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D2.4
How to refurbish a supermarket

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Deliverable number:	D2.4
Deliverable title:	How to refurbish a supermarket
Deliverable description:	This report discusses the specific topic of how to refurbish a supermarket, including the overall process and steps of refurbishing an existing supermarket taking into account different stakeholder's interests and requirements as well as the non-technological barriers; the technologies which allow achieving high energy efficiency as well as the challenges to their implementation at present; financing measures; golden rules and checklists to facilitate the refurbishing of supermarkets to the involved stakeholders; as well as best practice cases and success stories.
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Table of Contents

The research leading to these results has received funding from the
European Union/EASME H2020 Programme under Grant Agreement No 696076.

Table of Figures

Page

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EXECUTIVE SUMMARY

This report serves as a starting point material for training supermarket stakeholders in refurbishing supermarkets. The majority of the report is dedicated to the technological aspects, covering refrigeration systems, building envelope, heating, ventilation and air conditioning systems (HVAC), as well as lighting. Different solutions have been proposed both for retrofitting and refitting a supermarket to improve its energy performance, accompanied with case examples from different parts of Europe.

For the refrigeration system, the document focusses on different options for retrofitting existing equipment, taking into account all physical and legislative restrictions in order to analyse whether actions with smaller or bigger scope are needed. Thus, the replacement or addition of different equipment and replacement of refrigerants is considered, but also a complete substitution of the main equipment.

All systems that consume energy in a supermarket have been analysed, including refrigeration system, HVAC and lighting as major energy consuming systems, but also the building envelope. Operation and maintenance criteria are also covered.

Apart from the technical aspects, the report discusses the non-technical barriers for refurbishing supermarkets, as well as possible solutions to overcome these barriers. Increased investment costs and lack of full skilled technicians, are often regarded as the biggest non-technical barrier, and financing opportunities to overcome this barrier are therefore included for different European countries.

1 INTRODUCTION

Efficient solutions for supermarket heating, cooling and refrigeration - such as integrated systems or the use of equipment based on natural refrigerants - are already available in the marketing Europe. However, their use is not yet widespread due to remaining non-technological barriers, including lack of knowledge and awareness, social and organizational and political barriers.

The European project SuperSmart aims at removing these barriers and additionally supports the introduction of the EU Ecolabel for food retail stores. The EU Ecolabel can encourage supermarket stakeholders to implement environmentally friendly and energy efficient technologies and thus reduce the environmental impact of food retail stores.

Within the project several activities are carried out to remove the barriers: campaigns to raise the general awareness and spread the information about energy efficient and eco-friendly supermarkets, as well as training activities within the following specific topics:

1. Eco-friendly supermarkets – an overview
2. How to build a new eco-friendly supermarket
3. How to refurbish a supermarket
4. Computational tools for supermarket planning
5. Eco friendly operation and maintenance of supermarkets
6. EU Ecolabel for food retail stores

For each of the topics a set of training material is developed, which will be used in the training activities. The different kinds of training activities are:

1. Conference related activities
2. Dedicated training sessions
3. Self-learning online activities

Dedicated training sessions are free-of-charge for the different stakeholders in the supermarket sector. This means, those highly-qualified experts from the project consortium will carry out a training session on a specific topic at the premises of the stakeholder. If you are interested in receiving such a training regarding any of the above mentioned topics, please contact the project partner via the project website: www.supersmart-supermarket.info.

The present report forms part of the topic "How to refurbish a supermarket". It can be used for self-studying and is freely available. There will be conferences, where this topic is included as a training activity. Information on conferences where SuperSmart-team will be present and the planned training activities can be found on the project website.

1.1 Introduction to how to refurbish a supermarket

The main objectives for supermarket owner when refurbishing his/her facilities are usually to reduce energy costs and to become more attractive towards existing and potential new customers.

When analyzing the annual budget for supermarkets, energy expenses are one of the highest after the labor costs, according to Energy Star (US) (Energy Star, 2008). For this and other reasons, such as the targets established in the EU Energy Efficiency Directive (Directive 2012/27/EU), or the customers' interests, saving of energy together with reduction of CO_2 emissions are becoming one of the most important strategic goals of grocery stores. In order to reduce the energy consumption in the grocery sector, it is important to focus on the most energy intensive processes, which are, according to different sources (Energy Star, 2008) (Evans, Maidment, & Foster, 2011) (Mukhopadhyay, 2013) (Fedrizzi & Rogers, 2002):

- Electricity consumption: refrigeration followed by lighting and HVAC.
- Gas consumption: mainly space heating, followed by water heating, and in some cases cooking.

