.

$$SEC\ \left(\frac{kWh}{kg}\right) = \frac{energy\ use\ \left(\frac{kWh}{year}\right)}{warehouse\ size\ (m^3) \cdot \alpha\ \left(\frac{kg}{m^3}\right)} \cdot \tau\ (year) \quad (2)$$

The storage time can be defined through the inventory turnover ratio if no inefficiencies are considered. Specifically, the days of inventory (DSI), i.e. the inverse of the inventory turnover, looks at the average time a company can turn its inventory into sales.

$$DSI\ (days) = \frac{average\ inventory\ level\ (kg)}{consumption\ rate\ (kg/year)} \cdot 365 \quad (3)$$

Figure 2 illustrates the behavior of inventory at the raw material supplier, producer and the retailer warehouses, and that of the items stocked on shelves in the retailer's display area.

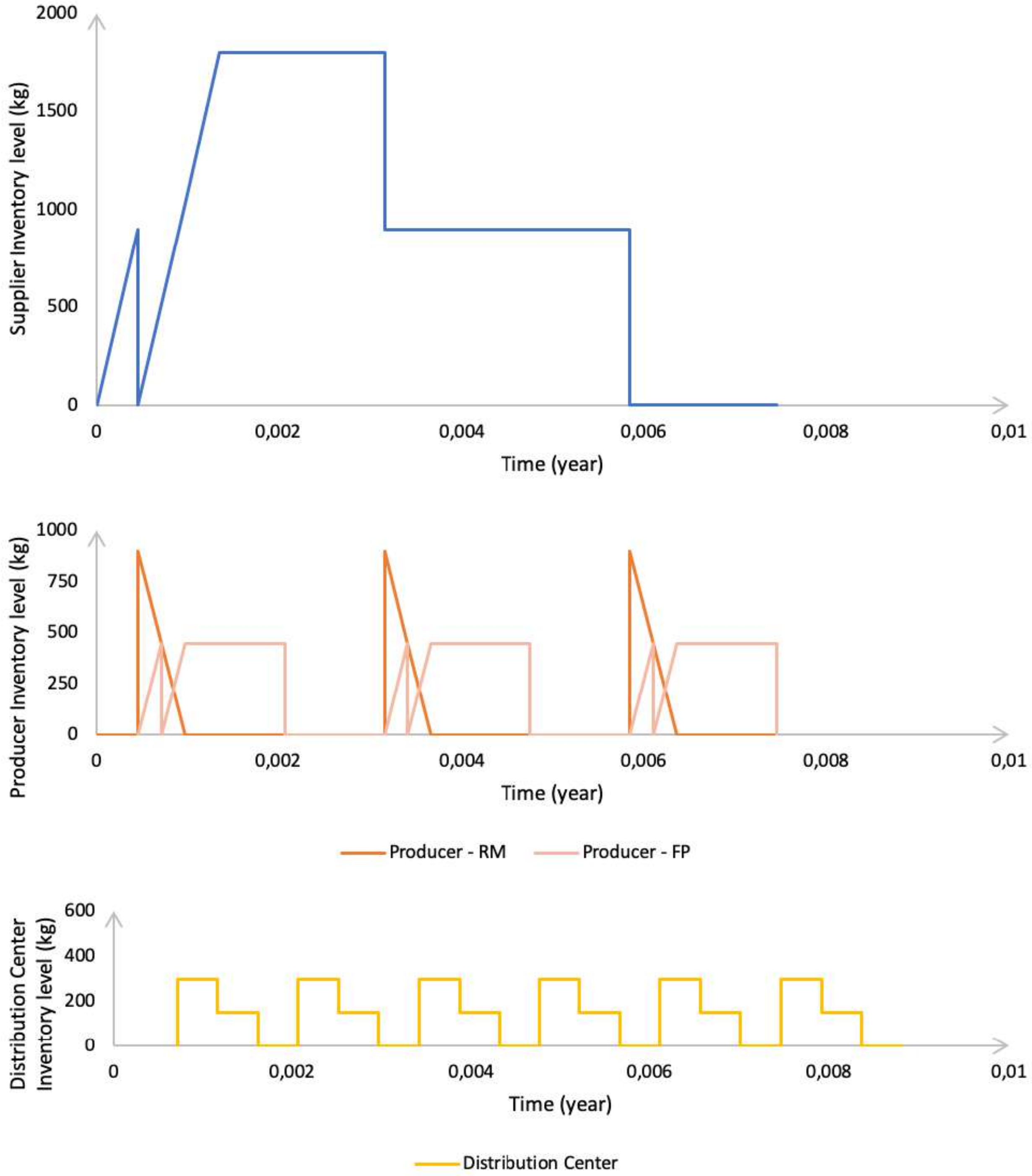

Figure 2. Inventory level over time of the different warehouses in the supply chain

From the inventory level trend, the average inventory levels of the different warehouses in the supply chain are defined as follows:

Raw material supplier	$AIL_S = \frac{\alpha q}{2}\left(\frac{D n_P n_{DC} n_R (2-n_S)}{P_S} + n_P n_{DC} n_R n_S - 1\right)$	(4)
Producer (RM–raw material)	$AIL_P^{RM} = \frac{n_P n_{DC} n_R \alpha q}{2}$	(5)
Producer (FP- finished product)	$AIL_P^{FP} = \frac{q}{2}\left(\frac{D n_R n_{DC} (2-n_P)}{P_P} + n_P n_{DC} n_R - 1\right)$	(6)
Distribution center	$AIL_{DC} = \frac{(n_R - 1)^2 (n_{DC} + 1) q}{2 n_R}$	(7)
Retailer (Backroom)	$AIL_R^{BR} = \frac{(n_R - 1) q}{2}$	(8)
Retailer (Display area)	$AIL_R^{DA} = \frac{q}{2}$	(9)

Hence, the average storage time becomes:

Raw material supplier	$\frac{AIL_S}{P_S}$	(10)
Producer (RM)	$\frac{AIL_P^{RM}}{P_P}$	(11)
Producer (FP)	$\frac{AIL_P^{FP}}{P_P}$	(12)
Distribution center	$\frac{AIL_{DC}}{D}$	(13)
Retailer (Backroom)	$\frac{AIL_R^{BR}}{D}$	(14)

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Retailer (Display area) $\frac{AIL_R^{DA}}{D}$ (15)

The SEC is affected by the filling level of the refrigerated warehouse, $I(t)$. The formulation of how the utilization rate affects the SEC, defined in equation (16), was based on empirical data and observations.

$$SEC(T_r, I(t), I_{max}) = SEC(T_r, I_{max}) + \delta\left(1 - \frac{I(t)}{I_{max}}\right)^{\gamma} \quad (16)$$

where the first term is given by equation (2), while the second term defines the increase in the specific energy consumption due to the not fully utilization of the warehouse (i.e. when the filling level is lower than 1) which is a function of the two coefficients δ and γ. It should be noted that the filling level is evaluated as the ratio between the volume of the materials in the warehouse requiring refrigeration and the warehouse size.

The specific energy consumption should also be adjusted to consider the actual inside temperature, T_w. In fact, the input data are evaluated for a reference temperature, T_r, and deviations from this value affect the energy consumption: i.e., lower (higher) cooling temperatures increase (reduce) the SEC.

$$SEC(T_w, I(t), I_{max}) = SEC(T_r, I(t), I_{max}) \cdot \rho_{T_w} \quad (17)$$

where $\rho_{T_w} = \frac{COP_{T_r}}{COP_{T_w}}$, and $COP_T = \frac{T_{cold}}{T_{hot} - T_{cold}}$. Specifically, T_{hot} and T_{cold} are the absolute temperatures of the hot and cold heat reservoirs, respectively. For sake of simplicity, it is possible to consider T_{hot} as the average outside environmental temperature at the locations of the cold chain actors in the hottest season, while T_{cold} as the average temperature inside the warehouse.

3.2. Transport activities

The energy consumption of the transportation activities is linked to the power required by the refrigeration and ventilation equipment, and the energy related to the fuel consumption.

$$SEC_{transport} = \frac{n \cdot (P_e \cdot t + \varepsilon \cdot fc)}{Q_i} \quad (18)$$

where fc represents the fuel consumption per trip (lt/trip), ε the fuel conversion factor (kWh/lt), n the number of vehicles needed to transport the ordered lot of size Q_i, P_e the electrical power required to power on the equipment (kW), Q_i the lot size ordered that should be shipped among the different actors, and t the average travelling time requiring refrigeration (h/trip). The number of vehicles per trip depends on the payload of the same vehicle and the lot size.

3.3. Quality losses

The quality degradation of food products depends on the storage time t, the storage temperature T, and additional parameters depending on the storage atmosphere, and can be described as follows:

$$\frac{dq}{dt} = kq^n \tag{19}$$

where q is the quality of the product, k the rate of degradation (depending on the environmental conditions) and n is a power factor defined as the order of reaction, determining how the reaction rate is dependent on the amount of quality remaining.
The link between the rate of quality degradation k and temperature can be expressed with the Arrhenius equation:

$$k = k_0 e^{-(E_a/RT)} \tag{20}$$

where k_0 is a constant, E_a the activation energy [J/kg] (an empirical parameter characterizing the exponential temperature dependence), R the gas constant [J/kg K], and T the absolute temperature [K].
It should be noted that the temperature along the cold chain distribution could not be always uniform. Therefore, the total quality decrease may be related to the original quality and may be determined by summing the quality decrease at every step of the chain (depending on the temperature level at each supply chain step).
The quality level of a product $q(T,t)$ can be defined as:

$$q(T,t) = q_0 e^{-k_0 t e^{-(E_a/RT)}} \tag{21}$$

Peleg et al.[1] proposed a Weibull-power law model to describe the isothermal degradation of food quality, depending on the storage temperature and time:

$$q(T,t) = q_0 e^{-b(T)t^{n(T)}} \tag{22}$$

where $b(T)$ and $n(T)$ are temperature-dependent coefficients. In particular, $b(T)$ can be described by the empirical model as follows:

$$b(T) = \ln\left(1 + e^{m(T-T_C)}\right) \tag{23}$$

where T is the temperature [°C] and m and T_C are constants.

Additionally to the well-known production of methane and other greenhouse gases during food degradation and the societal impact of wasting food in a world where the population is constantly growing and land resources are reaching the saturation point, a relevant consequence of food waste includes the loss of the energy consumed for food processing and storage [2]. Hence, the quality losses obtained from eq. (22) is valued through the overall SEC considering all the supply chain activities from farm to fork, as follows:

$$SEC = \frac{\sum_j SEC_j}{q(T,t)} \tag{24}$$

where j represents the activities of the supply chain, while $q(T,t)$ the quality level at the final step of the supply chain in %.

4. Energy efficiency measures: best practices

Stakeholders of the cold chain are currently implementing actions to fight global warming focusing on two main objectives: (i) the reduction of direct releases of fluorocarbons in the atmosphere mainly due to leakages, and (ii) the improvement of the energy efficiency in order to reduce the primary energy use.

Improvements can range from the investment in new and more performant technologies, which have the potential to reduce energy consumption by 15% – 40%, to the implementation of more straightforward and less expensive maintenance and operational practices for the refrigeration system and the overall production process which can frequently reduce energy costs by 15% or more [3].

Energy efficiency measures (EEMs) have excellent potential for introducing noteworthy economic, environmental, and social benefits. In fact, energy efficiency can deliver a wide range of sustainable benefits in addition to energy savings, namely non-energy benefits [3–5]:

- Increased profitability mainly due to reduced operating costs (e.g., energy and maintenance costs) and increased productivity. Some measures can also provide improved system reliability and a better match between the refrigeration load and the equipment capacity leading to a more efficient system.
- The improved working environment in terms of ergonomics and safety, and reduced impact on the external environment thanks to the lower resources' consumption and greenhouse gas emissions.
- Reduced vulnerability to fluctuations of the energy prices, which may be sensitive to numerous external factors, such as significant weather events and changes in national and local regulations.
- Enhanced public image. Due to the growing concerns of the community over global warming and other environmental issues, players in the cold chain want to demonstrate to customers that they operate in a responsible way aiming at protecting the natural environment through conservation and sustainable practices.
- Increased sales. A more pleasing shopping and working environment and a reduction of the environmental impact of the cold chain can attract and retain more customers, which are more and more environmental-friendly, leading to an increase in sales.
- Reduced spoilage. Upgrades in the refrigeration and lighting systems and better monitoring and management of the time-temperature relationship allow reducing the spoilage of perishable goods while also saving on energy bills. Waste of products entails the loss of the energy consumed for processing and storing the goods, the production of GHGs, such as methane, during degradation, and the societal impact of wasting resources [6].

The EEMs relevant for the cold chains have been grouped into 10 categories (Figure 3): auxiliary technologies, buildings, employee, energy generation and recovery, industrial symbiosis, maintenance, management, monitoring and control, refrigeration system, and transport.

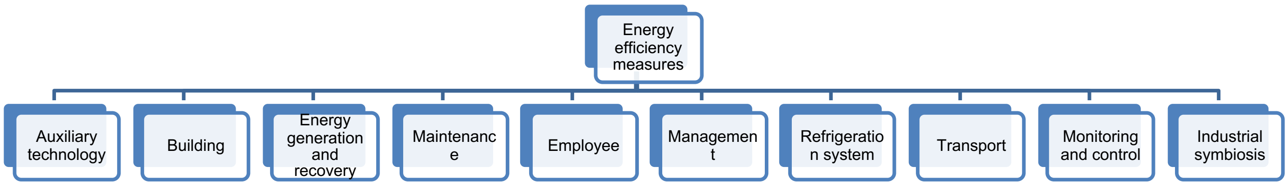

Figure 3. Categories of energy efficiency measures

Each measure is reported in Table 2, and details on specific case studies have been reported in the technical sheets provided in the Annex.

Category	Type of EE-measure
Auxiliary Technology	More efficient ventilation system for cold warehouses
Auxiliary Technology	More efficient lighting system (e.g. LEDs for cold warehouses)
Auxiliary Technology	Efficient motors/filter/pumps/drive systems/steam generator with the appropriate sizing
Auxiliary Technology	Efficient inside refrigerant cycle: compressor, heat exchanger: evaporator, condenser, throttle valves
Building	Improved insulation (e.g., replacement of old windows, removal of thermal bridges, insulation of walls/ceilings/roofs/pipework, reduction of air infiltration of rooms and/or display area, repairing door deals and curtains, ensuring that door can be closed, air curtains on doors)
Building	Warehouse with separated compartments, with automated glide racks
Energy generation /Recovery	Waste heat recovery (e.g., absorption chiller)
Energy generation /Recovery	Renewable energy for electrical and thermal energy (e.g., PV, ST, HP, solar cooling)
Energy generation /Recovery	Energy storage system

Employee	Improved employees' awareness, active engagement, training and education of operators and drivers
Maintenance	Regular cleaning of condensers and evaporator coils
Maintenance	Minimization of compressed air leakages
Maintenance	Review/ optimisation of the cooling distribution system
Management	EMS, energy audit, exploitation of energy benchmarks
Management	Set temperature range for cooling to upper limit, adjustment of cooling temperatures
Monitoring and control	Visualization of EnPis, real-time monitoring system, automated tracing
Monitoring and control	Use of smart heating systems/ automatic/ intelligent control system
Refrigeration System	Less oversized cooling systems
Refrigeration System	Alternative refrigeration technology, design and refrigerant, retrofitting refrigeration display systems, closed display cabinets
Refrigeration System	Refrigerant cycle (e.g., one, two stage, intercooler etc.)
Refrigeration System	Design and usage of free cooling
Refrigeration System	Alternative refrigeration technologies: e.g., solar cooling systems, thermal chillers, heat pumps
Refrigeration System	Retrofit of R22 refrigeration system by centralized ammonia (NH_3) system
Transport	Improved insulation of trucks (e.g., air curtain)
Transport	Fuel monitoring for drivers and training drivers for fuel consumption reduction
Transport	Optimised travel routes (e.g., reduction of empty return trips), modal shift
Transport	Alternate means of transport (e.g. portable refrigerated units for LTL)
Industrial symbiosis	By-product exchanges
Industrial symbiosis	Sharing of infrastructures, utilities or access to services (e.g., energy or waste treatment, biogas)
Industrial symbiosis	Cooperation on issues of common interest (e.g., emergency planning, training or sustainability planning)

Table 2. Energy efficiency measures as best practices for cold chains

Conclusion / Summary / Policy recommendations

This report defines the boundaries of the cold chains of the different products with details on the temperatures and the actors characterizing the different stages involved in the production and supply of the goods.

Then, a model supporting the analysis of the energy consumptions through the supply chain is developed by taking into account the refrigeration requirements and the quality losses of both storage and transportation activities.

Finally, the main best practices among the energy efficiency measures for the improvement of the energy performance of the supply chain are investigated and case studies are provided for each of them.

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Annex 1 – Energy efficiency measures

ICCEE
Improving Cold Chain Energy Efficiency in food and beverage sector

BEST PRACTICES – AUXILIARY TECHNOLOGY
FACTSHEET

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'Reusing waste heat'

Germany
Retail

Investment
450,000 €

Savings
14,500 €/year
81,800 kWh/year

Main NEBs (other benefits)
Reducing greenhouse gas emissions
Environmentally friendly
Customer-friendly climate controlling

Energy efficiency and heat recovery

Using auxiliary technology is one way to improve energy efficiency in businesses. A small supermarket in Germany effectively demonstrated an efficient use of heat energy, by reusing the waste heat from their cooling installations to heat the sales floor of their store. They invested in energy-efficient freezers, with an automatic defrosting system and refrigeration shelves, with an efficient ventilator, a modern refrigerator that uses heat recovery for air conditioning and they installed LED lighting for all the items, as well as for the entire store.

This new system makes it possible to reuse the excess heat from the cooling installations for the climate controlling of the sales floor and thus save a lot of electricity Even in the summer months when the outside temperature reaches above 30ºC, the sales floor temperature can be kept at a pleasant 21ºC, which the modern system manages without technical issues. The store's manager received a prize for his commitment, with the jury praising the measures as an example of how even a small, energy-efficient company can hold its own against larger retail chains if it is economical.

Description

A small supermarket in a medium-sized town in Germany underwent a substantial renovation with the aim of increasing their energy efficiency and contributing to climate protection through a decrease in their electricity consumption. By investing €450,000 in auxiliary technology, such as new cooling installations and heat recovery systems, they managed to halve their energy consumption, while increasing their sales floor from 600 to 930 square meters. In 2018, the store manager was awarded a prize for his commitment to saving energy and contributing to climate protection, and by demonstrating that small companies can be energy efficient in an economical way.