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When improving the energy performance of a supermarket is under consideration by the owner or manager, it is desirable to take into account a series of decision criteria which will help to the process, based on the Decision Criteria established by F-gas Support (F-gas support, 2009):

1. **Age.** Replacement should be taken into account when the refrigeration, HVAC and lighting systems are over 20 years old. Adjustment or refitting would have to be considered when systems are more than 10 years old.

2. **Condition.** If the system is kept in good condition, it is more suitable for refitting rather than retrofitting/replacement. It is important to take into account the previous adjustments or refitting. Sometimes replacing the system might be more feasible, in order to meet the existing demand and legislation.

3. **Legislation** is changing frequently. When considering retrofitting, the compliance with the prevailing legislation should be considered.

The objectives of this report are:

- To present and explain energy efficiency solutions in refrigeration, HVAC and lighting systems as well as for building envelope retrofitting for supermarkets (Chapter 2)
- To propose the introduction of renewable energy systems for supermarkets (Chapter 2)
- To present energy management and certifications as tools creating added value and energy efficiency improvements in supermarkets (Chapter 2)
- To discuss the non-technological barriers and possible solutions for refurbishing existing supermarkets (Chapter 3)
- To present case examples of supermarkets with outstanding energy solutions from different parts of Europe (Chapter 5)

In addition, financing options for refurbishing supermarkets are given in appendix A for different European countries, including EU and partner countries, and more specifically Germany, Norway, Spain and Macedonia.

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2 TECHNOLOGICAL MEASURES

Considerable energy savings can be obtained through both technical and non-technical measures. Even considering that supermarket operation depends on several factors such as size, refrigeration needs, applied technologies, number of workers, etc. as well as location, the most suitable technical measures are discussed in the following sections:

- Energy efficiency in refrigeration systems
- Improvement in the building envelope
- HVAC optimization
- Energy efficient lighting
- Renewable energy systems
- Energy management and certifications

2.1 Energy efficiency in refrigeration systems

The main energy efficiency measures to achieve a more eco-friendly supermarket, applying existing refrigeration systems, are included in the following actions, which are explained in the next sections:

- Replacement or addition of equipment in the refrigeration system
- Refrigerant change to a lower GWP refrigerant
- Efficiency measures in cabinets
- Operation and maintenance issues

2.1.1 Replacement or addition of equipment in the refrigeration system

This chapter deals with the measures for improving the refrigeration system involving substitution of some equipment with more efficient models, as well as addition of new equipment to the existing system in order to improve the efficiency.

2.1.1.1 Equipment to obtain floating head pressure

This measure consists in reducing the head pressure and allowing it to fluctuate with the ambient conditions. Energy consumption as well as the leakage of refrigerant is reduced due to the pressure reduction.

Conventional system controllers switch fans and compressors “on” and “off” with the purpose of adjusting the refrigeration capacity to the current system refrigeration load level. With this minimum control, it is difficult to adjust the system capacity required for a particular level of loading. Furthermore, the system is usually set to the evaporating and condensing temperatures required in the worst working conditions, which results in a very inefficient system at part load conditions.

Varying the head pressure allows the compressor to operate at the minimum pressure necessary at all ambient conditions, reducing the energy consumption in compressors and their maintenance and progressive wear. For instance, reducing the head pressure from 15 to 12 bar may result in energy savings of about 22 % (Carbon Trust, 2012). Figure 1 shows the effect of floating head pressure on (compressor) power consumption.

In this purpose, the use of Variable Frequency Drive (VFD) to modulate the condenser fans and compressors is the most efficient control system, achieving safer operation and overall energy savings of 15-30 % when compared to refrigeration systems using conventional refrigeration control devices and controllers (Singh, n.d.).

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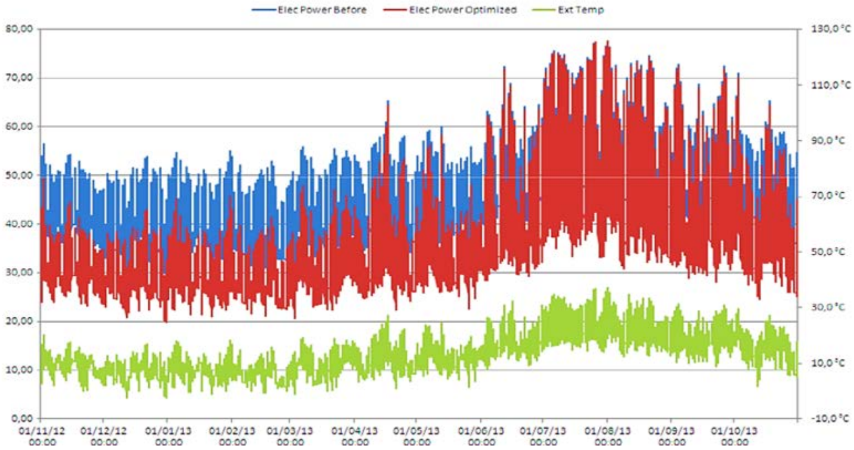

Figure 1 Effect of floating head pressure in compressor power consumption (Asensio, 2015)

Additionally, in some cases it might be necessary to replace expansion valves in cabinets to electronic expansion valves (EEVs) instead of thermostatic expansion valves (TEVs) as the last ones do not operate well with low pressure differences.

Alternatively, liquid pressure amplification (LPA) could be considered to raise the liquid line pressures with a pump, in order to accomplish with the floating head pressure but maintaining the pressure level across the expansion valve. The system principle is shown in Figure 2. The conventional cycle and the cycle with floating LPA system are shown in a Log(p)-h diagram in Figure 3, where the conventional system works between 1-2-3-4-1 and the floating LPA system between a-2-b-c-a (Al-Rabghi & Akyurt, July 2004).

However, this measure is still not as extensively implemented in supermarkets as it is in other food cold chain applications.

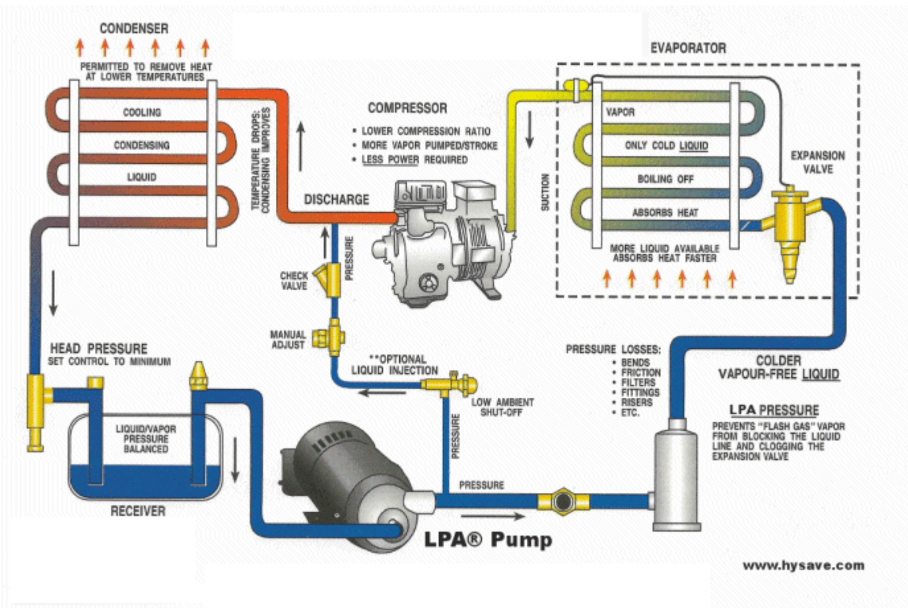

Figure 2 Floating LPA system (Hy-save technologies, 2015)

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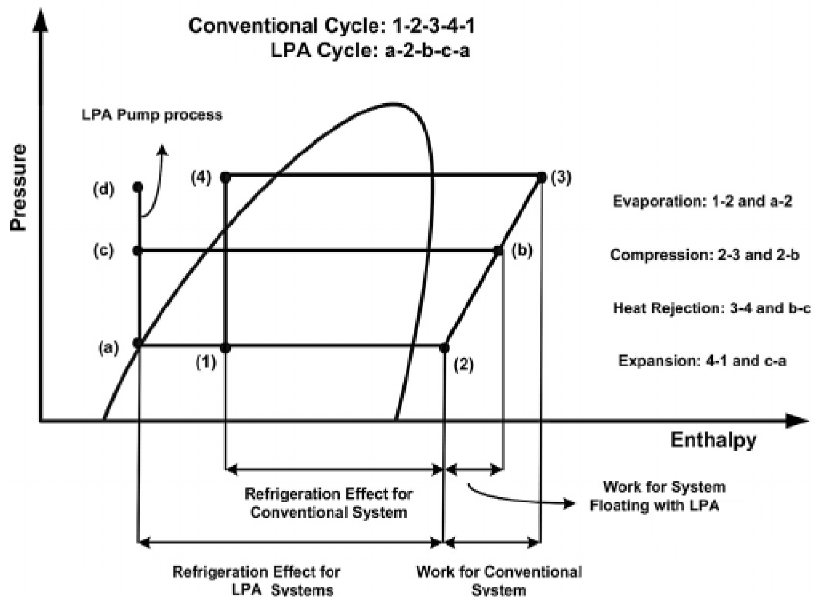

Figure 3 Log (p)-h diagram for a Floating LPA system (Vakiloroaya, Samali, & Pishghadam, January 2014)

2.1.1.2 Equipment to procure floating suction pressure control

In conventional systems, the suction pressure is fixed for the maximum load conditions, what may produce lower evaporator temperatures than needed over a substantial period of time. Furthermore, the entire pressure is determined by the worst temperature performing cabinet connected to a refrigeration pack.