BEST PRACTICES – AUXILIARY TECHNOLOGY
FACTSHEET

Improving Cold Chain Energy Efficiency in food and beverage sector

What is the improvement focus?

The store installed a modern, more energy efficient cooling system, with an energy-saving ventilator. Because cooling installations need to be running continuously with high-duty cycles, energy-saving fans have a high impact on the total energy use of the entire system.

Additionally, the new system is also upgraded with LED lighting. Compared to traditional bulbs, light emitting diodes (LED) typically use about 25%-80% less energy and their lifetime is 3-25 times longer. The main reason that LED lighting is more energy efficient than traditional bulbs is that LEDs emit very little heat, whereas conventional bulbs emit around 80% of their energy as heat. This makes LEDs more suited to cooling installations than traditional bulbs.

The new system is also able to reuse the excess waste heat emitted by the cooling installations to heat the sales floor. The waste heat emitted by the refrigerator is intercepted before it escapes into the atmosphere, and reused to heat water which is used for room heating purposes. This reduces the need for additional energy to heat the water, saves energy and reduces carbon emissions.

Benefits

During the renovation, the sales floor was increased from 600 to 930 square meters, and the refrigerated shelves were extended from 21 to 35 meters. Despite these increases in spaces that need temperature-controlling, the new system has been able to cut the store's electricity use for heating by half, and the electricity consumption for cooling by more than a quarter.

The system is able to keep the temperature of the sales floor at a comfortable 21ºC without technical issues, even in the summer months when the outside temperature can rise far above 30ºC. The investment has thereby led to lower energy costs while preserving the quality of the service.

The improvement of energy efficiency made by using the new refrigeration technology and heat recovery can be implemented in all kinds of supermarkets or other buildings with a refrigeration system. Energy efficient lighting has the potential to save electricity in every building.

Opportunities and barriers to implementation

Opportunities	*Barriers*
Improved costumer experience due to temperature change	Additional costs for renovating
Lower electricity consumption and related cost	Additional costs for new technologies
Cross-business technology	

Calculations

The calculations show a quick idea of the costs and returns of this practice, as well as the economic impact after the implementation of the new equipment. For transparency's sake, the initial situation is directly compared with the final situation and a table of differences is shown broken down into the different key points of savings, using an average price of electricity and emissions taking into account their expected evolution.

	Initial situation	Final situation
Productive capacity	600 m^2	930 m^2
Annual energy consumption [kWh/year]	281,500	199,700
Annual energy cooling consumption [kWh/year]	237,000	185,000
Annual economic energy expenditure [€/year]	50,000	35,500

Total investment (€)	450,000[1]
Energy savings [kWh/year]	81,800

[1] This is the total investment sum. The store received funding for their investment, but there is no data on how much exactly.

BEST PRACTICES – AUXILIARY TECHNOLOGY
FACTSHEET

Improving Cold Chain Energy Efficiency in food and beverage sector

Average electricity price[€/kWh]	0.3147[2]
Average emission price [€/tCO_2]	25[3]
Emission reduction [tCO_2/year]	46.38[4]
Energy economic saving (€)	14,500
Emission economic saving (€)	1,159.50
Total economic savings (€)	15,659.50
Return period (years)	28.7

References

[1] Handelsverband Deutschland: Klimaschutzoffensive des Handels: Erfolgsgeschichten: Nahkauf Schramm, Potsdam. Zuletzt eingesehen am 23.06.2020 unter:

https://www.hde-klimaschutzoffensive.de/de/kampagne/erfolgsgeschichten/nahkauf-schramm-potsdam

[2] This is the average retail electricity price in Germany in 2018.
[3] This will be the carbon price in Germany in 2021.
[4] The carbon intensity of German electricity is 567g/kWh.

BEST PRACTICES – AUXILIARY TECHNOLOGY
FACTSHEET

Improving Cold Chain Energy Efficiency in food and beverage sector

‘Switching lights to LED”

Latvia
Freezing industry
TRL 9

Investment (real or estimated)
26 000 €

Savings
2 883 €/year
17,72 MWh/year

Main NEBs (other benefits)
Reduced greenhouse gas emissions
Longer lifetime of lighting system

Consumption and emissions savings

Company “Rīgas Saldētava” is one of the largest refrigeration storage complexes in Riga. The company offers storage of products at different temperatures in cold stores from -20 °C to +6 °C. Each customer can determine the appropriate temperature for storage. The company has a total of 12 production storage cameras.

The company underwent an energy audit that suggested the switching of lighting to LED types for reduced energy consumption. This led to the switching of lighting to LED type lighting in refrigeration cameras and their connecting corridors.

Description

According to the Energy efficiency law, Rīgas saldētava is considered as a big energy consumer and has an obligation to carry out energy audit and introduce at least three energy efficiency measures within next the next four years.

Based on that, the company carried out an energy audit and switched to LED lighting in refrigeration cameras and corridors.

Before tubular fluorescent lamps were mostly used. Lighting was manually controlled. In refrigerating cameras lighting was switched on only when needed, but it burned longer in the hallways.

The corridors of the cold storage contain 52 tubular fluorescent lamps, while the freezer chambers contain 192 tubular fluorescent lamps.

Benefits

According to the energy audit calculation, lighting consumes 52.66 MWh of electricity per year, representing 8.33% of all energy consumed. According to the energy audit analysis, switching lights to LED reduces energy consumption by

17.72 MWh per year and CO_2 emissions by 1 931.8 t.

The replacement of the fluorescent lamps to LED results not only in energy savings, but also in longer lifetime for the lighting system, and the heat emitted by the bulb is also less. LED luminaires will also reduce maintenance costs in refrigerating chambers where a specific temperature is to be maintained. LED luminaires provide less discharge of heat from luminaires, thereby also reducing electricity consumed for cooling.

and lower energy costs	
Reducing greenhouse gas	

Calculations

The calculations show a quick idea of the costs and returns of this practice, as well as the economic impact after the implementation of the new equipment. In order to be clear, the initial situation is directly compared with the final situation and a table of differences is shown broken down into the different key points of savings.

Opportunities and barriers to implementation

Opportunities	*Barriers*
Increased lifespan of lighting system	Lack of trust in the potential savings and increased lifespan of lighting system
Better lighting quality	Lack of skilled workforce
Lower energy consumption	

	Initial situation	Final situation
Productive capacity [t/year]		
Annual energy consumption [kWh/year]	631 500	613 780
Annual energy cooling consumption [kWh/year]		
Annual economic energy expenditure [€/year]	89 141	81 184

	Switching lights in 4th freezer chamber	Switching lights in the rest of the freezer chambers	Switching lights in cold storage hallways
Total investment (€)	1 600	19 200	5 200
Electricity savings [kWh/year]	1 780	7 840	8100
Average electricity price[€/kWh]	0.16	0.16	0.16
Average emission Price [€/tCO_2]	25	25	25
Emission reduction [tCO_2/year]	0.194	0.854	0.883
Energy economic saving (€/year)	284.8	1 254.4	1 296.0
Emission economic saving (€)	4.85	21.36	22.07
Total economic savings (€)	289.65	1 275.76	1 318.07
Return period (years)	5.5	15	3.9

References

[1] Company internal energy audit acording to Latvian Regulation No. 487 Regarding Energy Audit of Enterprises

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BEST PRACTICES – AUXILIARY TECHNOLOGY
FACTSHEET

ICCEE
Improving Cold Chain Energy Efficiency in food and beverage sector

Consumption and emissions savings

'Double saving'

Spain
Dairy industry

Investment
Less than 22,500 €

Savings
9,000 €/year
69,000 kWh/year

Main NEBs (other benefits)
Reducing CO_2 emissions
New renting method
Maintenance included

A Spanish dairy company decides to carry out an energy efficiency study of the traditional hydraulic pumps that they use for their cold systems, heat systems and also for hot water.

After an energy audit, company realised its systems were obsolete. They decided to replace the old hydraulic plant with more efficient pumps in its engines, hydraulic systems and electronics. The benefits of this change are **less energy consumption** and emissions savings thanks to speed control of hydraulic pumps and thanks to the recognition of the own system to know when it is being used and when it is stopped.

In addition, the company have rented the whole system. It is a new concept for hydraulic pumps which you rent them during their life span (10 – 15 years) to have a Return on Investment (ROI) immediately, because you obtain more savings than rental price.

Description

The dairy company had used during several years 4 hydraulic pumps with 5 kW of nominal power each unit. After a comparative study, they became aware that they could improve system's efficiency by 60 – 80% in 5 years.

These pumps worked 5,840 hours per year, approximately; with 95 percentage rate of charge.

After the change, the industry still uses 4 units of these new hydraulic pumps, however they reduce their nominal power to 4.5 kW each unit, with only 40 percentage rate of charge.

BEST PRACTICES – AUXILIARY TECHNOLOGY
FACTSHEET

Improving Cold Chain Energy Efficiency in food and beverage sector

What is the improvement focus?

The profitability parameters can be seen in almost two years. This is because the new hydraulic plant uses smart pumps, cloud connectivity and digital services. This reduces system stress, downtime, and maintenance and system complexity while reducing life cycle costs.

One of the most important points of change is the digitization of pumps within the industry. This allows hydraulic pumps to work autonomously, recognizing working hours and when they should stop working; achieving a huge consumption saving and also economic saving.

Benefits

With this renovation you get an energy optimization of the pumping system.

Having an overview of the life cycle costs of a pump, the purchase price represents only 5%, service and maintenance, only 10% while 85% of the total refers to the energy costs used for the operation of the pump.

Two-thirds of all pumps installed today are inefficient and consume up to 60% more energy.
If inefficient pumps were replaced worldwide, global electricity consumption could be reduced by 4 per cent - equivalent to the annual energy consumption of 1 billion consumers.

The new current pump presents a way in which you can immediately reduce energy consumption from 110,960 kWh to 42,048 kWh. Moreover, there is a reduction of carbon emissions: 20.67 tons per year.

Other important benefit is lower maintenance requirements of the new equipment thanks to being able to rent such equipment during its whole life span.

Calculations

The calculations show a quick idea of the costs and returns of this practice, as well as the economic impact after the implementation of the new equipment. In order to be clear, the initial situation is directly compared with the final situation and a table of differences is shown broken down into the different key points of savings, using an average price of electricity and emissions taking into account their expected evolution.

	Data
Productive capacity [t/year]	900
Annual energy consumption currently [kWh/year]	110,960
Annual improvement energy consumption [kWh/year]	42,048
Annual energy savings [€/year]	68,912
Annual economic savings [€/year]	8,958.56

Total investment (€)	22,396.40
Energy savings [kWh/year]	68,912
Average electricity price[€/kWh]	0,13
Average emission price [€/tCO_2]	20
Emission reduction [tCO_2/year]	20,67
Energy economic saving (€)	8,958,56
Emission economic saving (€)	413,47
Total economic savings (€)	9,372.03
Return period (years)	2.39

BEST PRACTICES – AUXILIARY TECHNOLOGY
FACTSHEET

ICCEE
Improving Cold Chain Energy Efficiency in food and beverage sector

Consumption and emissions savings

Company “Teikas Saldētava” offers storage facilities. freezer warehouse and office spaces. Mainly working with frozen meat and fish suppliers. as well other kind of suppliers mainly in food and retail sectors. Company considers energy costs and efficient use of resources as an important objective.

The biggest energy efficiency measure implemented was the instalment of new compressors that are virtually capable of covering a larger portion of the cold load.

The switching of compressors resulted in a significant reduction in electricity consumption and CO_2 savings. It also it improved working conditions and safety due to ammonia leakage detection system that was improved when old compressor system was changed.

‘Compressor replacement’

Latvia
Freezing industry

TRL 9

Investment (real or estimated)
250 000 €

Savings
35 000 €/year
362 MWh/year

Main NEBs (other benefits)
Increased lifespan
Improved control
Lower water consumption
Improved safety
Reduced greenhouse gas emissions

Description

The freezer rooms have an average temperature of up to -18°C while the premises in the basement with a total area of 1175 m^2 provide a temperature interval from 0 to 5°C. Shock freezing is available upon request with a temperature regime of -30°C. Freezer space is arranged across five floors and covers a total area of around 5 665 m^2. Generation of cold energy for refrigeration is carried out using ammonium as a cooling agent during the compression cycle.

For many years, condensation of ammonia in the compressors was carried out using water spraying and recirculation basins.

The new compressors were installed together with the dry cooling/condensation tower. The new system provides possibility to switch between the two condensation options, however due to high water consumption company is planning to use only dry cooling/condensation tower.

What is the improvement focus?

The amount of electricity consumed in the company depends heavily on outdoor air temperature. In particular, the largest electricity consumer in the company is refrigeration equipment, for which the amount of energy

Improving Cold Chain Energy Efficiency in food and beverage sector

BEST PRACTICES – AUXILIARY TECHNOLOGY FACTSHEET

consumed depends on the amount of cooling energy needed.

Benefits

The compressor change saves 362 MWh of electricity per year, representing 30.7% of the total electricity consumption of the company. It also improves working conditions and safety due to ammonia leakage detection system that was improved when old compressor system was changed.

Other important benefits are the increased lifespan lower maintenance costs of the new equipment and improved control system.

Opportunities and barriers to implementation

Opportunities	*Barriers*
Increased lifespan of equipment	Lack of human resources (development, implantation and general project management)
Improved control	Lack of affordable financing
Lower water consumption	Lack of skills and knowledge of installers
Improved safety	
Reducing greenhouse gas	

Calculations

Annual reduction in electricity consumption achieved by switching compressors was calculated. The electricity savings were determined at the regulatory outdoor air temperatures specified in the Latvian construction standard in Riga. On average. electricity consumption in the company is seen to have decreased by 30 MWh per month. Depending on outdoor air temperature. it accounts for 25% to 43% of the total company's electricity consumption. A higher percentage of electricity savings are seen in the coldest winter months. which is due to the use of a “dry” cooling tower for new compressors. As the amount of data available is relatively small. the estimated electricity savings may change over time.

Month	Outdoor air temperature	Electricity consumption of the company. MWh		Savings	
		With old compressors	With new compressors	MWh	%
January	-4.7	69.8	40.3	29.5	42.3%
February	-4.3	70.9	41.3	29.6	41.7%
March	-0.6	80.6	50.8	29.8	36.9%
April	5.1	95.6	65.5	30.1	31.5%
May	11.4	112.1	81.6	30.5	27.2%
June	15.4	122.6	91.9	30.7	25.1%
July	16.9	126.6	95.7	30.8	24.4%
August	16.2	124.7	94.0	30.8	24.7%
September	11.9	113.4	82.9	30.5	26.9%
October	7.2	101.1	70.8	30.3	29.9%
November	2.1	87.7	57.8	29.9	34.1%
December	-2.3	76.1	46.5	29.7	39.0%
Total	6.2	1181.3	819.1	362.3	30.7%

BEST PRACTICES – AUXILIARY TECHNOLOGY
FACTSHEET

The calculations show a quick idea of the costs and returns of this practice. as well as the economic impact after the implementation of the new equipment. In order to be clear. the initial situation is directly compared with the final situation and a table of differences is shown broken down into the different key points of savings. using an average price of electricity and emissions considering their expected evolution.

	Initial situation	Final situation
Productive capacity [t/year]	n/a	n/a
Annual energy consumption [kWh/year]	1 934 300	1 572 000
Annual energy cooling consumption [kWh/year]	981.600	608.592
Annual economic energy expenditure [€/year]	184.285	135.265

Total investment (€)	250.000
Energy savings [kWh/year]	362 000
Average electricity price[€/kWh]	0.097
Average emission price [€/tCO_2]	25
Emission reduction [tCO_2/year]	39.458
Energy economic saving (€)	35 143
Emission economic saving (€)	986.45
Total economic savings (€)	36 129.55
Return period (years)	7

References

[1] Company internal energy audit acording to Latvian Regulation No. 487 Regarding Energy Audit of Enterprises

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BEST PRACTICES - BUILDING
FACTSHEET

Improving Cold Chain Energy Efficiency in food and beverage sector

'Building and chamber insulation support industry energy efficiency'

Spain
Food industry

TRL 9

Process chambers' wall insulation

In food and beverage industries there are many buildings and chambers that need to keep a certain temperature, which in practice is typically a tight range of temperatures, i.e. 2-3ºC for fresh meat keeping or 10-12ºC in fresh food working areas.

Keeping the temperature within this tight range is a matter of two main issues, the refrigeration machines power and the insulation of the chamber and buildings.

This food industry developed a project on increasing the insulation thickness from 10 cm to 30 cm, reducing the heat loss from 100 W/m^2 to less than 30 W/m^2.

The refrigeration needs due to loses in the walls was reduced by 70%, while the cooling consumption in reducing or keeping the temperature of the food pieces was similar. In the overall, this reduction is approximately 5% of the electricity needed to keep the right range of temperatures.

Investment cost
135.000 €

Savings
11.000 €/year
91.000 kWh/year

Main NEBs (other benefits)
Best ROI

Description

This Spanish food industry uses finned coils in a number of different applications to transfer heat either into or out air streams.

What is the improvement focus?

When the industry is facing some infrastructure renovation, as increasing the capacity or renovation of the buildings for process, increasing the overall insulation is an interesting energy efficiency measure. It also improves the building or chamber envelope and makes it modern.

Benefits

The increase in the insulation thickness brings energy efficiency benefits and improves the overall industrial plant.
The result in this industry was an energy efficiency improvement of 5% (7% energy savings in the refrigeration system), thus the food industry reduced its energy consumption from 1,821,000 kWh to 1,730,000 kWh.

Calculations

The calculations show a quick idea of the costs and returns of this practice, as well as the economic impact after the implementation of the renovation. In order to be clear, the initial situation is directly compared with the final situation and a table of differences is shown broken down into the different key points of savings, using an average price of electricity and emissions considering their expected evolution.

	Data	
Productive capacity [t/year]	2,000	
Annual energy consumption currently [kWh/year]	1,821,600	
Annual improvement energy consumption [kWh/year]	1,730,520	
Annual energy savings [€/year]	91,080	
Annual economic savings [€/year]	10,930	

Total investment (€)	135,000
Energy savings [kWh/year]	91,080
Average electricity price[€/kWh]	0.12
Average emission price [€/tCO_2]	20.00
Emission reduction [tCO_2/year]	27.32
Energy economic saving (€)	10,930
Emission economic saving (€)	546
Total economic savings (€)	11,476
Return period (years)	11.8

BEST PRACTICES – BUILDING
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'For each one what it needs'

France
Food retailer

TRL 9

Implementability: 99%

Main NEBs (other benefits)
Saving costs
Green image

Separated compartments warehouse

Looking for energy efficiency potentials in a warehouse of a food retailer, a separation of the warehouse is made among other things. Goods that need to be cooled to the same temperature are stored together in one compartment. In this way, a significant amount of energy can be saved, as it is no longer necessary to cool all goods to that temperature of those goods that need to be the coolest.

Another effect of subdividing the food warehouse is to reduce the heat input by convection through open doors. In contrast to a large area, only a smaller area can cool down due to the subdivision.

An HVAC expert (Heating, Ventilation and Air Conditioning) was invited to plan this measure. When implementing this, the separation of the compartments was optimized so that fewer cooled compartments are located on the outside wall of the warehouse and colder goods are located as far as possible on the inside, so that there is as little temperature difference as possible on all walls.

Description
For the subdivision, it was first analysed which goods are to be stored and which temperatures are required for this in each case.

Based on Table 1, food groups can be derived which can be stored together in one temperature section. The table is based on sources of the German Federal Institute for Consumer Health Protection and Veterinary Medicine [1].

In order to minimise heat transfer to the refrigerated areas, frozen areas are planned so that they border on as few external walls as possible. In this way, and by ensuring that the doors of the freezer areas do not lead directly to the outside, but to other cooling areas with a slightly higher temperature, the refrigeration capacity is not completely lost, but finds further use in the less cooled areas.

In addition, the office areas must be included in the planning. This area is planned in such a way that it does not border on areas with frozen food, so that an area in a corner of the warehouse, i.e. with two external walls, appears to be suitable.

Table 1: Maximum storage temperatures T for different food products in °C, based on [1]

T [°C]	Food products
- 18	Frozen foods (except ice cream)
- 12	Frozen meat, frozen egg products
2	Fresh fish and fish products
4	Fresh poultry meat, Hares, game and domestic rabbits, minced meat (products), feathered game, egg products
7	fresh meat (except poultry), game (except hare, and rabbits and feathered game), feathered game (pheasant, partridge, quail) even if they are farmed, gourmet salads, raw food (e.g. fresh mayonnaise)
8	Preferential milk, chicken eggs
10	butter, cream cheese, dairy products, pasteurized milk, soft and semi-hard cheeses, Live bivalve snails

What is the improvement focus?

The key to this measure is mainly to reduce the unwanted heat input to the cooled areas, thus reducing the cooling load and power consumption. This mostly impacts the electricity consumption

Benefits

In addition to the main benefit of the electricity saved by the measure, there are also the other advantages of energy saving. For example, the reduction of electricity savings contributes to the reduction of the negative environmental impact of electricity generation. In addition, there is an equivalent cost saving for the food trade.

Opportunities and barriers to implementation

Opportunities	*Barriers*
Lower power consumption and related cost	Know-how required
Greatest potential for new construction	Staff for planning required
Improved food quality	Limited Implementability for existing warehouses
Negligible maintenance	Additional cost for glide racks
Green image	

References

[1] BGVV (Bundesinstituts für gesundheitlichen Verbraucherschutz und Veterinärmedizin, German Federal Institute for Consumer Health Protection and Veterinary Medicine) https://files.dreamway.com/filer/186/2011/1/31/temperatur.pdf. Accessed 24 March 2020.

BEST PRACTICES – ENERGY GENERATION
FACTSHEET

Improving Cold Chain Energy Efficiency in food and beverage sector

Waste heat and heat recovery from refrigeration

Recovering heat from the refrigeration process can save energy and cut energy costs. Heat-recovery equipment can be fitted to existing plants or integrated in new plants. There are two types of heat recovery systems from refrigeration, depending on the installation and refrigerant used: **High-grade heat recovery**, where heat (of between 60 and 90ºC) is recuperated in refrigeration systems from de-superheating the refrigerant between the compressor and the condenser. **Low-grade heat recovery**, where heat (of between 20 and 40ºC) comes from the refrigerant being condensed.

'Heat pumps, aborption chillers & free cooling'

Europe

(Food and Beverage sector)

TRL 9

Investment (depending on size of installation)

3.500 - 200.000 €

Typical payback time

2 - 6 Years

Savings

30 - 45% Energy cost savings

Main NEBs (Other benefits)

Improved performance
Reduced greenhouse gas emissions

Heat recovery in the food sector

The most commonly used heat recovery methods in the food sector are the following:

- direct usage via **heat exchangers** making use of heat as it is in the surplus stream
- **heat pumps** upgrading the heat in relatively cold streams by aid of electrical power

In the food industry it is possible to recover heat from different sources: cooling systems and compressors, pasteurisation, exhaust gases from burners, etc. Recovered heat can also be used for heating tap water or ventilation, thawing deep frozen goods, preheating cleaning liquids and products, and space heating, among other reported applications.

Refrigeration & heat recovery

Heat recovery in refrigeration can be done in two ways:

- Waste heat generated from the refrigeration unit can be used as a heat source; e.g. to preheat water in order to reduce the energy use of the boiler.
- Waste heat from other processes can be used for refrigeration, through the use of absorption refrigeration.

Refrigeration systems cannot make heat disappear – they just move it from one place to another.

The refrigeration process includes a heat rejection stage to cool the refrigerant for reuse in the cycle. About 20 % of heat expulsion is due to 'de-superheating' of the refrigerant prior to condensation, and this heat has potential to be recovered as 'high-grade' heat for other purposes. One way you can do this is to install a de-superheater ahead of the condenser in the circuit.

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The amount of heat that can be recovered from a refrigeration system will be heavily influenced by the temperature required for use. The higher the required temperature (typically up to a maximum of around 65°C), the lower the amount of heat from refrigeration that can be recovered. Heat pumps are generally only a good solution when the site energy recovery has been fully optimized and only low-grade heat remains.

Useful tips for implementing heat recovery systems in refrigeration:

- Ensure that the system is operating as efficiently as possible
- Ensure that there are no refrigerant leaks
- Consider linking a heat pump (in case you need upgrade remaining low-grade heat)

Absorption chillers: Best practice for optimizing performance

Absorption chillers use heat, instead of mechanical energy, to provide cooling. Compared to mechanical chillers, absorption chillers have a low coefficient of performance (COP = chiller output/heat input). Nonetheless, they can substantially reduce operating costs because they are driven by low-grade waste heat, while traditional vapor compression chillers must be motor- or engine-driven.

Example:

In a plant where low-pressure steam is currently being exhausted to the atmosphere, a mechanical chiller with a COP of 4.0 is used 4,000 hours per year (hr/yr) to produce an average of 300 tons of refrigeration. The cost of electricity at the plant is 0.13 € per kilowatt-hour (kWh). An absorption unit requiring 2.4 tons per hour of 2 bar steam could replace the mechanical chiller, providing annual electrical cost savings of:

Annual Savings =
300 t x (3.5 kWh/t / 4.0) x
4,000 hr/yr x 0.13 €/kWh
= 136,500 €

Use waste heat only if waste heat is unavoidable

For the improvement of industrial energy efficiency waste heat recovery takes on a certain special role, as it should only be considered after the causes of the heat generation have been reduced as far as possible. Therefore, the following questions should be answered before a more detailed examination of waste heat recovery

- **Dimensioning**: Is the underlying process correctly dimensioned or is there unnecessary capacity?
- **Control**: Is the plant or process correctly controlled (e.g. inefficient operating points or idle times)?
- **Temperature level**: Is the currently selected temperature actually required?
- **Insulation**: Can better insulation reduce the amount of waste heat?
- **Alternatives**: Are energetically more advantageous alternative processes applicable?

No recovery, then free cooling

Free cooling is a fast and effective, economic method of using low external air temperatures. It can be used to assist in cooling water for industrial processes or in HVAC systems. When outdoor temperatures are lower relative to indoor temperatures, this system utilizes the cool outdoor air as a free cooling source. In this manner, the system replaces the chiller in traditional air conditioning systems while achieving the same cooling result. A free cooling coil is installed in series with the chiller system's evaporator so in lower ambient conditions partial or 100% free cooling can be achieved.

Free cooling operation, makes the most of natural low ambient temperatures and in doing so benefits from a reduction in energy costs of up to 80%.

In winter, when outdoor temperatures are low enough, the water is chilled solely by the free cooling coil. This allows the chillers' compressors to stop operating, saving significant amounts of energy. The only electrical power used in winter operation is for fan operation. This can be achieved once the ambient air temperature is 3 °C to 5 °C below the process supply water temperature. •

BEST PRACTICES – ENERGY GENERATION
FACTSHEET

Improving Cold Chain Energy Efficiency in food and beverage sector

Opportunities and barriers to implementation

Opportunities	*Barriers*
Optimization of heat fluxes in a plant (optimized heat recovery)	Modifications in production processes might be necessary
Combined heating and cooling in one system (heat pumps)	
Reduced operating and energy costs	

References

[1] Aermec S.p.A, Industrial Refrigeration.

[2] Reindl, Douglas & Jekel, Todd. (2007). Heat recovery in industrial refrigeration. 49. 22-28.

[3] U.S. Department of Energy Washington, Energy Efficiency & Renewable Energy - Advanced manufacturing office, Steam Tip Sheet #14. January 2012.

[4] JRC (EU), Best Envionmental Management Practice for the Food and Beverage Manufacturing Sector. 2018.

[5] Publicatins Office of the European Union, Best Available Techniques (BAT) Reference Document for the Food, Drink and Milk Industries. 2019.

BEST PRACTICES – ENERGY GENERATION
FACTSHEET

ICCEE
Improving Cold Chain Energy Efficiency
in food and beverage sector


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'Energy-efficient make-over'

Germany
Retail

Environmentally friendly renovation

Changing the way of energy generation can require some reconstruction measures. Thus, a renovation is a perfect opportunity to become more energy efficient, as discovered by a medium-sized sales facility in Germany. They took the opportunity to rebuild and remodel their entire store and made sure to take environmentally friendly options into account. All equipment was replaced with energy efficient and climate-friendly alternatives.

With a large investment like this one, the store's managers gained themselves a complete energetic renovation of the building, including façade insulation, new windows and doors and modern LED lighting, as well as a new central ventilation system with a heat recovery system. To ensure the use of green energy they additionally installed a PV-system and a combined heat and power unit with a fuel cell. This enables them to consume less external electricity and therefore reduce the amount of CO_2 and other greenhouse gases. They also use sustainable materials for storing and packaging.

Investment
361,000 €

Savings
50% in heat and electricity costs

Main NEBs (other benefits)
Reducing greenhouse gas emissions
Environmentally friendly

Description

Every now and then, a building needs to be renovated. When that time came for a medium-sized store in Germany, the environmental aware managers took the opportunity to ensure that not only the processes inside but also their whole newly remodelled store is as environmentally friendly as possible.

With a total budget of 361 thousand euros, they were able to halve energy costs and decrease climate gas emissions significantly. In 2013 an energy consultant was hired and the renovation started with the installation of LED lighting and adding heat-insulating layers to the roof. A central ventilation system was installed, which uses a heat recovery mechanism and thus improves the effects of energy and greenhouse gas savings. Just one year later around 20 % of the store's energy consumption was covered by a new PV-system, which was installed on the roof of the store. The complete make over was done in 2016, when windows and doors were replaced by high efficient models and the building's façade got a complete make over, using a thermal insulation composite system. The store invested further, in a combined heat and power unit with a fuel cell to further improve their use of green energy.

Additionally, in order to save plastic and use sustainable materials, the store owners started a cooperation with a producer of recycled paper bags and donate all the incomes from those bags to a social forestation project.

What is the improvement focus?

The additional insulation, that was done during the renovation enabled the store owners to reduce their energy losses and improve their energy efficiency by using excess waste heat. This was further improved by changing the windows and doors. Those parts are usually the most common sources for heat losses. These measurements reduce the need for additional energy, save energy and thus reduce carbon emissions.

By producing their own energy with renewable technologies, such as PV and the combined heat and power union with a fuel cell, further climate gas reductions were achieved and even less additional energy was required.

Additionally, the store is now being lit with LED lighting. Compared to traditional bulbs, light emitting diodes (LED) typically use about 25%-80% less energy and their lifetime is 3-25 times longer. The main reason that LED lighting is more energy efficient than traditional bulbs is that LEDs emit very little heat, whereas conventional bulbs emit around 80% of their energy as heat.

Benefits

The energy-saving measures introduced during the renovation have reduced the store's energy consumption by 50%, which means that its costs and carbon emissions have also reduced accordingly.

The renovation helped the store improve its physical appearance as well as showcase its green identity, while preserving the quality of its service and products. It could work as a role model for many older stores.

Investment in energy efficient technologies, as well as in sustainable materials is even more advantageous, if considered from the very beginning of the planning of a business. This does not only apply for the food industry but all sorts of industries.

The measures implemented here are cross-sectional technologies that can be implemented in companies of different industries and sizes. But ir can only be renovated by retailers with own properties, in case of a rental this measurement will not be implemented.

Opportunities and barriers to implementation

Opportunities	*Barriers*
Lower electricity consumption and related cost	extensive measures that are most sensibly implemented during a major renovation
Lower energy losses in winter due to façade insulation	investment costs for renovation
Environmentally friendly and sustainable technologies and materials	Retailers who rent the property for their shop will not invest in renovation
Cross-business technologies	

Calculations

BEST PRACTICES – ENERGY GENERATION
FACTSHEET

The calculations show a quick idea of the costs and returns of this practice, as well as the economic impact after the implementation and renovation. For transparency's sake, the initial situation is directly compared with the final situation and a table of differences is shown broken down into the different key points of savings, using an average price of electricity and emissions taking into account their expected evolution.

	Initial situation	Final situation
Productive capacity	*No data*	
Annual energy consumption [kWh/year]	*150,000*	-50%
Annual energy cooling consumption [kWh/year]	*No data*	
Annual economic energy expenditure [€/year]	*45,000*	-50%

Total investment (€)	361,000
Energy savings [kWh/year]	70,000 (-50%)
Average electricity price [€/kWh]	0.3147[1]
Average emission price [€/tCO_2]	25[2]
Emission reduction [tCO_2/year]	50 (- %)
Energy economic saving [€/year]	22,000 (- %)
Emission economic saving [€/year]	1.250 (- %)
Total economic savings [€/year]	23.250 (- %)
Return period (years)	*16*

[1] Handelsverband Deutschland: Klimaschutzoffensive des Handels: Erfolgsgeschichten: INTERsport Postleb, Landau. Zuletzt eingesehen am 25.06.2020 unter:

https://www.hde-klimaschutzoffensive.de/de/kampagne/erfolgsgeschichten/intersport-postleb-klimaschutz-mit-leib-und-seele

[1] This is the average retail electricity price in Germany in 2018.
[2] This will be the carbon price in Germany in 2021.

'Reaching the energy independence'

TRL 9

Main NEBs (other benefits)

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

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.

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

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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].

Opportunities and barriers to implementation

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

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

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BEST PRACTICES – EMPLOYEE
FACTSHEET

Improving Cold Chain Energy Efficiency in food and beverage sector

'Employees awareness, training and energy management system'

Latvia
Freezing industry
TRL 9

Investment (real or estimated)
2 400 €

Savings
7 838.4 €/year
78.6 MWh/year

Main NEBs (other benefits)
Employees awareness and engagement

Reduced greenhouse gas emissions

Consumption and emissions savings

Company "Teikas Saldētava" offers storage facilities, freezer warehouse and office spaces. Mainly working with frozen meat and fish suppliers, as well other kind of suppliers mainly in food and retail sectors.

Company considers energy costs and efficient use of resources as an important objective. Form August till November 2017 company carried out an energy audit in accordance with the requirements of the Latvian Energy Efficiency law. It served as the basis for energy management system and introduction of trainings for workers, in particular on the logistics, loading and unloading the warehouse.

Description

Employees awareness, training and energy management system stared within the framework of energy audit which took place from August and November 2017. During the analyses of potential energy efficacy measures the total electricity consumption as well as electricity consumption for the tenants was analysed. Analyses also included the calculation of energy costs, the distribution of energy consumption by consumer groups, the amount of energy consumed by energy sources and an analysis of a number of energy efficiency measures.

After energy audit, energy management system was developed and implemented. One of the challenges was to coordinate delivery time at warehouse to minimize waiting time for trucks, unloading/loading and checking what are the required minimum storage temperatures for products.

Based on the energy data analyses and main findings worker trainings regarding unloading/loading process and safety were carried out as it was acknowledged that the trucks were waiting too long at the loading ramps and it was taking too much time for unloading/loading the warehouse. One the biggest obstacle for energy efficiency measure implementation for the cold supply chain that the company focus on their own facility and are not involved in decisions taking on the whole cold supply chain.

One of the challenges faced to improve loading and unloading process was to coordinate delivery time at warehouse to minimize waiting time for tracks,

BEST PRACTICES – EMPLOYEE FACTSHEET

Improving Cold Chain Energy Efficiency in food and beverage sector

unloading/loading and checking what are the required minimum storage temperatures for products.

But because each involved company has their own priorities, it makes it hard to negotiate between different companies that are involved. As some clients/ other companies can't agree on different delivery times to warehouse they waste energy waiting to unload or load the tracks.

Company "Teikas Saldētava" implemented measures to improve energy efficiency in cold supply chain regarding their responsibilities. They carried out regular training of workers regarding logistics, delivery and unloading to minimize waiting times for tracks. Also focusing on worker safety, including fire safety and the safety of ammonia system.

Benefits

Energy savings from the implemented energy management system and worker trainings were estimated as 78,6 MWh/year.

Employee trainings helped to achieve not only energy savings but also helped to increase working environment safety.

Opportunities and barriers to implementation

Opportunities	*Barriers*
Employees awareness and engagement	
	Lack of human resources for implementation
Reduced energy consumption and energy costs	Lack of experience in providing trainings and setting up new procedures

Calculations

Even it is hard to estimate benefits of employees training and energy management system the calculations shows that energy savings are approximately 78.6 MWh/year.