Floating suction pressure control consists of adjusting the suction pressure to the maximum possible, capable of maintaining the cabinets at the correct temperature, by means of an electronic pressure regulator.

The system controls the operation of the compressors depending on the pressure needed in the cabinets, and may generate energy savings of about 6 % (Carbon Trust, 2012),
However, this measure is not widely applied in supermarkets, although it is relatively simple to apply and usually has short payback periods.

2.1.1.3 DC fan motors in evaporator and condenser

Recent improvements in fan motor technology have led to DC fans with efficiencies of 70 % - 75 % (Carbon Trust, 2012). This means a reduction in electricity consumption in evaporator fan motors in cabinets, and also a decrease in the heat load that needs to be removed by the refrigeration system.

Technologies such as electronically commutated motors (ECM) or permanent-split-capacitor (PSC) motors may enable savings of approximately 6 % in cabinets, when compared to evaporator fans with shaded pole motors with efficiencies between 17 and 30 % (Carbon Trust, 2012).

These improvements are applicable also in the condenser fans. Additionally, this equipment can be operated at variable speeds to increase the chiller coefficient of performance (COP) in certain operating conditions, enabling savings of up to 5 % (Singh, n.d.) (Carbon Trust, 2012).

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2.1.1.4 *Evaporative condensers*

Evaporative condensers offer energy savings by providing lower system condensing temperatures than conventional air-cooled condensers. These systems spray water over the condensing coil, so that heat is rejected also for evaporating the water. This may result in savings of 5% in energy consumption (Carbon Trust, 2012) and maximizes the life duration of the cooling unit.

On the other hand, evaporative condensers have higher maintenance costs than conventional condensers and require certain procedures and inspections set by national regulations to prevent contamination with Legionella bacteria, as it is a common issue which needs a specific maintenance and monitoring.

2.1.1.5 *High-efficiency evaporators and condensers*

When using CO_2 (R744) as the working fluid, flooded evaporators can be used instead of conventional direct expansion evaporators. In flooded evaporator operation, the refrigerant may exit with some carry-over of liquid, which results in a higher heat transfer rate during evaporation and enables several degrees higher evaporation temperature. Energy savings of 10 % can be achieved when operating with R744 and using fully flooded evaporators compared with conventional CO_2 evaporators (Evans & Foster, 2015). The use of flooded evaporators is discussed in more detail in the SuperSmart report D2.3 (Kauko, Kvalsvik, & Hafner, 2016).

Additionally, new high-efficiency heat exchangers for evaporators and especially for condensers/gas coolers based on micro-channel technology could be used. Using micro-channel heat exchangers allows decreasing the required refrigerant charge due to enhanced heat transfer on the air side. This leads to a reduction in the compressor power demand of around 3-4 % (Carbon Trust, 2012). This new technology is relatively costly, however it is still in developing phase and costs may therefore become lower during the coming years, as the demand for increases.

2.1.1.6 *Anti-frost evaporators*

Hydrophobic surface treatment of evaporators is a possible measure for reducing the frosting behaviour of evaporators, since the amount of residual water on the surface of the heat exchanger is reduced. This reduces the energy required for defrosting as well as the heat load that the freezing water introduces in the refrigeration system. This measure could produce energy savings of around 2 % (Carbon Trust, 2012).

The technology is still new and hence expensive, and undergoing further development. It is hence suited for new cabinets, rather than for retrofitting existing cabinets.

2.1.1.7 *Heat recovery systems*

Cooling generates considerable quantities of heat, which is usually rejected to the ambient. The utilization of condenser waste heat is interesting wherever refrigeration and heating are required at the same time. This is the case for supermarkets with hot water and/or space heating demand, or when the supermarket is a part of a larger building complex.

Some conditions have to be taken into account: the waste heat temperature must be high enough for the heating application, and the operating time of the refrigeration machine must be closed to the working period of the heat consumer. However, thermal storage systems are an interesting option in order to match those time frames, both in a diurnal scale (e.g. water tanks, PCMs) and in a seasonal scale (e.g. geothermal storage/energy wells). Thermal storage in supermarkets is discussed in more detail in the SuperSmart report D2.3 (Kauko, Kvalsvik, & Hafner, 2016).