	Initial situation	Final situation
Productive capacity [t/year]	n/a	n/a
Annual energy consumption [kWh/year]	1 572 000	1 493 400
Annual energy cooling consumption [kWh/year]	1078	980
Annual economic energy expenditure [thousand €/year]	128	80

	Energy management system
Total investment (€)	2400
Electricity savings for freezing [kWh/year]	78 600
Average electricity price[€/kWh]	0.097
Average emission price [€/tCO_2]	25
Emission reduction [tCO_2/year]	8.567
Energy economic saving (€/year)	7 624.2
Emission economic savings (€)	214.2
Total economic savings (€)	7 838.4
Return period (years)	0.3

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BEST PRACTICES - MAINTENANCE
FACTSHEET

ICCEE Improving Cold Chain Energy Efficiency in food and beverage sector

'Is cleaning cooling machines important? The simple answer is YES'

Spain
Food industry

Cleaning of condenser and evaporator for maintenance

Industrial process chilling systems come with four main components: evaporator, throttle valve/ expansion valve, compressor and condenser.

After an energy auditory in a Spanish food industry, they realized that chillers are the single most energy consumers, so a comprehensive maintenance program is necessary.

In fact, dirty condenser and evaporative coils have a negative impact on energy efficient system operation, because at this industry the compressor had to work longer and, therefore, the system was using more power because the coefficient of performance/energy efficiency ratio (COP/EER) was severely affected.

For this reason, preventive maintenance is still the best way to ensure sustenance of chiller efficiency for getting economic and consumption savings.

Maintenance extra cost
15,000 €

Savings
11,560 €/year
85,000 kWh/year

Main NEBs (other benefits)
Increased life span
Best ROI

Description

This Spanish food industry uses finned coils in a number of different applications to transfer heat either into or out air streams.

Over time the surfaces of these coils had become dirty as the air moving over the coils contain dust, dirt, pollen, moisture and other contaminants. A build-up of contaminants decreased the available surface area for heat transfer, reducing the efficiency of the heat transfer process, leading to excessive energy consumption and poor system performance.

BEST PRACTICES - MAINTENANCE
FACTSHEET

This report claims that systems whose heat transfer surfaces have not been cleaned in the last three years an immediate energy saving of at least 10% is expected to be achieved following cleaning

For this reason, it is important that air conditioning coils are regularly inspected and maintained to ensure they operate at optimum efficiency.

What is the improvement focus?

After the cleaning of finned coils there was a decrease in the condensation temperature from 35 to 40ºC, increasing the cooling capacity by 10%, then 10% of savings are reached by this improvement.

This means that the nominal cooling capacity of the 2 coils increase from 630 kW per unit to 700 kW as previously operated, thus the electric power from goes down to 315 kW instead of 350 kW to keep the same cooling power.

Benefits

With this maintenance you get energy consumption savings and economic savings.

Furthermore, regular maintenance and cleaning allows greater durability of life span of the systems

Postponing maintenance and cleaning can have a detrimental impact on process equipment and heating and cooling systems. When dirt and grime coat a chiller's or air-conditioner's coils, it can drastically increase the costs of running that system.

Cleaning the surfaces of the condensers and evaporators showed an average reduction of 10%, thus the food industry reduced its energy consumption from 850,080 kWh to 765,072 kWh, getting a Return on Investment in one year.

Calculations

The calculations show a quick idea of the costs and returns of this practice, as well as the economic impact after the implementation of the new equipment. In order to be clear, the initial situation is directly compared with the final situation and a table of differences is shown broken down into the different key points of savings, using an average price of electricity and emissions taking into account their expected evolution.

	Data
Productive capacity [t/year]	900
Annual energy consumption currently [kWh/year]	850,080
Annual improvement energy consumption [kWh/year]	765,072
Annual energy savings [€/year]	85,008
Annual economic savings [€/year]	11,051

Total investment (€)	15,000
Energy savings [kWh/year]	85,008
Average electricity price[€/kWh]	0.13
Average emission price [€/tCO_2]	20
Emission reduction [tCO_2/year]	25.50
Energy economic saving (€)	11,051
Emission economic saving (€)	510
Total economic savings (€)	11,561
Return period (years)	1.30

Compressed air leakage reduction

'Stop turning money into thins air.'

Europe
(Food and Beverage sector)

TRL 9

Investment
starting from 0 €

Annual savings per fixed 3 mm leak
900 €/a
9000 kWh/a

Main NEBs (Other benefits)
Improved performance
Less noise

Air leaks are tireless consumers of compressed air, even after office hours and during the week ends. Even small leaks can entail substantial losses in electrical energy and may thus cause substantial energy costs. Dealing with them is often quite easy and a regular check on leaks is thus a good strategy to both minimize electricity costs and save money.

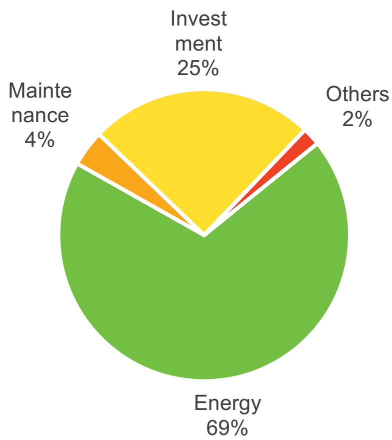
Compressed air: Versatile and energy-intensive

Compressed air is used for a large variety of applications, e.g. for powering pneumatic tools or as process medium directly used in production. On average, compressed air generation is responsible for about 10% of electricity demand in industrial companies. Electricity costs are an important aspect of compressed air usage since they easily hold a share well above 70% of the costs of an optimized compressed air station over a period of five years. According to estimates, energy demand at a nominal flow rate and a typical pressure of 7 bar is between 85 to 130 Wh per Nm³ of compressed air for a correctly dimensioned and well managed installation. This typically translates into some 1 to 3 Euro-cents per Nm³ of compressed air, depending on the system performance and electricity prices.

Multiple opportunities for energy savings

Despite the substantial costs for providing compressed air, considerable energy saving potentials have been identified in the past. This concerns all parts of a compressed air system. While some measures like using high-efficiency compressor systems are usually relevant during the occasional major overhaul of entire compressed air stations, others are easily to implement also during normal operation.

Costs of an optimized compressor station within 5 years



BEST PRACTICES - MAINTENANCE
FACTSHEET

ICCEE
Improving Cold Chain Energy Efficiency in food and beverage sector

Reducing air leaks to save money

An usually easy to implement and cheap measure for normal operation is the reduction of air leaks. These have been identified as major sources of energy losses in compressed air systems. They originate from badly carried out installation work, worn equipment or a lack of sensitivity from the user, e.g. from semi-shut air valves.

Under typical pressure conditions, a 3 mm leak, for instance, requires approximately an equivalent of 3 kW in compressor input power while a 5 mm leak already requires more than 8 kW.

A particular challenge with air leaks is that they are always present in a compressed air system under pressure, even during the weekend when nobody is working. Thus, avoiding leaks can result in an average reduction of electricity demand for compressed air provision between 10 and 20% of the total energy demand of a compressed air system.

Air leak occurence & detection

Air leaks may occur in all parts of a compressed air system, from air compressor to the end-use including:

- Couplings, fittings and valves
- Pipe joints, disconnections
- Presure regulators and condensate traps
- Tools and pneumatic equipment

Leak diameter [mm]	Losses [l/s]	Power [kW]
1	1.2	0.3
3	11.1	3.1
5	31	8.3
10	123.8	330

	Applicability	Gains	Potential savings
Air leackage and compressors optimization options			
High efficiency motors in compressor	25%	2%	0.5%
Speed control for compressor	25%	15%	3.8%
Upgrading of compressor	30%	7%	2.1%
Use of sophisticated control systems	20%	12%	2.4%
Recovering waste heat for other use	20%	20%	4.0%
Improved cooling, drying and filtering	10%	5%	0.5%
Overall system design incl. multi-pressure systems	50%	9%	4.5%
Reducing frictional pressure losses	50%	3%	1.5%
Optimizing certain end use devices	5%	40%	2.0%
Reducing air leaks	80%	20%	16.0%
More frequent filter replacement	40%	2%	0.8%

Figure 1: Savings from different EEMs on compressed air systems

There is a variety of ways to detect or reduce air leaks:

- Especially larger leaks make audible noise and/or can even be felt in the near proximity
- The use of soapy water applied with a paint brush used on suspect areas can be an easy mean to identify leaks
- Leaks lead to ultrasonic sound emissions. The market offers acoustic detectors which can help to also localize such emissions from smaller leaks
- Leaks can also be traced using particular gases

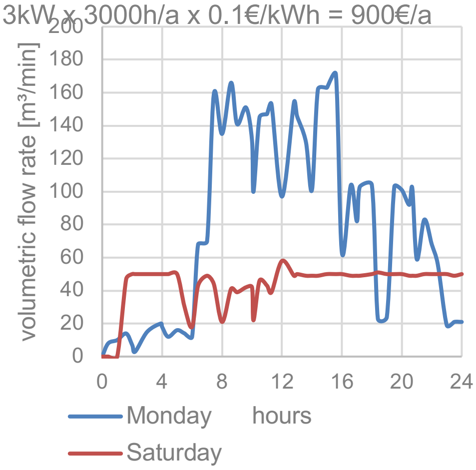
Another strategy to deal with air leaks is separating of parts of the compressed air network while production is not running, e.g. by automated valves or by adding manual switches, e.g for idle times during the week-ends. This can also be a strategy if leaks are difficult to localize or fix.

Economics

Depending on the situation and strategy, detecting and fixing leaks is nearly free, yet can have a substantial impact on energy costs.

For instance, fixing a 3 mm leak with 3 kW in power requirement under 3000 hour operation leads to annual savings in electricity costs of:

3kW x 3000h/a x 0.1€/kWh = 900€/a



BEST PRACTICES - MAINTENANCE
FACTSHEET

Improving Cold Chain Energy Efficiency in food and beverage sector

Opportunities and barriers to implementation

Opportunities	*Barriers*
Can be implemented at minor costs (often during normal operation)	
Improved performance	
Less noise	

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BEST PRACTICES – MAINTENANCE
FACTSHEET

Optimisation of the cooling distribution system

'Don't lose the cold you produced.'

A well-balanced circuit can save up to 35% of energy consumption.

Belgium
Pasta production

TRL 9

The conception and maintenance of the cooling distribution system is key to achieve optimal efficiency of the overall industrial cooling process. The efficiency of a cooling distribution system depends on two main factors:

- The isolation of the cooling fluid distribution pipes to prevent heat losses and equipement degradation;
- The optimization of the distribution pumps' controlling system to reduce pressure losses and cavitation.

In some distribution cooling systems, it can be observed that pumps work with at higher flow and pressure head than necessary. If the system is not properly pressurized, the risk of pump cavitation is high. Using differential pressure control solutions can help optimize the performance of variable speed pumps and avoid overconsumption.

Main NEBs (other benefits)

Reduced heat losses and pressure drops
Maintenance of the equipments
Prevent degradation of the pipes
Prevent overconsumption of the pumps

Description

A SME company from Belgium employs about thirty people and produces pasta and pasta products (lasagna, eggplant rolls, etc.). The company produces about 2500 tons of pasta per year.

The cold occupies an important part of the energy consumption of the company. It is used both to cool production areas and some equipment, but also to store finished products (fridges and freezers).

The company invested in a new cold production unit in order to meet its growing needs and, in the context of legislation aiming at gradually eliminating the use of HCFC R22, harmful to the ozone layer, as a gas refrigerant (still used within the company in old refrigeration plants).

BEST PRACTICES – MAINTENANCE
FACTSHEET

Improving Cold Chain Energy Efficiency in food and beverage sector

This project was an opportunity to implement an energy optimized solution.

The chosen cold production unit works with ammonia as the refrigerant gas and uses an intermediate fluid (glycol water) to distribute the cold to the different consumers of the company (cold rooms, machines, production and storage areas).

Optimisation of the cooling distribution system

The cold distribution throughout the company is carried out by a glycoled water circuit.

In order to adapt the control of the distribution pumps to the flow rate required by the circuit (consumers), the pumps are fitted with frequency converters.

Particular care has been taken in insulating the glycoled water circuit pipes, in order to reduce heat losses but also to avoid condensation and corrosion that are commonly observed in this type of distribution systems.

Opportunities and barriers to implementation

Opportunities	*Barriers*
Reduced heat losses	Additional cost for maintenance of the equipment
Reduced pressure losses and cavitation	
Lower electric consumption and related cost	
Prevent degradation of the pipes	
Prevent overconsumption of the pumps	

References

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Managing energy in a systematic manner

There are many reasons for dealing with energy in a systematic manner. A dominant motive is decreasing the energy bill. When referring to “energy management”, the first thing to come to mind is often an “energy management system”. Yet realizing energy savings does not necessarily require a formalized management system. Progress can already be made when workers are sensitised about energy-related issues.

‘Don’t simply buy energy, manage it!’

Europe

TRL 9

Investment (real or estimated)
Starting from 0 €

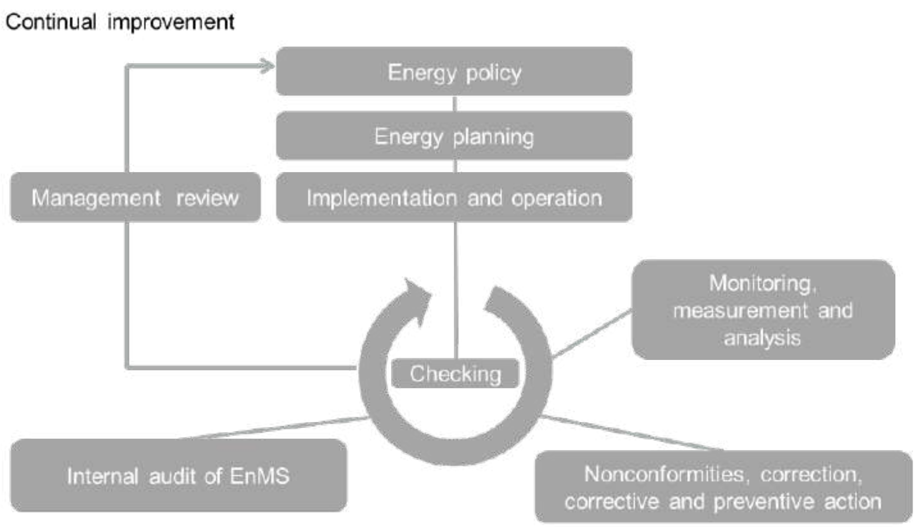
Savings
Depends on level of ambition

Main NEBs (Other benefits)
Increase transparency
Higher motivation
Green image

Energy management: Why at all?
There are many motivations for managing energy. A straight forward and obvious reason are the economic benefits from reducing energy demand by decreased energy costs. Yet there are other motives, as well, that make conciously dealing with energy-related matters attractive. One is improving the security of supply by achieving more inpedendence from external energy suppliers. Another is that taking a closer look on energy costs can help to bolster a company against fluctuating and in particulary rising energy costs. Thus, it is akin to risk management. Knowing where and when energy is used may also open up possibilities to adress areas with heavy energy consumption. And finally, energy savings mean a contribution to environmental protection. Dealing thorougly with them may also allow for advertising this to customers and to position oneself as environmentally friendly company.

Energy management: From informal approaches to formalized systems

Refering to energy management is often taken identical to introducing a fully-fledged energy management system according to ISO 50001. Yet energy management as a general term can be perceived more broadly. running and well-mainainted production.



Experience shows that in small companies in particular, the topic is driven by indiviudals who are interested in keeping a smoothly Thereby, they also look on energy demand among the various aspects related to running the operation, even without relying on a formalized energy management system. Larger companies, on the contrary, need to rely more on structured energy management systems due to the distribution of specialized tasks and responsiblities within larger organizations. Input by third parties within energy audits can also be valuable to get a neutral and better understanding of the energy saving opportunities within a company.

Energy audits as one-off interventions

The general nature of an energy audit is that it is typically designed as a one-off intervention. Energy auditors check on the energy flows, identify major energy consumers and compile a report with recommendations for reducing energy demand.

An energy audit is "a systematic procedure with the purpose of obtaining adequate knowledge of the existing energy consumption profile of a building or group of buildings, an industrial or commercial operation or installation or a private or public service, identifying and quantifying cost-effective energy savings opportunities, and reporting the findings."

Energy management systems as frameworks for regular reviews

As compared to the energy audits, energy management systems are more comprehensive approaches that seek to integrate energy-related issues in the management system of an organization. Usually, these management systems follow the structure as laid down in ISO 50001 series. Their elements are based on the plan-do-check-act (PDCA) cycle, i.e. a continual improvement process. The entire system seeks to establish an energy policy, an energy planning and an implementation within the organization and a regular review of the achievements (see also illustration).

Due to the continuous approach to energy related-matters, energy management systems are usually more sustainable in terms of the achieved savings in the longer run. Yet it also has to be kept in mind that the management framework has to be filled with "life" to get beyond a mere certification issue. Estimations on the actual effects and benefits of energy management systems vary, e.g. depending on organizaitonal structure and prior activities in energy-related issues.