The measure may be implemented by including an auxiliary condenser (or gas cooler in the case of R744) in parallel or in series with the existing that supplies the heating system, and an adequate control system including specific valves depending on the application. Main applications are: hot-water preheating, preheating of the supply ventilation air and reheating of dehumidified air. Floor heating is a

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good way to utilize low-temperature waste heat; this system reduces the demand for heating through ventilation and hence the overall energy consumption (Kroppanmarka, 2014). Heat recovery is discussed in more detail the SuperSmart report D2.3 (Kauko, Kvalsvik, & Hafner, 2016).

2.1.1.8 Pipe insulation and reduced pressure drops

Refrigeration systems in supermarkets may have long piping distances. Improved insulation and reduced pressure drops may hence have a huge effect on energy efficiency, especially in the compressor suction line. Adequate pipe insulation may reduce heat loads on the refrigeration plant with about 5 %, whereas reduced pressure drop in refrigeration piping can improve the COP by approximately 4-7 % (Carbon Trust, 2012).

2.1.2 Refrigerant change to a lower GWP refrigerant

Since the ban of CFCs (e.g. R12, R502) and HCFCs (e.g. R22, R401A) due to their ozone depletion potential, other non-ozone depleting refrigerants were developed, mainly hydrofluorocarbons (HFCs), that generally have low toxicity and are non-flammable (e.g. R-134a, R-404a, R-410a, R407a). However, these substances have a high global warming potential (GWP) and should be replaced with other refrigerants, mainly natural refrigerants, depending on operational conditions and other technical restrictions. Apart from low GWP values, and a well-documented and predictable environmental impact of natural refrigerants, well-designed CO_2 systems in particular offer also a significant reduction in energy use compared to state of the art HFC units.

Refrigerant replacement has a significant effect on the environmental impact of supermarkets, not only due to reduction in the energy consumption, but mainly because of a lower global warming potential of the refrigerants and a reduction of direct emissions owing to refrigerant leakage. However, it is necessary to analyse the climatic conditions and design temperature set points in order to make sure the system change to applying natural refrigerant gives such benefits.

The European Union has recently published an updated regulation (EU Regulation No 517/2014) that came into force on the 1st of January 2015, replacing the previous version (842/2006). This regulation involves some restrictions on refrigeration products and equipment to be introduced on the market, limits on the use of high GWP gases in existing refrigeration equipment and additional changes including requirements for leakage control, checks and detection systems, end-of-life recovery, training and certification programs, etc.

Furthermore, the legislation associated with refrigerants is continually evolving and, thus, the use of different refrigerants should be reviewed periodically; however, periodic churning with synthetic fluids offered from chemical companies can be avoided when applying natural working fluids.

2.1.2.1 Retrofitting existing equipment with lower GWP HFCs

As mentioned, the new European regulation has adopted limits on the use of high GWP gases (GWP = 2500 kg CO_2 eq./kg and above) in existing refrigeration equipment from 2020. The most common installations using R404A and R507 are in this situation. When evaluating replacement options, and the investment for a complete change of the refrigeration system designed for a natural refrigerant is budgeted to be realised within a few years, it is recommended to retrofit the old equipment and use another gas, available on the market, as a drop in solution.

The main suitable measures that can be taken to comply with regulations are the following. However, they cannot be considered in an eco-friendly supermarket, since their GWP is extremely high compared to natural refrigerants:

- Replacement of R404A with R407A, reducing GWP from 3922 to 2100. Both refrigerants have similar thermodynamic properties, share many of the same HFC components, and are designed to use the same lubricants. Thus, generally, only a straightforward substitution is needed. An additional advantage is that R407A operates at a lower pressure than R404A and this means that its leakage would be slightly less.

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- Replacement of R507A with R407C, reducing GWP from 3985 to 1774. Some R507 systems can use similar retrofit gases as with R404A and allow direct substitution. However, some alternatives are not simple retrofits and some equipment or process design changes may be necessary. Therefore we recommend further analysis on a case-by-case basis.

2.1.2.2 Retrofitting gases that may imply replacement of existing equipment

It is very likely that HFCs with a GWP less than 2500 will need to be retrofitted with lower GWP gases where possible in the longer term. There is a wide range of refrigerant gases available with lower GWP; these include some HFCs, and a wide range of natural refrigerants, including ammonia (NH_3, R717), carbon dioxide (CO_2, R744), and hydrocarbon refrigerants.

- Unsaturated HFC refrigerants (also called HFOs) are the fourth generation of fluorine-based gases, which, compared to the old HFC refrigerants, contain at least one double bond between the carbon atoms, extremely reducing its GWP. Many unsaturated HFC blends are currently in the development process. The main application is the replacement of the R407 series with R1234yf, reducing GWP from 1774 to 4. R1234yf can also be a direct replacement of R-134a, but is only suitable for medium temperature systems and not optimal for centralized systems.
  However, many of these alternatives are not simple retrofits, and some equipment or process design changes may be necessary. For example in Denmark, machine rooms where the compressor racks are placed have to be equipped with additional safety features and ventilation, as with flammable hydrocarbon refrigerants. Furthermore, unsaturated HFC refrigerants are yet another synthetic refrigerant, whose entire environmental impact is not fully known. Hence a shift to natural refrigerants is the best, safest way forward, resulting in the lowest cost of ownership.

- Refrigerants such as ammonia (NH_3, R717), carbon dioxide (CO_2, R744) and non-halogenated hydrocarbons (propane, isobutene) have a low or no (ammonia) GWP. However, these working fluids, in particular CO_2 and ammonia, have very different properties as compared to HFCs. Therefore 'drop in' is not possible and a change of the entire refrigeration system is required when changing to natural refrigerants. This issue is covered in detail in the report D2.3. How to build a new eco-friendly supermarket (Kauko, Kvalsvik, & Hafner, 2016).

2.1.3 Efficiency measures for cabinets

This chapter deals with measures intended especially for the refrigerated cabinets. Most of these measures are relatively cheap and easy to apply, and are suitable for retrofitting of existing cabinets, although the recommendations are also applicable when selecting new equipment.

2.1.3.1 Cabinet location

Locating display cabinets in inadequate areas may increase energy consumption significantly. Cabinets should be located in cool areas of the supermarket, protected from exposure to sunlight, and far from the external environment affected by high temperatures, humidity and wind, as well as far from air-conditioning inlets. These aspects are particularly critical for open-fronted cabinets.

2.1.3.2 Anti-sweat heater controls

Anti-sweat heaters (ASH) are typically applied to low-temperature (ca -18 °C) refrigerated display cabinets to prevent formation of condensation on glass doors and other cold surfaces. Commonly, ASH stay on at full load continuously, adding a significant heat load in the refrigeration system.

ASH controls adjust the time the heaters are running depending on the amount of condensation formed on the glass door of a cabinet due to the cooling temperature and level of humidity in the supermarket. Savings of around 7 % (Carbon Trust, 2012) of the total energy consumption of the cabinet can be achieved.

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This measure has become quite common in supermarkets. Furthermore, standard glass doors on cabinets can be replaced with special glass doors that require minimum ASH contribution.

2.1.3.3 Doors on open-fronted cabinets

Most supermarkets have had open-fronted cabinets as their main display equipment due to commercial reasons. From an energetic point of view, open-fronted cabinets are some the most inefficient equipment in supermarkets, since infiltration loads are the highest cabinet heat load (see the SuperSmart report D2.3 (Kauko, Kvalsvik, & Hafner, 2016). For existing cabinets, the installation of doors is a simple option to reduce infiltration of air and, thus, reduce the energy consumption. The measure could achieve between 12 and 30% energy reduction compared to the open-fronted model, depending on the type of cabinet and level of use (Carbon Trust, 2012).

Furthermore, based on observations from retailers, no losses in sales were documented after retrofitting of individual supermarkets with glass doors (Kauffeld M. , 2015). Moreover, with glass doors, the air temperature in the aisle in front of the cabinets will be higher. The customers hence tend to spend a longer time in front of the cabinets, increasing the sales.

When adding doors to cabinets the system may require a resetting in order to adjust the operation parameters to the new, reduced refrigeration load.

2.1.3.4 Anti-fogging glass

Surface coatings have become a suitable solution for preventing condensation on glass doors in cabinets. New coatings reduce or even eliminate the need for heating of glazing surfaces by ASH, resulting in energy savings of around 5 % (Carbon Trust, 2012). These surface coatings consist of different layers, including polymer chains, glass nanoparticles and air bubbles, which prevent water droplets from forming fog or condensate on the glass door surface.

2.1.3.5 Air curtains in open-fronted cabinets

Another measure to reduce infiltration loads on open-fronted cabinets is the addition of air curtains. It is a device that creates a controlled stream of air along the cabinet opening in order to reduce the air movement from the outside in and inside out, resulting in energy savings of around 5 % (Carbon Trust, 2012).

Dual and triple air curtains can be used to reduce infiltration and, thus, energy consumption in open-fronted cabinets even more. They consist of two or three layers of air at different temperatures, the innermost being the coldest. However, nowadays they are not much more efficient than a single air curtain cabinet (Carbon Trust, 2012).