Energy benchmarks: Managing energy by comparisons

The general idea of energy benchmarks is to allow comparing energy demand values of objects to derive helpful conclusions about their energy performance. In one of the most simple of cases, the consumption of two identical lines with the same product is compared to each other. If there are differences in their energy consumption values, this could be an indication that a more thorough investigation on the differences is needed. While this general idea is appealingly simple, there are many challenges in the details. Identical lines with the same outputs are rather the exception than the rule and many factors affect the overall results including:

- Product-related factors (e.g. number of pieces, weight, length, volume, material)

- Organizational factors (e.g. shift models, staff at site, frequency of energy analysis)
- Process-related factors (e.g. operating time, cycle time, speed, number of different setups, quality rate)
- Personnel (e.g. user behaviour, intensity of instruction and education, presence of specialized staff members)
- Ambient conditions (e.g. external and internal temperature, humidity, pressure, light)
- Location-specific factors (e.g. area, space, refurbishment, age of equipment, status of supply infrastructure)
- Production structure (e.g. degree of vertical integration, product segments, number of different products)
- Economic factors (e.g. turnover, production costs, energy costs)

Such factors have to be considered for meaningful comparisons. In practice, this can be challenging, especially when the amount of details or knowledge about the factors is limited. Helpful benchmarks can therefore be quite difficult to establish, yet if properly done, they are valuable to better understand performance issues. •

Case sudy: The story of how Berriak saves 20.300€ anually

Berriak Supermarkets is a leading company in the food industry around the Basque Country (Spain). The main challenge for GESE Servicios Energéticos was to reduce the consumption without modifying the comfort conditions of the clients in Berriak. Exemplary saving measurement & results from introduction of EMS[1]:

- Improved vertical display refrigeration management
- Optimized bakery oven on/ off schedule
- Improved lightning technology
- Optimization of contracted power and free market terms
- Savings verification
- Reduction of CO2 emissons by 34.000 kg
- Reduced electricity bill with 37% of saving out of the total

Opportunities and barriers to implementation

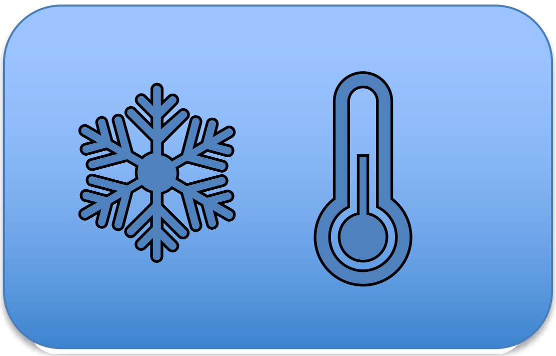
Opportunities	*Barriers*
More broadly running and well-maintained production	Additional staff capacities, training and education of employees
Possibility to address areas with heavy energy consumption and reduce energy costs	Lack of available data, time-consuming recording of data and measurements
Improved security of supply (f. ex. by achieving more independence from external energy suppliers)	
Green Image for advertising to customers	

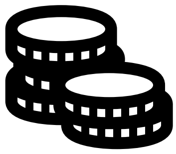
References

[1] Dexma, Energy Management for SMES. 2016.

[2] JRC (EU), Best Envionmental Management Practice for the Food and Beverage Manufacturing Sector. 2018.

[1] https://get.dexmatech.com/hubfs/Whitepapers/SMEs_EN.pdf





'Choose freezing temperatures wisely'

Germany (Europe)

TRL 9

Investment (real or estimated)
Starting from 0 €

Savings
3-5 % of refrigeration consumption per °C

Other benefits
Reduced effort due to temperature management system

Adjustment of cooling temperatures

Taking a view on the necessary cooling temperatures of your products is a very low-cost and easy measure with a significant potential to save energy costs. Besides from simply checking if your thermostats are set adequately you can also reorganise the way product groups with different temperature needs are stored or apply an intelligent temperature management system.

To realise the low-cost efficiency potentials in cooling, an appropriate temperature selection based on the requirements of the products to be refrigerated or frozen, as well as on the properties of the equipment is easily feasible.

Smarter temperature selection

Many frozen food products must be kept below -18°C. So, to achieve this limit, manufacturers of such products will generally set their thermostats to -23°C or lower allowing a safety margin. This buffer is selected to account for doors to the freezers being opened or perhaps for high ambient temperatures. But for every extra degree of cooling, significant additional energy is consumed. Thus some frontrunners will accept a slightly warmer temperature, perhaps -21°C. This is enabled by improvements to air curtains and freezer door seals and acceleration of the opening and closing of freezer doors. Due to these and other factors refrigeration equipment has become way more efficient in recent years. So checking if your older rules of thumb on setting the temperatures still apply for the newer equipment can lead to significant energy savings.

Efficient product arrangement

Another significant potential to realise lower energy costs is the arrangement of refrigerated or frozen products. Better temperature settings by separating products which need to be stored at different temperatures or by taking into account ambient temperature can result in a 4% energy saving for chill temperatures and 2% for low temperatures by increasing the temperature setting. For instance, where a Product A requiring 5°C is stored with Product B needing -5°C, the freezer will be maintained at the 'lowest common denominator' of -5°C. Thus, Product B will be kept 10°C cooler than

BEST PRACTICES – MANAGEMENT
FACTSHEET

Improving Cold Chain Energy Efficiency in food and beverage sector

necessary wasting perhaps 15% to 20% of power input.
The appropriate grouping of products (or ingredients) requires different storage temperatures in the same cold store to prevent some of the goods from being stored at unnecessarily low temperatures.
A general overview on optimal storage temperatures for different product groups is given in the adjacent table.

—

Whenever possible, cooling at lower temperatures than required should be avoided, as each degree of decreased temperature increases the energy consumption by an order of magnitude of 3-5%.

—

Example:
Intelligent temperature management saves electricity, costs and effort
In order to increase efficiency, reduce power consumption and thus act more sustainable, a german company in direct sales of ice cream and frozen specialities introduced an intelligent temperature and energy management system for their sales vehicles in the summer of 2013. The company guarantees its customers uninterrupted compliance with the closed deep-freeze chain right up to the domestic freezers. Therefore, the cold protection of the approximately 3,000 sales vehicles that leave for the 2.5 million customer households in Germany every day requires a considerable amount of energy. Previously, the temperature of the sales vehicles was usually controlled manually to -36°C, but the new temperature management system, which was developed in-house, regulates the temperature of the refrigerated body at a constant level according to the residual cold and outside temperature. For this purpose, modules in all vehicles measure the core and air temperature in the cooling structure. A receiving station transmits this data to a PC in the respective branch, where it is processed further for each vehicle. Taking into account the weather forecast for the coming day, the management program then calculates how much cold each individual vehicle will need for the next day. This not only reduces power consumption, but also significantly minimizes the effort required for temperature control. Whereas previously the temperature had to be read from the vehicles every day and the data had to be transmitted, this is now done by the measuring module. In case of temperature deviations, it immediately gives an alarm. A benefit for everyone: power consumption, costs and effort are reduced - the environment is protected.

Food product	Optimal storage temperature
Deep-frozen food	
Meat	-25°C
Poultry	-24°C
Fish	-29°C
Fruits and concentrated juices	-18°C
Vegetables	-18°C
Frozen food	
Frozen butter	-20°C
Chilled food	
Fresh meat	-1.5°C
Meat products	-2°C
Manufacturing meat	-2°C
Poultry	-1.5°C
Fish	In melting ice (-0.5°C to 0°C)
Dairy products	0°C to 2°C
Fruits and vegetables	
Low temperature (apple, blueberry, lettuce, etc.)	0°C to 2°C
Moderate temperature (pumpkin, melon, etc.)	6°C to 9°C
High temperature (banana, cucumber, etc.)	12°C to 16°C

Table 1: Optimal storage temperatures of various food products

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Opportunities and barriers to implementation

Opportunities	*Barriers*
Improved product quality	New equipment for intelligent temperature management needed
Reduced effort for temperature control with intelligent temperature management	
Can be implemented already at minor costs (by reorganising the way product groups with different temperature needs are stored)	

References

[1] Cool-Save Project, Best practice guide on how to save energy in food and drink companies' ooling systems,

[2] Swedish Addociation for Frozen and Regriferated Foods, Correct temperature during storage and transport, 2016.

[3] https://www.resourceefficient.eu/en

[4] JRC (EU), Best Envionmental Management Practice for the Food and Beverage Manufacturing Sector. 2018.

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BEST PRACTICES – MOTNITORING AND CONTROL
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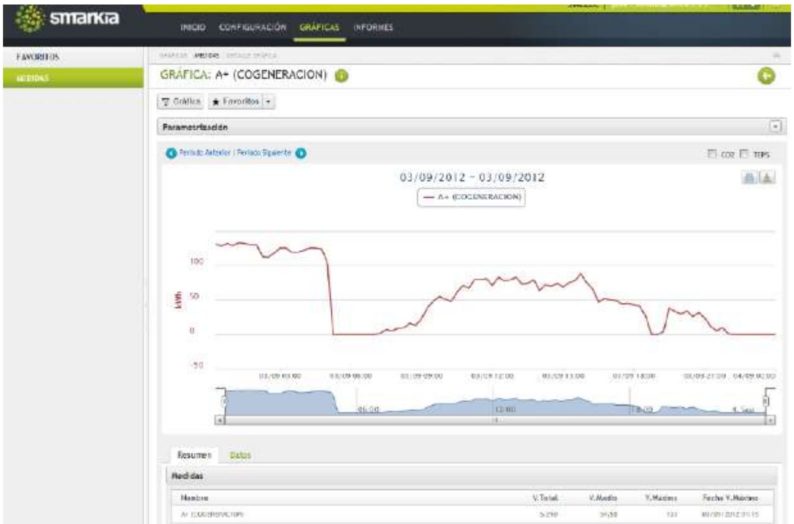

'Monitor, detect, improve'

Spain
Food industry

TRL 9

Investment cost
40,000 €

Savings
46,000 €/year
425,000 kWh/year

Main NEBs (other benefits)
Improved management
Reduced energy consumption
KPIs potential increased

Monitoring system

In industry it is essential to know the energy consumption of each of the production processes, to optimize it and be able to control any deviation that may occur. The automation of reading processes greatly simplifies operations and generates significant cost savings.

This industry incorporated a new system to integrate all the measurement equipment by using SMARKIA MONITOR.

The monitoring system has allowed the middle and high-level directors to better know the energy consumption in the process areas, incorporate and follow up KPIs for their processes and obtain an better picture of the industry energy consumption, detecting energy efficiency measures.

Description

The use of a monitoring system allowed the plant to:

Monitor: Smarkia's telemetry cloud service allows real-time monitoring of any energy source (electricity, gas, water, heat ...). Easily track your consumption or energy variables that have relevance to the costs.

Analyze: due to its powerful algorithms, the telemetry service analyses energy data, generates indicators, calculates baselines, detects deviations and predicts future consumption.

Share: information flows in real time throughout your organization generating events and alarms, delivering reports to measure, benchmarking ... Your user policy will allow you to adjust access privileges by workplace, facility or country.

Optimize: the telemetry service not only saves you energy, it also saves time and resources. Eliminate your needs infrastructure hardware and software, maintenance contracts, backups ... It gives you the possibility of receiving the information in a timely manner that you need without

BEST PRACTICES – MOTNITORING AND CONTROL FACTSHEET

the need for complex procedures of information processing, verification and validation of results.

What is the improvement focus?

To use monitoring system to improve the overall energy management of the industry, detecting high consumptions, benchmarking and using the information to propose energy efficiency measures.

Benefits

The result in this industry was an energy efficiency improvement of +2% due to the detection by the monitoring system, thus the food industry reduced its energy consumption from 8,500,000 kWh to 8,075,000 kWh.

Calculations

The calculations show a quick idea of the costs and returns of this practice, as well as the economic impact after the implementation of the management system. In order to be clear, the initial situation is directly compared with the final situation and a table of differences is shown broken down into the different key points of savings, using an average price of electricity and emissions considering their expected evolution.

The investment costs include the initial costs plus fees for 5 years, which is the lifetime of this project. It could be extended to more years afterwards.

	Data
Productive capacity [t/year]	1,200
Annual energy consumption currently [kWh/year]	8,500,000
Annual improved energy consumption [kWh/year]	8,075,000
Annual energy savings [€/year]	425,000
Annual economic savings [€/year]	46,000

Total investment (€)	40,000
Energy savings [kWh/year]	425,000
Average electricity price[€/kWh]	0.11
Average emission price [€/tCO_2]	20.00
Emission reduction [tCO_2/year]	127
Energy economic saving (€)	46,000
Emission economic saving (€)	2,500
Total economic savings (€)	48,500
Return period (years)	0,8

‘Watching the savings’

Italy
Dairy industry

TRL 9

Implementability: 99%

Main NEBs (other benefits)

- Quality assurance
- Energy management
- Time saving
- Production increase
- Predictive maintenance

Smart monitoring

The dairy considered for this example implements an energy management system, for which in general the measurement and processing of energy-related data is crucial. A computer program that collects all energy and production flows and evaluates the data seems to be most appropriate for this task. First, the already existing data points are merged in this program. In addition, the installation of further measuring devices is necessary, to ensure that all relevant energy flows can be recorded. Based on the data analysis, the improvement of the energy-related performance can be monitored, and new measures can be derived.

The measure of implementing the data processing program also has the significant advantage that production can be monitored more effectively. It is also beneficial for a quality or environmental management system. Through better knowledge of the production procedures, processes can be optimally coordinated, and the productivity of the factory can be increased.

Description

The data software represents the interface of all information flows concerning energy-related performance. The existing data collection from measurement data concerning energy flows and production quantities is integrated into the new smart system and converted into a consistent format.

In accordance with the energy management, key performance indicators (KPI) are automatically evaluated, displayed and visualized together with relevant parameters.

The system allows the various user groups to view the production process at any time. For example, malfunctions are immediately visible and corresponding personnel are automatically informed. In this way, the causes of an unexpected increase can be found and eliminated quickly.

What is the improvement focus?

As an essential part of energy management, smart monitoring significantly promotes the intended continuous improvement process with regard to energy-related performance. This covers all kinds of energy sources. The analysis of the

BEST PRACTICES – MONITORING AND CONTROL
FACTSHEET

KPIs can be automatically performed with the help of this software.

Benefits

In addition to the advantages for the EMS, smart monitoring can also be of significant benefit for a quality or environmental management systems (ISO 9001 and ISO 140001). As soon as the software is completely implemented, it represents a great time saving due to the automated evaluation. The results of the software are very useful for the documentation of the EMS. The data can also be accessed remotely.

In addition, the ideal maintenance cycles can be calculated through this data evaluation. This makes it possible to schedule maintenance and reduce unexpected malfunctions, which results in cost savings.
A further advantage is the extension option to include load management.

With regard to the cold chain, the monitoring system can make a significant contribution to quality assurance, as interruptions in the cold chain can also be noticed immediately and remedied as quickly as possible. This reduces production waste, thus increasing the efficiency of the dairy operation.

Opportunities and barriers to implementation

Opportunities	*Barriers*
Smart monitoring contributes to energy management certification, which may grant tax benefits	Additional cost for software
Production increase	Additional cost for hardware
Predictive maintenance	Staff training required
Available worldwide	
Simple handling	
Saves all kinds of energy sources	

BEST PRACTICES – REFRIGERATION SYSTEM
FACTSHEET

Improving Cold Chain Energy Efficiency in food and beverage sector

"How to consume less and better!"

TRL 9

Main NEBs (other benefits)

Lower greenhouse gas emissions
Longer equipment life
Lower maintenance costs
Lower operational costs

Control strategies for oversized cooling systems

Some cooling systems could prove to be oversized for several reasons: for instance, they could have been designed considering an eventual future extension or evaluating different cooling loads, that have changed during the years. Moreover, mainly in the past, bigger machines were more reliable and efficient thus were preferred instead of several smaller machines. This aspect can represent a challenge in the load control of the system, mostly in case it is old and do not have an updated control strategy or there isn't a thermal storage, etc.

There can be, in fact, several control strategies that is possible to evaluate in case it is necessary to change the cooling system, both for technical reasons and for regulatory updates. The need to change the refrigerant, for example, could offer the opportunity to consider also a different approach, for instance less oversized machine, several smaller machines, variable speed machines, etc

Description of the possible technologies

Traditionally, an oversized cooling system, operates at partial load via an on/off strategy, that is surely not expensive to set up, but can cause problems during transient periods, in which, generally, machines work with lower performances, moreover on/off cycles tend to be more wearing. In addition, in many cases machines designed or adapted to operate at partial load can have at partial load a higher efficiency than at full load.

There are different approaches to solve or at least attenuate the on/off strategy problems.
First of all, it could be interesting to consider a thermal (cold) storage. This could allow the system to work at its best condition (100% load) and use the storage to adapt the load

demand of the circuit. Another opportunity could be using a Variable Speed Drive (VSD), that gives the chance to better operate at partial loads and reduce the starting stress of the motor.
Another way is to make a mechanical partialisation, excluding one or more cylinders for reciprocating compressors or using a slide valve for screw compressors: both these opportunities have the aim to mechanically reduce the load by lowering the refrigerant flow in the compressor, but it isn't much efficient.
Another opportunity could be using more smaller compressors in parallel so that they can be turned off if required, eventually only one with VSD.
Finally, another opportunity, could be using a by-pass valve after the compressor, thus reducing the refrigerant circulating in the circuit.

Benefits

A well-designed control strategy, together with the energy savings can offer different benefits, such as:

- Reduced operational costs
- Reduced maintenance costs
- (in some cases) Risen reliability.

Overview of the possible approaches

	System	How it works	Advantages	Possible disadvantages
Load shift	***Cold Storage***	*Cold storage to buffer the required load*	*Reduction of on/off cycling*	*It is necessary to carefully design the circuit to avoid cold over production.*
Electric	***On/off***	*Turn on and turn off the compressor*	*Simple and cheap, just a thermostat needed*	*Ambient (or fluid) temperature is never constant. Frequent transient periods in which the compressor performances are low. Higher stress of the machine.*
	VSD	*Variable speed drive*	*Reduction of on/off regulation, good performances at partial loads, lower stress for the machine*	*If the engine speed is too low there can be problems for the lubrication*
Mechanical	***Cylinders closure***	*On reciprocating compressors, one or more cylinders can be excluded*	*More power levels with just one compressor*	*The pistons not compressing the gas are still active, this means that the energy saving is not directly related to the lowering of cooling power*
	Slide Valve	*On screw compressors, it is possible to put a slide valve that generates a gas recirculation*	*Having more power levels with just one compressor*	*The energy saving is not directly related to the lowering of cooling power*
On the refrigerating system	***Compressors in parallel***	*More compressors are used: some of them can be turned off*	*Consolidated system in the refrigeration sector. Good performances at partial loads. Higher reliability due to redundancy*	*More Expensive*
	By-pass valve	*A by-pass is inserted to leak a certain quantity of gas after the compressor to lower the flow inside the circuit*	*Continuous load variation from 100% to 50%*	*The specific consumption increases since the gas flow is constant, while reducing the load: it is necessary to carefully design the circuit.*

BEST PRACTICES – REFRIGERATION SYSTEM
FACTSHEET

ICCEE
Improving Cold Chain Energy Efficiency
in food and beverage sector


© Alexas_Fotos, Pixabay

'Double saving'

Germany
Retail

Investment
57,800 €

Savings
3,500 €/year
17,000 kWh/year

Main NEBs (other benefits)
Reducing greenhouse gas emissions
Product quality improvement
Environmentally friendly

Electricity costs and emissions savings

A small German village shop has proven that it is possible for small and medium-sized enterprises to be a climate pioneer: in 2010, it installed 100 m^2 of photovoltaic modules on its roof, which has already saved 46 tonnes of CO_2 emissions since. In 2017, the shop's management, voluntarily run by inhabitants from the village, decided to do more: after a comprehensive consultation with an energy consultant, they found further efficiency potentials for the store.