2.1.3.6 Other equipment to reduce infiltration in open cabinets

- Strip curtains: consist of transparent, flexible strips that cover the front of open-fronted cabinets (see Figure 4 (a)). Like doors, they also reduce the infiltration of ambient air, but tend to slightly reduce visibility of the food and require some maintenance to keep them clean and tidy.

- Night blinds: This equipment can reduce air infiltration in stores that are closed for a part of the day. It is essential that night blinds are well-fitted to the cabinet. In some cases they might disturb cabinet loading during the night, which can be solved by installing automatic models. Night blinds can reduce the cabinet energy consumption with around 25 – 40 % (Axell & Fahlén, Evaluation of commercial refrigerated cabinets - Experience from laboratory tests according to prEN 441., 1995) (Axell, Boraas, & Fahlen, 1998).

(a) (b)

Figure 4 (a) Strip curtains (TMI International LLC, 2000) and (b) Night blinds for open front cabinet (Commercial Blinds UK Limited)

2.1.3.7 Cabinet lighting with LED and high-efficiency fluorescent technologies

Standard lighting in cabinets implies high electricity consumption and, furthermore, adds a considerable heat load that has to be compensated by the refrigeration system. There are several options for replacing existing lamps in cabinets for more efficient models.

LED lights consume approximately half of the lighting energy compared with fluorescent tubes while maintaining adequate product lighting. Additionally, LED technology has the benefit of reducing the heat load into the cabinet and thus, the energy consumption for cooling. Use of LED lights may hence reduce the energy use by a factor of 60-70 % as compared with the use of fluorescent lamps (Raghavan & Narendran, 2002).

Furthermore, LEDs have a longer operating life, reducing the number of replacements needed in the long term. As opposed to fluorescent tubes, they also operate more efficiently at lower temperatures, rendering them well suited for cabinet lighting. Additionally, they can be switched on or dimmed instantaneously, which makes them excellent to be applied together with presence detection controls. However, lighting levels should be analysed when substituting conventional lighting with LED lights, since in some cases light level has been improperly reduced after the LEDs were fitted. LED lighting is further discussed in the specific section about energy efficiency in lighting.

High-efficiency fluorescent lights are a good option also to reduce energy consumption in cabinets, being less expensive than LEDs, and an interesting option in the short-term. This technology could reduce energy use by up to 35 % when compared to standard fluorescent lamps. The internal loads can also be reduced by using more efficient lighting T5 fluorescent tubes instead of traditional T8 models (see Figure 5) and through the installation of electronic ballasts. High-efficiency fluorescent lights may achieve savings around 4-5 % of cabinet consumption.

Apart from using energy efficient lights, it may also be possible to place the lighting outside of the refrigerated zone/cabinet, or to install reflectors or light conductors (Kauffeld M. , 2015).Further details of different lighting technologies can be found at section 2.4 Energy efficiency in lighting.

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Figure 5 T5 Fluorescent lamp versus T8 (EMOPA, S.L.)

2.1.3.8 Presence detection devices in cabinet

Presence detection systems can be installed to sense customer movement and to switch cabinet lighting on or off accordingly. Depending on the level of use of the cabinet, this measure may result in savings around 40 % of energy consumption in cabinet lighting (Carbon Trust, 2012).

This measure is still little used in cabinets, but is readily available and widespread in other areas of the supermarket, such as the cold storage. Lighting controls are especially suitable with LED technology, since these lamps can be rapidly switched on and off.

2.1.4 Operation and maintenance

Maintenance is very important to identify leaks and repair them during the refrigerant change and the operation, but also to maintain cabinets and refrigeration plant in right conditions to avoid energy use increase. This section discusses the most crucial operation and maintenance procedures.

2.1.4.1 Cleaning of condensers and evaporators

Dirt on external heat exchanger surfaces can have a dramatic effect on heat transfer if it is not removed periodically. As heat transfer becomes poorer, the condensing temperature is increased and evaporating temperature is reduced by several degrees. In consequence, the energy use may be increased by between 2 and 10 % (Carbon Trust, 2012).

2.1.4.2 Minimizing refrigerant leakage

Refrigerant loss is a major cause of direct emissions and system inefficiency. Reduced amount of refrigerant implies less heat being removed, which has to be compensated with increased operating time or lower evaporation temperatures. The energy use may increase between 11 and 15 % (Carbon Trust, 2012) when the system is undercharged. Furthermore, this may lead to oil breakdown and overheating problems that generate acid formation in the compressor. Thus, maintenance work to identify and repair leaks is essential for guaranteeing the energy efficiency and safety of the system.