In spring 2018, the new refrigeration system and deep-freeze technology with a modern CO_2 compound, which replaced four old refrigerators, was installed. Using CO_2 as a natural refrigerant, it is more energy efficient, functions as a more environmentally friendly alternative to CFC and HCFC fluids, and gives CO_2 a second life. Thus, electricity could be saved, and the use of environmentally harmful substances was reduced. A new refrigerated service counter and a refrigerated and deep-freeze shelf were put into operation for this purpose. Now cheese, sausage, meat and frozen products are kept fresh and presented in an attractive way.

Description

Climate-friendliness is not just a goal for the big corporations: a small village shop in Germany has proven that it is possible to enable citizen participation and climate protection as a small business. In 2010, the shop's 200-year old building was renovated and comprehensively insulated, reducing the need for heating and cooling energy in the winter and summer months. Additionally, over 100 square metres of solar PV panels were installed on the shop's rooftop, producing environmentally friendly electricity for the shop's own consumption. This measure alone has already resulted in a reduction of 46 tonnes of CO_2 emissions.

In 2017, the shop's chairman, applied for a nation-wide energy efficiency project. This project supports small and medium-sized enterprises in becoming more energy efficient, by providing funding and support in the planning phase.

After consultation with an energy expert, the village shop found further energy efficiency potential. In spring 2018, four old refrigerators were replaced with a new refrigeration and deep-freeze technology with a modern CO_2 compound refrigeration system.

What is the improvement focus?

Using CO_2 as a refrigerant means a natural and environmentally friendly alternative to the traditional HCFC/CFC refrigerants that damage the ozone layer. Additionally, its volumetric cooling capacity is significantly higher than that of conventional refrigerants, and could be considered safer due to lower toxicity levels and non-flammability. It has to be noted that CO_2 as a refrigerant, leads to higher pressure, and associated hazards can present additional challenges. Due to the higher pressure, CO_2 is also not suitable as a retrofit refrigerant.

Benefits

Nine months after the installation of the new refrigeration system, the shop has used 12,000 kWh less than it would have otherwise. Thanks to this latest energy efficiency measure, the shop's energy consumption has dropped by an additional 30%, contributing to climate goals and shielding the shop from rising electricity prices.

Combined with the existing PV installation, the shop's total electricity consumption has dropped with over 31,000 kWh, or 58%, saving the shop around €6,500 per year.

Another important benefit is the improved presentation of the shop's cooled goods in the new refrigerated service counter, which is more attractive than it was in the four old refrigerators.

Using PV panels, energy efficient refrigeration systems and natural refrigerants, such as CO_2 is a cross-sectional possibility for businesses of different sizes to decrease electricity consumption, greenhouse gas emissions, the use of harmful substances and related costs.

Opportunities and barriers to implementation

Opportunities	*Barriers*
Lower electricity consumption and related cost	investment costs for PV panels and new refrigeration technology
Environmentally friendly technology (Reducing greenhouse gas emissions)	
Cross-business technology also for small businesses	

Calculations

The calculations show a quick idea of the costs and returns of this practice, as well as the economic impact after the implementation of the new equipment. For transparency's sake, the initial situation is directly compared with the final situation and a table of differences is shown broken down into the different key points of savings, using an average price of electricity and emissions taking into account their expected evolution.

	Initial situation	Final situation
Annual energy consumption [kWh/year]	56,476	39,359
Annual energy cooling consumption [kWh/year]	*No data*	
Annual economic energy expenditure [€/year]	12,424	8,625

BEST PRACTICES – REFRIGERATION SYSTEM
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Improving Cold Chain Energy Efficiency in food and beverage sector

Total investment (€)	57,800[1]
Energy savings [kWh/year]	17,117
Average electricity price [€/kWh]	0.3147[2]
Average emission price [€/tCO_2]	25[3]
Emission reduction [tCO_2/year]	9.7[4]
Energy economic saving (€)	3,799
Emission economic saving (€)	242.50
Total economic savings (€)	4,041.50
Return period (years)	14.3[5]

References

[1] Handelsverband Deutschland: Klimaschutzoffensive des Handels: Erfolgsgeschichten: Dorfladen & AllerCafé Otersen, Potsdam. Zuletzt eingesehen am 23.06.2020 unter:

https://www.hde-klimaschutzoffensive.de/de/kampagne/erfolgsgeschichten/dorfladen-otersen

[1] The village shop received financial support in the height of €45,121, making their own investment costs €12,679.
[2] This is the average retail electricity price in Germany in 2018.
[3] This will be the German carbon price in 2021.
[4] The carbon intensity of Germany's electricity is 567g/kWh.
[5] This is the return period for the entire investment. The return period for the shop's own investment (€12,679) is 3.1 years.

BEST PRACTICES – REFRIGERATION SYSTEM
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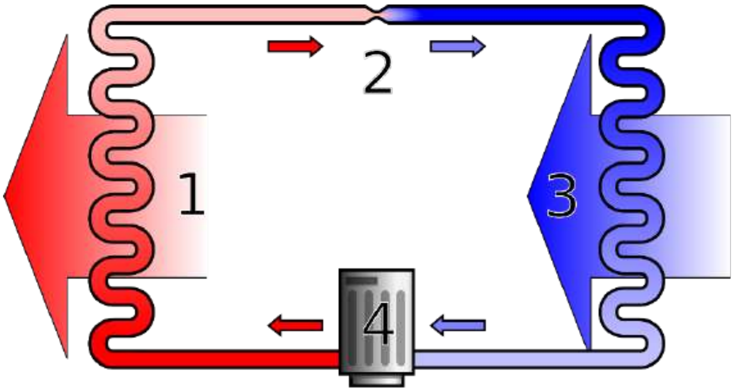
ICCEE Improving Cold Chain Energy Efficiency in food and beverage sector



'Operating at very low temperatures requires special solutions.'

Food and Beverage sector
TRL 9

Refrigerant cycle

Operating at very low evaporation temperatures (e.g. when providing cooling for a deep-freezer and still using ambient air as a heat sink for the condenser) often requires special system solutions.

Low-temperature evaporation requires low evaporation pressures while the condensing pressure is at normal levels. It is often beneficial, and in some cases necessary, to separate the evaporation and condensing pressure levels by more than one compressor step. This is because when the pressure ratio over the compressor increases, the discharge temperature out of the compressor will also increase. Simultaneously, the compressor efficiency decreases, which increases operating costs and energy consumption. High discharge temperatures may cause both the refrigerant and the lubrication oil to decompose. This in turn could shorten the life of the compressor.

Main NEBs (Other benefits)

Increased equipment life
Refrigeration at different temperature levels

The "classic" refrigerant cycle

As a reminder, in a classic one-stage cycle, the refrigerant is transformed and exchanges heat by flowing through 4 main components:

- **Evaporator:** the refrigerant enters into the evaporator as a low-pressure liquid and then expands, absorbs heat, and evaporates, changing to a low-pressure gas at the evaporator outlet.
- **Compressor:** the compressor pumps this gas from the evaporator through the accumulator, increases its pressure, and discharges the high-pressure gas to the condenser.
- **Condenser:** in the condenser, heat is removed from the gas, which then condenses and becomes a high-pressure liquid.
- **Expansion device:** between the condenser and the evaporator an expansion device is located. The flow of refrigerant into the evaporator is controlled by the pressure differential across the expansion device or, in the case of a thermal expansion valve, by the degree of superheat of the suction gas.

The limitations of a single stage vapour compression system

Hence, a single stage vapour compression refrigeration system has one low side pressure (evaporator pressure) and one high side pressure (condenser pressure).

The performance of single stage systems shows that these systems are adequate as long as the temperature difference between evaporator and condenser (temperature lift) is small.

However, there are many applications where the temperature lift can be quite high, in particular when the required evaporator temperature is very low. For example, in frozen food industries where the required evaporator can be as low as -40°C.

As the temperature lift increases, the single stage systems become inefficient and impractical. For a given condenser temperature, as evaporator temperature decreases:

- Throttling losses increase
- Superheat losses increase

- Compressor discharge temperature increases
- Quality of the vapour at the inlet to the evaporator increases
- Specific volume at the inlet to the compressor increases

The assets of multi-stage systems

As a result of this, the refrigeration effect decreases and work of compression increases. Due to these drawbacks, single stage systems are not recommended when the evaporator temperature becomes very low (or when the condenser temperature becomes high). In such cases multi-stage systems are used.

In practice, for fluorocarbon and ammonia-based refrigeration systems, a single stage system is generally used up to an evaporator temperature of –30°C. A two-stage system is used up to –60°C and a three-stage system is used for temperatures below –60°C.

Apart from high temperature lift applications, multi-stage systems are also used in applications requiring refrigeration at different temperatures. For example, in a dairy plant refrigeration may be required at –30°C for making ice cream and at 2°C for chilling milk. In such cases it may be advantageous to use a multi-evaporator system with the low temperature evaporator operating at –30°C and the high temperature evaporator operating at 2°C

Two-stage system

A two-stage system is a refrigeration system working with a two-stage compression and mostly also with a two-stage expansion. Flash gas is separated from liquid refrigerant in an intermediate receiver between the two expansion valves. The high-stage compressor will then remove the flash gas. The removal of the gas between the expansion stages reduces the quality of the refrigerant vapor that enters the evaporator. Each mass unit of refrigerant passing through the evaporator will then be able to absorb more heat, reducing the required refrigerant mass flow rate for a given cooling capacity. This in turn reduces the required low-stage compressor size. Because of the enhanced heat transfer coefficient in the evaporator, the heat transfer area needed is also reduced.

Intercooler

An intercooler system uses an intermediate evaporation step to cool the discharge gas from the first compressor step.

The refrigerant liquid leaving the condenser is split into two streams. The smaller part of the liquid is fed through an intermediate expansion valve, and then allowed to evaporate on one side of the intercooler. The main flow is sub-cooled by leading it through the other side of the intercooler. The sub-cooled refrigerant liquid leaving the intercooler is fed through the main expansion valve and then through the main evaporator.

The sub-cooling decreases the inlet vapor quality, which reduces the refrigerant mass flow rate through the evaporator and the required low-stage compressor size for a given cooling capacity. This results in efficient gas cooling. The discharge gas from the high stage compressor can be kept at an acceptable temperature, and the compressor efficiency is increased.

Cascade systems

The cascade system consists of two separate refrigeration circuits connected only by an intermediate cascade heat exchanger. The high-temperature circuit is cooled by an air condenser at ambient temperature, and uses the cascade heat exchanger as the system evaporator. The low-temperature system produces the low-temperature cooling in the cold evaporator, and uses the cascade exchanger as a condenser. The cascade heat exchanger connects the two refrigerant circuits thermally by acting simultaneously as an evaporator and a condenser.

The primary advantage of a cascade system is that the two stages do not necessarily contain the same refrigerants. A refrigerant with a higher vapor pressure can be used in the low-temperature system, while a refrigerant with a lower vapor pressure is suitable for the high-temperature system.

Multi-stage refrigeration cycles can also achieve very low temperatures efficiently, but there are some major disadvantages compared with the cascade cycle. In multi-stage refrigeration, the same refrigerant must work at the highest and the lowest pressure levels. The selection of refrigerant to avoid excessively large pressures in the ambient condenser, and evaporation pressures below one atmosphere in the cold evaporator, can be difficult.

BEST PRACTICES – REFRIGERATION SYSTEM
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Improving Cold Chain Energy Efficiency in food and beverage sector

Opportunities and barriers to implementation

Opportunities	*Barriers*
Increased equipment life	Additional cost for adding a new system
Refrigeration at different levels of temperature	
Temperature difference between evaporator (low temperature) and condenser (high temperature) is higher	
Increased compressor efficiency	
Lower operating costs and energy consumption (electricity, gas)	

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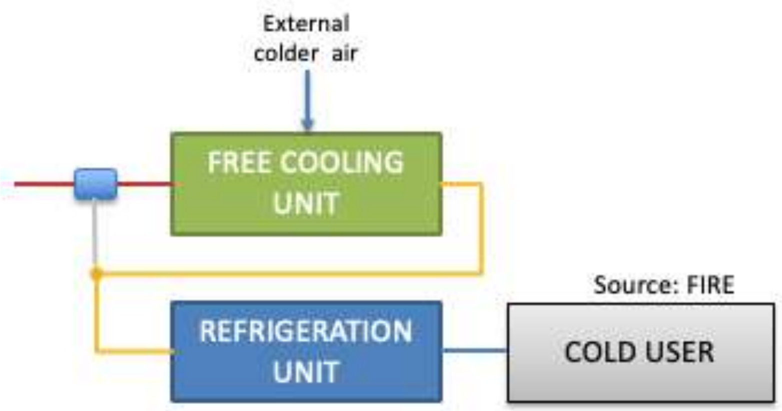
[2] SWEP Refrigeration handbook – Low temperature systems

The ICCEE project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement no. 847040.

BEST PRACTICES – REFRIGERATION SYSTEM
FACTSHEET

ICCEE
Improving Cold Chain Energy Efficiency in food and beverage sector



Source: FIRE

"Free Cooling for sustainable refrigeration and air conditioning"

Food Industrial Plant

TRL 9

Free Cooling

Free Cooling indicates the direct use of an external source, typically air, but can also be water, when its temperature (and humidity in case of direct external air use) allow its use directly (e.g. introduction of external air without any treatment) or indirectly (treating the air or exchanging heat with air or other heat carriers) with a lower energy consumption of the HVAC or cooling system. It is typically used in HVAC (Heating Ventilation and Air Conditioning) systems but can be also exploited to assist cooling for industrial applications. New HVAC systems usually are designed to allow free cooling, while other systems or older ones can often be modified to exploit free cooling.

The most suitable environment for Free Cooling is a combination of a cold or mild climate zone and the need of cooling energy for most of the year. This encompasses many manufacturing industries, such as food and beverage ones, but also other kind of facilities like data centres and spaces where constant temperature and humidity levels must be maintained (clean rooms, cold rooms, areas of hospitals, etc.)

Investment
15.000 €

Savings
10.000 €/year
100.000 kWh/year

Main NEBs (other benefits)
Lower greenhouse gas emissions
Longer equipment life
Lower maintenance cost
Lower operational cost

Description of the technology

Traditionally HVAC and cooling systems utilises a chiller to generate the cooling required for processes or HVAC application.
Free Cooling systems, instead, aim to reduce or even bring to zero the energy required by chillers. These systems can be added to air-cooled or water-cooled electric chillers and activate when the temperature of the external source has an appropriate value.
The choice between exploiting air or water is determined by a number of factors, such as the availability of water and its cost, the available space for a chiller, the cost of electricity and the period of time in which free cooling can be used. In general, water-cooled chiller and free cooling compared to air-cooled ones and occupy less space.
Food & Beverage industries require several kinds of cooling, such as the temperature control to reduce the

BEST PRACTICES – REFRIGERATION SYSTEM
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Improving Cold Chain Energy Efficiency in food and beverage sector

bacterial load and the quick freezing/cooling of pre-cooked of frozen foods.
The cooling systems could help to increase the productivity, without lowering the all-important organoleptic properties of the finished product such as taste, colour and smell.

What is the improvement focus?

Free cooling has the objective to reduce chiller energy consumption: it can be done via a (higher) direct intake of external air, via a chiller with a built-in free cooling coil or via a free cooler working in series with a chiller. The latter, usually, should be more efficient, due to the larger surface area provided by the air cooler.

Benefits

A Free Cooling system, together with the energy savings can offer different benefits, such as:

- Reduced water consumption
- Reduced operational costs
- Reduced carbon footprint
- Reduced maintenance costs

In particular, one of the most important voices can be seen in the reduction of maintenance costs. In fact, usually, Free Cooling chiller plants have a longer lifecycle compared to traditional chillers because of the reduced number of operation hours of the compressor during the year.

Opportunities and barriers to implementation

Opportunities	*Barriers*
Lower energy consumption and related cost	Possible major modifications of the distribution layout
Lower maintenance costs	Difficult to implement if external ambient temperatures are high
Higher equipment lifespan	

Calculations

The calculations below, for a system allowing a higher exploitation of external air, from the previous 10%-20% to around 50%, show a quick idea of the costs and returns of this practice, as well as the economic impact after the implementation of the new equipment. In order to be clear, the initial situation is directly compared with the final situation and a table of differences is shown broken down into the different key points of savings, using an average price of electricity taking into account their expected evolution. This example is taken by a real case study implemented in the Central Europe zone.

	Initial situation	Final situation
Inlet air flow [Nm^3/h]	60,000	60,000
Annual energy cooling consumption [kWh/year]	600,000	500,000
Annual economic energy expenditure for cooling [€/year]	60,000	50,000

Total investment (€)	15,000
Energy savings [kWh/year]	100,000
Average electricity price[€/kWh]	0.1
Energy economic saving (€)	10,000
Return period (years)	1.5

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Improving Cold Chain Energy Efficiency in food and beverage sector

'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.

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

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[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

Refrigeration system improvement

Spanish company dedicated to the elaboration of different high-quality meat products, decides to conduct a study to evaluate their facilities and detect possible inefficiencies in them. The is focused in the cured ham production, which must be elaborated under very specific temperature conditions to achieve the best quality and fulfil the food regulation requirements.

After an energy efficiency study, it was decided to change an old refrigeration system running on R22 by a modern centralized ammonia (NH3) aimed at producing significant **energy savings**, as well as a reduction of the emissions. Oher benefits include the better control of the refrigeration system, which improves the processes and product quality and a reduction in the operating and maintenance costs, with a reduced pay-back period.

'Double saving'

Spain
Meat industry

Investment
300,000 €

Savings
55,000 €/year
350,000 kWh/year

Main NEBs (Other Benefits)
Reducing greenhouse gas emissions
Increased equipment life
Product quality improvement

Description

For many years the industrial refrigeration system has used traditional R22 and its substituting refrigeration gases, with high power but also high GWP.
The study considered the option to transform this system by a new centralised ammonia system (NH3, R717) which brings a set of benefits as improved efficiency, easier maintenance, emissions reduction, better control, etc.

By substituting the old performance cooling plant by a new NH3 system it was also possible to use part of the heat produced in the factory processes, thus improving the overall heating and cooling performance.

The heat recovery system is integrated in the overall system, thus providing an integrated performance of great interest for any factory demanding cold and heat.

What is the improvement focus?

The NH3 refrigeration plant is located in the technical room and, by using a compression-evaporation centralised system, achieves a refrigerant load reduction in the system.

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FACTSHEET

The key of this improvement lies in greater efficiency from the new chiller plant to the existing refrigerated plant. Initially there was a plant constituted by a set of individual compressors with an average EER of 1.30 that have been upgraded to a centralised and controlled system with EER 3.5.

Benefits

A new system with technical, control and heat recovery improvements is available after this renovation.

The most important ones for the industry are present directly in the electricity bills since there is a significant energy efficiency increase of the entire cooling and heating system, from a plant <1,5 EER plant to an installation with a value next to 3.5, considering the heat recovery.

Reducing the greenhouse emission is another major benefit of this improvement due to operation with low GWP refrigerant, as well as supporting the company strategic aims in its environmental policy.

Other important benefits are the increased lifespan, lower maintenance requirements of the new equipment and improved control system.

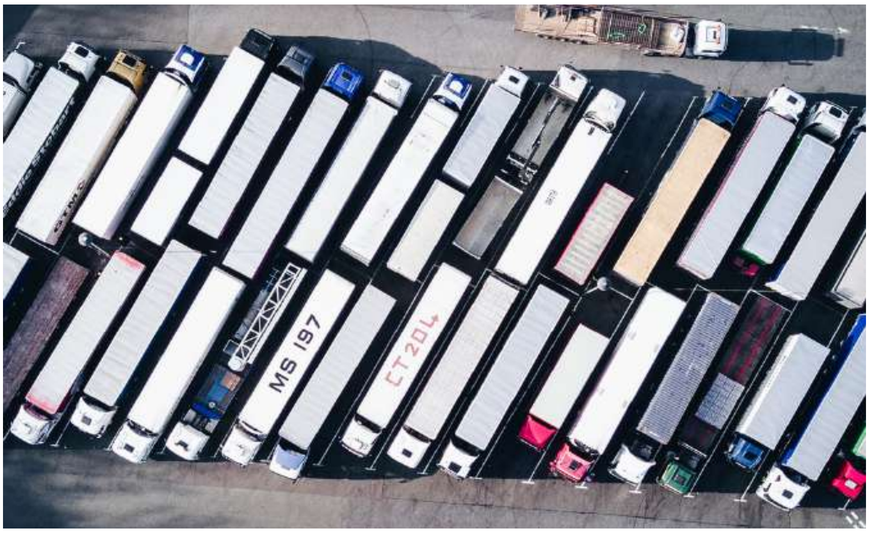
Calculations

The calculations show a quick idea of the costs and returns of this practice, as well as the economic impact after the implementation of the new equipment. In order to be clear, the initial situation is directly compared with the final situation and a table of differences is shown broken down into the different key points of savings, using an average price of electricity and emissions taking into account their expected evolution.

	Initial situation	Final situation
Productive capacity [t/year]	900	900
Annual energy consumption [kWh/year]	1,402,285	1,029,277
Annual energy cooling consumption [kWh/year]	981,600	608,592
Annual economic energy expenditure [€/year]	184,285	135,265

Total investment (€)	300,000
Energy savings [kWh/year]	373,008
Average electricity price[€/kWh]	0,13142
Average emission price [€/tCO_2]	36
Emission reduction [tCO_2/year]	150
Energy economic saving (€)	49,020
Emission economic saving (€)	5,400
Total economic savings (€)	54,420
Return period (years)	5.5

BEST PRACTICES – TRANSPORT
FACTSHEET



Less cooling load by improved insulation and air curtains

A logistics company that mainly transports chilled and frozen food wants to save both energy and costs by reducing the cooling load of its trucks. In order to achieve this, it was analyzed how heat enters the cold store and thus increases the cooling load. In this way, possible inefficiencies are to be identified and assessed to what extent this can be avoided.

The study has shown that especially transmission and open doors lead to heat transfer into the truck interior. Especially in the case of frozen goods, the loss due to the exchange of air when the doors are opened is very high.

For this reason, two energy efficiency measures were implemented that were able to significantly reduce the cooling load. Firstly, the vans were additionally insulated or old insulation, whose heat transfer coefficient has deteriorated over time, was replaced. Secondly, air curtains were fitted to the doors, which can significantly reduce energy losses via air circulation when the doors are opened.

'Fuel saving and quality assurance'

Germany
Logistics company

TRL 9

Implementability: 99%

Payback period:
Air curtain: 8 month

Energy savings
Insulation: up to 30 %
Air curtain: up to 40 %

Main NEBs (other benefits)
Less maintenance
Product quality

Description

Since transmission and air circulation when opening the doors are mainly responsible for heat input into refrigerated trucks (see Figure 1), the insulation is improved and air curtains are installed.

The old insulation is first cleaned and checked for damage. The age of the insulation is taken into account, as this is associated with a deterioration of the insulation. If necessary, trucks or the insulation will be renewed. For example, vacuum insulation can result in energy savings of up to 30% [1].

As a second measure, air curtains are used, which can result in energy savings of up to 40% [1]. In addition, open doors are avoided if possible.

Improving Cold Chain Energy Efficiency in food and beverage sector

BEST PRACTICES – TRANSPORT
FACTSHEET

What is the improvement focus?
The key regarding both measures is to reduce heat transfer to the cooled area. Improved insulation reduces thermal conduction and an air curtain minimizes convection by air circulation. In this way, the cooling load is reduced and thus the fuel consumption for refrigeration.

Benefits
The main advantage of both measures, insulation and air curtain, is the decrease in energy consumption and costs for cooling technology.

In addition to the energy savings, another benefit of the air curtain is that the goods are less exposed to temperature fluctuations. For example, it has been reported that avocados change color less due to an air curtain, thanks to less temperature fluctuations. [2]

In contrast to an automatically closing door, the air curtain does not cause any time delays and truck drivers are very satisfied with the result. It has been observed that the air curtain is just as energetically effective as an automatically closing door. [2]

Opportunities and barriers to implementation

Opportunities	*Barriers*
Lower fuel consumption and related cost	Costs for air curtain
Negligible maintenance	Staff training required
Available worldwide	
Simple handling	
Improves food quality	

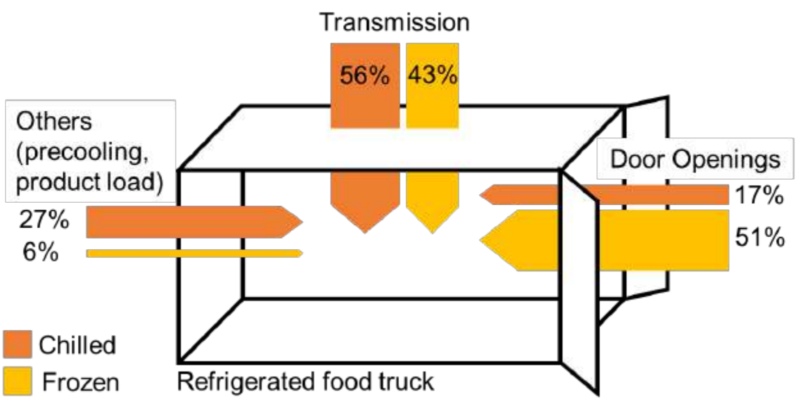


Fig. 1: Example for thermal loads chilled and frozen food trucks, based on [1]

References

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BEST PRACTICES – TRANSPORT
FACTSHEET

ICCEE
Improving Cold Chain Energy Efficiency in food and beverage sector

Saving costs by fuel monitoring

As part of the implementation of an energy management system, a logistics company uses fuel monitoring as a measure to detect irregularities in order to measure and reduce the fuel consumption. A sudden increase in fuel consumption or a rapid loss of fuel is noticed and the causes can be detected and remedied.

This also leads to a sensitization of the driver, as the fuel display shows which behavior leads to lower or higher fuel consumption. For example, this can motivate drivers not to leave the doors open unnecessarily long during loading and unloading.

A further advantage is that fuel theft is detected early on and damaged goods do not occur due to insufficient cooling.

'Saving fuel and costs'

Germany
Logistics company

TRL 9

Implementability: 99%

Main NEBs (other benefits)

Reducing pollutant emissions
Quality assurance

Description

When implementing an energy management system (EMS) some measuring points have to be installed and monitored. One goal of the logistics company regarding the EMS is to reduce the fuel consumption of the trucks. Therefore, the fuel consumption must also be monitored to check the extent to which the targets are achieved.

The monitoring system should display various data suitable for the EMS. The fuel consumption for cooling is displayed separately. A reference to the ambient temperature is also provided. For example, fuel consumption per temperature difference to be cooled is seen as a suitable key performance indicator (KPI). The fuel consumption per kilogram of refrigerated goods is also meaningful, or a combination of both figures, i.e. consumption per temperature difference and kilogram of goods.

What is the improvement focus?

The key element of fuel monitoring is to control the effectivity of measures which are already implemented and

to derive new additional energy efficiency measures. This also includes short-term small measures such as correctly closing the doors as soon as possible. In addition, in the long term, a deterioration in the truck's insulation is also evident.
In the long term, fuel monitoring can help to make the truck driver more aware of the influences on fuel consumption.

Benefits

The main advantage is the contribution to energy management. The measurement and monitoring of fuel helps to continuously improve the transport process.

An additional advantage is the precise knowledge of fuel consumption, so that invoicing can be controlled.
Interruptions in the cold chain must be avoided under all circumstances. Therefore, fuel level monitoring is urgently required so that even in the event of fuel theft, damage to goods can be prevented at an early stage.

Opportunities and barriers to implementation

Opportunities	*Barriers*
Lower fuel consumption and related cost	Additional cost for software upgrade
Negligible maintenance	Additional cost for new vehicles
Available worldwide	Staff training required
Simple handling	
Improved food quality	

BEST PRACTICES – TRANSPORT
FACTSHEET

Improving Cold Chain Energy Efficiency in food and beverage sector

Optimizing travel routes

In order to increase the energy efficiency of a logistics company within the framework of an energy management system (EMS), a special navigation program is implemented, which was developed especially for refrigerated transport.

In contrast to conventional navigation systems, not only the time and costs caused by transportation and e.g. tolls are taken into account, but also the energy and costs caused by the cooling system. This concerns, for example, the duration of the route related to the cooling load. In addition, the option of detours to transport more goods is also taken into account and the system reports whether or not it is energetically and economically feasible to take a detour. In this way, the routes can be optimized in such a way that, on the one hand, as little energy as possible has to be provided by the vehicle and the cooling system and, on the other, the vehicle can be loaded as fully as possible. Accordingly, one performance indicator (KPI) of the EMS is the energy consumption per kilogram of goods.

'Saving fuel and time'

Austria
Logistics company

TRL 8

Implementability: 99%

Main NEBs (other benefits)

Time and cost saving
Reducing vehicle abrasion
Reducing pollutants
Energy management

Description

In addition to the usual input data of a navigation system, which concerns the geographic data of the various route options, the data of the cooling system also are integrated in the program. From this, the energy consumption resulting from different route options is calculated.

The energy consumption results from the duration of the drive and the cooling load as well as from the route length and the fuel consumption for driving. On the other hand, the load of the transporter must be maximized, which sometimes requires detours of the route to pick up goods at locations that are not on the route. Whether a certain detour is reasonable from an energy point of view can be easily determined using the program. Truck drivers can access the data using an app and thus react to route changes even at short notice.

The app suggests the most energy-efficient, the fastest and the most cost-effective way. Toll costs and the costs of travel expenses due to personnel costs etc. are also taken into account. The KPI is calculated for each route. This KPI is not set in relation to the route, as potential detours for maximum load or minimum travel time can also contribute to energy efficiency. The kilometers driven must therefore be considered separately.

What is the improvement focus?

The main advantage of this efficiency measure is that it saves fuel by taking the cooling load into account when choosing the route. For example, toll roads that appear to be an uneconomical route option using a conventional navigation system may indeed be financially feasible if the costs of cooling over the duration of the journey are taken into account.

Benefits

The main advantages of this navigation program are the energy and cost savings that can be achieved compared to conventional navigation systems by an improved analysis of energy flows and costs.

In addition, this program contributes significantly to the monitoring of the EMS and thus to the continuous improvement process, as it helps to identify further efficiency measures.

Opportunities and barriers to implementation

Opportunities	*Barriers*
Lower fuel consumption and related cost	Additional cost for software
Negligible maintenance	Additional cost for new vehicles
Available worldwide	Staff training required
Simple handling	
Improved food quality	

BEST PRACTICES – TRANSPORT
FACTSHEET

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Improving Cold Chain Energy Efficiency
in food and beverage sector

'Portable cold'

Italy
Frozen foods

TRL 9

Investment (real or estimated)
€ 4,000

Pay Back Time
< 1 year

Main NEBs (other benefits)
Food quality
Lower fuel consumption
Lower leakages
Negligible maintenance

Portable refrigerated units for LTL

Refrigerated transport is critical not only in terms of maintaining the temperature integrity of the products but also in terms of the environmental impact in terms of energy consumptions and greenhouse gas and particulate emissions.
Portable refrigerated units (PRU) represent a novel solution that can be used by logistic companies to offer their customers a refrigerated transport service for small and medium volumes (e.g., Less than Truck Load transport) of perishable goods on board of their standard vehicles, without the need for investment in special vehicles and infrastructures.
The use of this particular solution can lead to relevant economic and environmental benefits with respect to the traditional refrigerated transport which is usually belt-driven from the vehicle engine with diesel as the fuel source.

Description

Refrigerated transportation of foodstuffs presents several challenges and issues (e.g., harsh environment, wide range of cooling demand and constraints, substantial temperature differences inside the vehicle due to air distribution) which make critical keeping the temperature of perishable goods in the desired range during the transportation activities.
Furthermore, these issues are increased by the recent globalization which results in long distances travelled and higher duration of land transportation. In addition, the increasing quantity of transported goods and of home deliveries, and the higher quality expectations of customers, bring to an increased use of refrigeration in order to reach lower temperatures, which result in tremendous amount of energy consumption [1].
There are many factors affecting design and performances of

transportation units, such as extreme exterior weather conditions, desired interior conditions, insulation properties, infiltration of air and moisture, trade-offs between construction and operating costs and physical deterioration from shocks and vibrations. In addition, there are logistic activities that cause air infiltrations which lead to a remarkable increase of the cooling demand and, consequently, of the energy usage, and which may also affect the product temperature and quality. The most relevant are the frequent temporary opening of the vehicle doors for the delivery of the products, and the temporary interruptions of refrigeration function due to engine power off, mainly during loading and unloading of the products [2]. For instance, a food product can be subject to about 50 door-openings during a multi-drop delivery [3]. While, ground operations for loading and unloading products frequently report increases in temperature due to the length of time that pallets are kept at inappropriate ambient temperatures waiting for material handling activities.
As a consequence, the stakeholders' awareness on these significant environmental impacts put an increasing demand for the definition of new solutions for more sustainable refrigerated transport activities. Recently, a portable refrigerated unit (PRU) has been proposed as a new solution for overcoming the previously defined issues [4]. The ColdTainer[1] solution is an active transportable insulated and refrigerated unit designed and produced by the company Euroengel Srl.

What is the improvement focus?
Portable refrigerated units are made of polyethylene for food use with a rotational molding technology, which allows to obtain unique impact resistant cable bodies. Such containers can be easily sanitized in compliance with Directive 93/43/EEC (HACCP). The thermal insulation is made of expanded polyurethane, with thickness ranging from 65 to 130 mm. Furthermore, the larger models are tested in accordance with ATP regulations and have a technical dispersion coefficient "K" less than 0.40 Wm2/K.
The refrigeration units use Danfoss hermetic compressors (12-24Vdc), developed specifically for use on vehicles and therefore with low absorption and can function perfectly even in the presence of vibrations and angles up to 30°C. Coolant gas is R134a, non-flammable and compatible with environmental regulations, for + 4 °C solutions while R404a for – 20 °C solutions.

Benefits
The use of active refrigerated containers simplifies different phases of the cold chain with obvious reduction in direct and indirect costs, a significant improvement in delivery time, and also a reduction in the risk of food contamination and breaks in the chain itself. This entails environmental benefits in terms of reducing energy consumption and CO_2 emissions. In particular, this technology simplifies transport and storage of refrigerated goods.
From the storage point of view, containers can be placed in non-refrigerated traditional warehouses and used as a local refrigerated space by connecting them to the power supply. This allows you to not make specific refrigerated warehouses while avoiding investments. From the transport point of view, these containers can therefore be loaded directly with a forklift truck on an un-refrigerated truck (powered by 12V/24V batteries of the vehicle) for direct delivery to their final destination. This system therefore eliminates the need for specialized refrigerated vehicles. PRUs enable also the joint delivery and storage of refrigerated and non-refrigerated goods, since they allow to set different temperatures to each unit avoiding the deterioration of products. In particular, in the food supply chain where the temperature, relative humidity, hygienic conditions and possibly even air composition must be strictly controlled and monitored to accelerate or slow down the product aging process (controlled atmospheres). PRUs allow also to avoid the partitioning of the warehouse into smaller cells for the preservation of goods with similar characteristics.

The use of active refrigerated containers simplifies different phases of the cold chain with obvious reduction in direct and indirect costs.

[1] https://www.coldtainer.it

BEST PRACTICES – TRANSPORT
FACTSHEET

Opportunities and barriers to implementation

Opportunities	*Barriers*
Improved food quality	Additional cost for renovating fleet equipment
Lower fuel consumption and related cost	
Negligible maintenance	
Lower leakages	
Available worldwide and cheaper than other solution	
Simplified handling, storage and transport of products	

Calculations

The calculations show a quick idea of the costs and returns of this practice, as well as the economic impact after the implementation of the new equipment. In order to be clear, the initial situation is directly compared with the final situation and a table of differences is shown broken down into the different key points of savings.

Total investment (€)	4,000
Fuel unit price [€/l]	1.65
Refrigerant price [€/kg]	29
Emission reduction	- 37%
Savings	- 43%
Return period (years)	<1

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'Resource recovery towards circular economy'

Italy
Fruit & vegetables

TRL 5

Industrial symbiosis: by-products exchanges

By-products exchanges allow the recovery of resources (e.g., mass and energy) from waste streams including food production plants and other players in the geographical proximity. These synergies can improve the overall sustainability of such processes from both economic and environmental points of view.
Resource recovery represents a key pillar in the transition from a linear to a circular economy.

Savings
0.68 – 1.6 M€/year

Main NEBs (other benefits)
Reduced greenhouse gases emissions
Improved productivity
Lower dependence on fossil fuels

Description

Among the different transactions characterizing the Industrial Symbiosis (IS) there is the by-products exchanges which refer to business-to-business relationships that mimic symbiotic interactions between organisms, where surplus resources generated by an industrial process are captured and redirected as 'new' input into other processes providing mutual benefits instead of being thrown away.

What is the improvement focus?

The main principles of industrial symbiosis include ensuring economic and environmental advantages for the involved companies and society and ensuring the least distance between companies that are implementing the by-product exchange in order to exploit the synergistic potentials offered by geographic proximity [1,2]. As the nature makes a complete and continuous recycle of every material, Resource recovery in industrial symbiosis networks represents a key pillar in the transition towards closed-loop solutions and circular economies for which everything is recycled or re-used and nothing destroyed, i.e. no waste and pollution are produced.
In the domain of food and beverage industry, different synergies can be found for the valorisation of by-products [3]: e.g., separation of valuable material from industrial food waste, utilization of food waste as a substrate/reactant in creating valuable compounds through fermentation, energy recovery form waste food or excess heat from nearby industries.

Resource recovery in industrial symbiosis networks represents a key *pillar in the transition towards closed-loop solutions and circular economies for which everything is recycled or re-used, and nothing destroyed.*

Benefits

IS represents a great opportunity to optimize the efficiency and the utilization of the resources and, at the same time, to improve environmental, economic and social performances leading to huge competitive advantages [2,4,5]. This is mainly due to the fact that the global benefits introduced with the industrial symbiosis network are greater than the sum of the single benefits that the actors could individually generate [6]. Moreover, a broader vision of industrial symbiosis considering an increasing collaboration between private companies and regional or national authorities, through public-private partnerships, allows to gain greater benefits also for public organizations [7]: (1) improved performance of the public service facilities; (2) reduced and stabilized cost for providing services such as heat, cooling and electricity to public service facilities (e.g. hospitals, offices and schools) leading to greater cost-efficiency and (3) reduced environmental impact.

Horticulture case study

In this case study, we consider the industrial symbiosis potential between an energy-intensive factory that make use of forging processes, and a nearby greenhouse installation [8]. The considered industrial process is particularly suitable for the application of carbon capture and utilization (CCU) through horticulture enrichment. Firstly, the properties of the process exhausts (such as the level of contaminants, and the temperature) match the requirements of the CO_2 horticulture enrichment. Secondly, the close proximity to an existing greenhouse installation allows the direct transportation of CO_2 through pipelines. The symbiotic potential among the industrial installation and the horticulture process could be exploited by using the waste heat and CO2 emissions of the forging process for, respectively, the heating of the greenhouse, and the supply of CO2 to the horticulture enrichment process.

If we consider only the synergy focusing on the use of CO_2 enrichment as CCU method for the reduction of industrial emissions, it is possible to reach economic savings, and to reduce the environmental impact with respect to a scenario without CO_2 enrichment and to a scenario with CO_2 enrichment provided by a traditional system (i.e., heaters burning natural gas).
The results highlight three different economic savings: the increase of revenues deriving from the CO_2 enrichment process, the savings due to avoided natural gas consumptions (used in traditional CO_2 enrichment methods), and savings due to the reduction of CO_2 emissions in the industrial installation.
In the considered case study, the implementation of the industrial symbiosis network would lead to economic benefits between 0.68 and 1.6 M€/year, assuming 2 production cycles per year, which corresponds to the typical cultivation schedules for the selected crops (i.e., tomatoes, cucumbers, and strawberries).
At the same time, the exchange of CO_2 among the forging process and the greenhouse installation would allow to recover from 1,500 to 2,000 tons of CO_2 per cycle, which represent from 16 % to 21 % of the overall carbon dioxide emissions of the considered industrial installation.

Opportunities and barriers to implementation

Opportunities	*Barriers*
Reduced greenhouse gases emissions	Investment cost
Improved productivity	Requires more R&D
Lower dependence on fossil fuels (i.e., natural gas)	
Economic savings	

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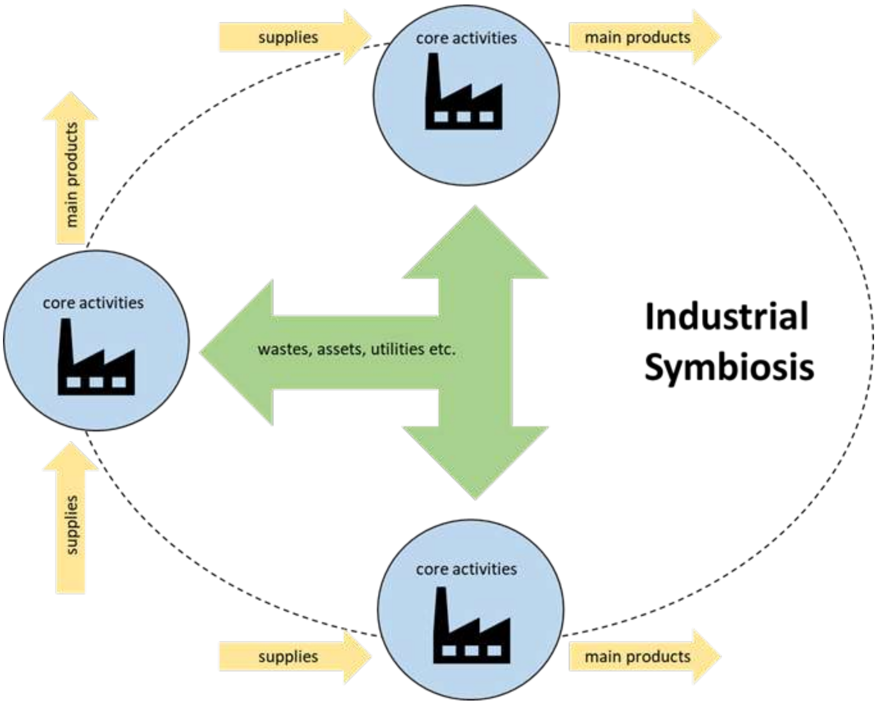

'Sharing means saving'

United Kingdom
Agriculture

TRL 9

Investment (real or estimated)
0 €

Savings for crop farms
28 - 57 € per acre

Industrial symbiosis: asset sharing

Whether used or not, your assets have continuous costs: depreciation, financing and interest, maintenance. Making sure that the asset is always used to its maximum potential ensures that no money is wasted during downtime.

Other benefits
Easier access to large and modern machinery
Less material consumption

What is Industrial Symbiosis?

Industrial Symbiosis engages traditionally separate industries in a collective approach to competitive advantage involving physical exchange of materials, energy, water and by-products. The keys to industrial symbiosis are collaboration and the synergistic possibilities offered by geographic proximity. Industrial Symbiosis activity in Europe is very diverse in terms of features, emergence and development patterns or the content of the transactions.
Examples of industrial symbiosis are wide ranging and include the use of waste heat from one industry to warm greenhouses for food production, the recovery of car tire shavings for use in construction materials, and the use of sludge from fish farms as agricultural fertilizer. Yet, collaborative strategies do not only include by-product synergy ("waste-to-feed" exchanges), they can also include wastewater cascading, shared logistics and shipping/receiving facilities, green technology purchasing blocks, multi-partner green building retrofit or district energy systems. Proximity plays an important role in the feasibility of synergies, with most synergies happening in a radius of less than 50 km.
For example, industrial symbiosis has been applied for waste management and valorization in Lahti, Finland, and Pécs, Hungary[1].

[1] https://ec.europa.eu/environment/europeangreencapital/wp-content/uploads/2018/05/Industrial_Symbiosis.pdf

BEST PRACTICES – INDUSTRIAL SYMBIOSIS
FACTSHEET

Sharing an asset with other companies can be done when you are not using the asset for 100%. An asset can be anything that you use to make your business run.
An alternative to sharing currently owned assets is to invest in a new asset together with a partner. The combined investment will lower the investment costs per partner enabling investments, which would otherwise be out of reach.

When you share assets, you can more easily scale your business: rent out the assets if you are not using them, or access others spare capacity when you need it.

To get started with sharing, you can follow these steps:

1. Make an inventory of chances for asset sharing
2. Acknowledge and quantify under-used assets
3. Develop sharing policy and appoint someone to manage this task
4. Make an inventory of supply and demand
5. Use online marketplace or set up ad-hoc partnerships
6. Integrate sharing of assets in your company culture and daily operations

Trust is essential in the sharing economy. Maybe you do not want to share your important assets - either because the other party is a competitor, because your equipment is so specific that there is no need for it by others, or because your assets are sensitive to disruptions or changed operating parameters. Two approaches are available:
Find non-critical assets to share so you need less trust or make use of an online sharing platform where users are verifiable and can be rated.

A symbiotic partnership is effectively the opportunistic coming together of two or more actors from sectors that, under normal circumstances, would not come into contact.

Key benefits
Collective arrangements for expensive assets help to share the costs of capital and depreciation.

Efficiencies are also made through access to more modern and larger machinery that would otherwise be out of reach for the small to medium companies.

A secondary benefit of sharing assets is in the environmental gains. If two businesses can share the same asset to avoid the purchase of a second asset, less material is consumed.

Sharing agricultural equipment

The advanced machinery that farms need to boost competitive advantage is often costly to buy and maintain, especially for smaller operators. This is why the sharing economy is an ideal option. Digital technology and online platforms make this exchange of assets much more efficient and regulated.

Sharing the equipment can be done in different ways. Neighboring farms can buy machinery together and split the costs equally or on a pay-per-use basis. During the asset's lifetime, it is important to agree on conditions for using the machinery and things like maintenance and general care, and what happens when a user damages the machinery. This requires careful planning. In cases where no solution can be found for the specific tool, more generic equipment such as forklifts, loaders and trailers can still be shared. Farms can also pool resources, which includes labor and even non-farm assets. Labor and machinery savings for crop farms, for instance, have been estimated at between 28 € and 57 € per acre.

Logistics pooling can help companies to maximiser loads and minimize the number of trips and distance travelled, resulting in lower overall transport (fuel, maintenance) and personnel costs.

According to Eurostat, 25 % of truck kilometers in EU countries run empty. For example, in the UK food supply chain only 52 % of the available space on loaded trips is used. Larger trucks, which can carry a payload of up to 29 tonnes, transport on average only 17.6 tonnes when loaded and 12.7 tonnes if empty running is allowed.

These statistics show that there is plenty of room for improvement, in many sectors. Multi-mode partnerships aimed at maximizing capacity (on outbound and return trips) can accomplish the following results:

- Reduce costs by 15 %
- Cut carbon emissions by as much as 50 %
- Improve delivery frequency by a factor 2 to 5
- Reduce stock levels by 15-20 %

Additionally, enterprise management and operations can focus on core business.

Pooling requires more planning than traditional logistics. However, with the emergence of smart online applications, this task can be performed by so-called 3rd or 4th party logistics providers (3PL or 4PL). These services can bundle multiple, higher-volume shipments from different origins, making multi-mode transportation (train, ship, truck) accessible to even SMEs who would otherwise struggle to reach the scale required.

Opportunities and barriers to implementation

Opportunities	*Barriers*
Lower the investment costs per partner by combined investment	Pooling requires more planning
Access to more modern and larger machinery	Diverging priorities of various actors
Possibility for optimized waste management (less material waste)	
Pooling of resources (labour, machinery, transportation) reduces costs and boosts competitive advantage	

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Side streams valorisations from food (cold) chain

'Best cases and examples of industrial symbiosis'

Europe
TRL 9

Main NEBs (other benefits)

Circular Economy

Energy-recovery from wastes or by-products

Sustainable Resource Management

The environmental impact of wood waste is an economic and ethical challenge, in some regions of the world, 25-50% of the food produced, could be lost on supply chain.

In this light European Commission promotes the concept of circular economy providing the ground for a sustainable waste management of 88–100 million tonnes of food waste are generated every year, with an economic impact estimated at 143 billion Euros in 2012. Based on the so called "waste hierarchy" (i.e. preventing, reuse, recycle and recovery, and disposal) many EU countries made their own policies with putting an emphasis on food supply chain.

Currently, there are two main technological process for food waste valorisation in Europe: composting and biogas production, both aiming to energy and/or bio fertilizers production. Studies at municipal or district level have shown the great impact, policy makers and governmental bodies have in tackling down food waste and increasing recycling rates, not only for food side streams but also for the packaging materials

.

Introduction

The food waste (FW) generation covers all the food life cycle: from the agriculture phase, up to industrial manufacturing and processing, transport activities, retail and household. Aside from the fresh food production and transportation chain a relevant aspect is addressed to the cold supply chain. Estimations showed between 25% and 50% of food produced was wasted along the food supply chain in America [2] by 2009, while in Europe, it was estimated that 88–100 million tonnes of food waste were generated every year [3] by 2012.

What is the improvement focus (i.e. industrial symbiosis and synergy)?

During years, organic waste, including food leftovers have been researched for its use as nutrient source or feedstock for multiple techniques. The main method used until now is composting, but it has been criticized due to the whole use of nutrients for simultaneous microbial growth [4]. According to [5], the most economical process for renewable energy production is the waste utilization, especially when the biohydrogen and biogas production is intended from FW and food processing waste. The use of waste to produce any energy type is known as waste to energy (WtE) and plays an important role in sustainable development by providing clean and affordable renewable energy limiting the negative social and environmental impacts. There are several WtE technologies for producing energy sources, being the mainly widespread: steam gasification, supercritical conversion, pyrolysis, gasification, and microbial conversion. Some them are not ready for commercial deployment.

Consequently, composting and anaerobic digestion for biogas production are the preferred routes for FW management under the recycling, reuse and recovery scenario (promoting landfill reduction of disposal of FW without energy recovery).

Benefits: potentials interventions for valorisations

Food wastes along its supply chain, must be addressed basically in four ways: prevention or avoiding of the side stream, valorization of the side stream (recycling, reuse and recovery), waste management exploiting the side stream to substitute a product or as a feedstock to an energy source (recycling and recovery), and FW disposal as last resource.

Vegetables and fruits.

The food industry and agricultural sector generate large amounts of vegetable and fruit wastes affecting municipal landfills due to FW high biodegradability resulting in leachate and methane emissions [6].

Side streams from apples production and consumption have been studied finding several options for industrial symbiosis. Potential production of an apple powder ingredient was developed by [7], which could be a valuable addition to the healthy food products portfolio since it was found that a small amount of it has the power to increase significantly the phytochemical content and antioxidant properties of foods if used as a dietary supplement. Another potential product from the apple peel was developed by [8], a powder ingredient suitable for food preparation, increasing the dietary fiber and as source of phenolic compounds.

Also, the recovery of phenolic antioxidants, even after oil content extraction from seed of different kind of berries, were proven to be valuable components [9]. Another use for berries was proposed in [10], where raspberry pomace in a dried form was used as replacement of flour for cookies in a 25 – 50 % level, resulting in fiber content increase without any negative effect. Similar applications have been studied for exotic fruits such as citrons, passion fruit, pineapple and mango, resulting in the technical feasibility for producing bioactive compounds in form of powder and food supplements [11], [12], [13] [14].

Since potatoes are one of the most consumed vegetables around the world, mainly containing carbohydrates, especially starch, vitamins, minerals and phytochemicals, valorization of the FW can have a large environmental and social impact in the food sector. Peels are the major side stream of potato processing industries and food services and contain the same amount of valuable macro and micronutrients of edible vegetable. Due to the large amount of potatoes waste, it can be a quantitatively important energy source in beef cattle diets and solved a potentially massive disposal problem [15].

Most of the cases presented up to this point, correspond to side stream valorisation, it means a by-product is recycled into the production of a new food related product, adding value to the initial feedstock and to the food sector.

Dairy products.

The dairy industry is an important part of the food industry and it is a major contributor of liquid wastes, which can contain proteins, salts, fatty substances, lactose and cleaning chemicals [16]. In 2011, the annual production of cheese was 9 million tonnes in the EU [16], and the waste coming from its production is the one, most studies have been paying attention of. Recently, the use of cheese whey combined with vinasse coming from the bioethanol production in Brazil, was studied for anaerobic co-digestion process, with excellent results for the biomethane production [17]. This case corresponds to the archetypal definition of waste management of side stream, where the FW is recovered for manufacturing another product or, as a source for renewable energy production.

Meat and derivative products.

Due to the global average reduction of poverty, less valuable meat products such as entrails and some muscles that used to be consumed, are now part of the by-products discarded by the slaughterhouses. By 2007, meat waste or by products accounted for 60-70 % of the slaughtered carcass [18], hence, the searching for recovery solutions of meat wastes is vital for environment and human health; however the recycling of this side stream is bound by several health and hygiene limitations and regulations.

Three ways for meat waste recovery have been initially identified, human food, pet food and other non-food and non-feed applications [19], nevertheless, other authors claim that there exist a large variety of non-food applications for this FW. So far, the major use for meat waste is the protein production for food preparations or protein powders [18] [20].

Best cases of waste management and industrial symbiosis

The cases considered as the initial leaders in waste management at municipal level in Europe are: Hammarby Sjöstad, a district in Stockholm (Sweden); Augustenborga, a neighborhood in Malmo (Sweden); Western Harbour Bo01, a district also in Malmo; the district of Rieselfeld, situated in the West of Freiburg (Germany); the Lincoln Neighborhood in Munster (Germany); and Pilestredet Park, an urban redevelopment project in central Oslo (Norway); South East False Creek district in Vancouver (Canada); and Yeongdeungpo-gu, an administrative district in Seoul (Korea) are some of these best municipal cases. In all of them the FW recycling rate increased up to 75-93% after implementing regulations an action plans [21]. For these specific cases environmental policies were set in place by implementing new legislations while for others by undertaking research and development projects funded by governmental entities, including not only the desired recycling rate and the logistics procedures, but also technological paths to follow for FW management, being the predominant composting, followed by biogas conversion, bio-fertilizers, and conversion to animal feed after electricity production. However, in most cases, an LCA for the FW management valorisation strategies has not been conducted yet to obtain a better understanding on the current and future operational conditions and what are the economic and environmental benefits.

Opportunities	*Barriers*
Industrial Symbiosis	Technological deployment
Energy Generation	High initial investment costs
Management and waste management	Behavioural changes and initial investment costs

Opportunities and barriers to implementation

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