2.1.4.3 Refrigeration system contamination

Refrigeration systems can become contaminated during use, mainly inside the components and pipes. These contaminants are mainly water, non-condensable gasses and oil, and its appearance is usually a result of a poor installation or maintenance. The system internal contamination, because of dirty and aggressive industrial environments and materials, can have a large effect on system efficiency, but ultimately can produce compressor failure, block filters and oil flow passages, and block the flow of refrigerant.

2.1.4.4 Re-commissioning of refrigeration equipment

Refrigeration system and cabinet control settings are frequently adjusted away from their original values. To perform a settings' re-adjusting periodically is a low cost measure which can be implemented very quickly and easily, and may result in 15 % energy savings (Carbon Trust, 2012).

2.1.4.5 Optimizing cabinet management

Energy savings can be achieved by means of developing an adequate management of the cabinets, including temperature control, adequate loading and periodic defrosting.

- Temperature set-point on cabinets. Temperatures in cabinets are specified by food safety regulations, but also by supermarkets' own specifications. However, differences between the recommended temperature and the real working temperatures can sometimes be observed. Increasing the set-point temperature of a cabinet can by 1°C will typically produce energy savings of between 3 % - 5 % (Carbon Trust, 2012).

- Correct cabinet loading volume. Overloading display cabinets decreases product quality and increases energy use by 10 % - 20 %. On the other hand, fully loaded shelves are likely to improve the efficiency of standing cabinets, since less air is infiltrated. Energy savings of approximately 1 % could be achieved through adequate loading (Carbon Trust, 2012).

- Reducing loading times. The time taken to load food into cabinets with doors affects the amount of air infiltrated into the cabinet, and the heat gained by the food stuff. Extended door openings can also increase the number of defrosts as well as the use of cabinet heaters to prevent condensation build up on doors.

- Defrost control. Defrost controls minimise the number of defrosts needed by a cabinet, reducing directly the energy consumption. This measure can be applied to frozen food cabinets where electric defrosts are required to melt ice that has built up on the evaporator; however, this technology is not appropriate on passive or 'off-cycle' defrosts. Overall savings of around 1 % could be achieved by implementing defrost controls (Carbon Trust, 2012).

2.2 Building envelope retrofitting

The building envelope plays a major role in regulating the indoor environment. Consisting of the building's foundation, walls, roof, windows, and doors, the envelope controls the flow of energy between the interior and exterior of the building. A well-designed envelope allows the building to provide comfort for the occupants and respond efficiently to heating, cooling, ventilating, and lighting needs.

The envelope retrofitting consists in an improvement of the existing building envelope, which may reduce the building heating and cooling demand considerably. A number of different approaches can be taken, depending on the type of building, the supermarket location within the building, other uses of the building (when the supermarket is a part of a bigger building complex), existing building materials and other factors. Some of the main actions in envelope retrofitting are discussed in the following sections.

2.2.1 Retrofitting in façades and party walls

2.2.1.1 Adding or increasing external insulation in walls.

This measure consists in adding an additional layer of thermal insulation material (e.g. expanded polystyrene (EPS), extruded polystyrene (XPS), glass wool, cork) externally attached to the façades and visible party walls (stuck, plastic pins and profiles). The insulation layer is then protected using a new finish coating, usually based on mortar.

2.2.1.2 Adding or increasing internal insulation in walls.

This measure consists of the placement of thermal insulation in the internal layers of façades and party walls, using e.g. plasterboard panel, or cladding finish of hollow bricks. This system blocks out the thermal mass of the external walls, reducing the thermal inertia of the interior, and therefore allows a rapid warming of the habitable areas. Respectively, the external walls will not radiate heat stored during warm days to the inside.

2.2.1.3 Installation of ventilated façades.

Ventilated facade is a double façade system provided with an external coating usually fastened with metal profiles to the internal part of the enclosure. Between the walls, there is a ventilated space partially filled in with thermal insulation. The ventilation can be natural or mechanical and is raised through top and bottom openings or through the design of envelope seals.

This system reduces both heating and cooling loads: in summer (or generally in warm climates), the external wall is heated and induces a convective effect which forces the air replacement with fresh air from the bottom; in winter (or cold climates) the air layer is heated by the building interior, but much less to create enough flow, thus improving the heat retention in the wall. Furthermore, ventilated façades prevent condensation problems, which are frequent in wet climates.

2.2.2 Retrofitting in roofs

In the case of stand-alone supermarkets, the following measures for retrofitting the roofs can be applied.

2.2.2.1 Adding or increasing external insulation in roofs.

This measure consists of adding a layer of insulation to the exterior of the roof. The measure is of great interest for 1- or 2-storey buildings, which have a high ratio between roof surface and façade surface. It is not equally relevant for high-rise buildings or buildings which have a thermal buffer space or non-conditioned spaces below the roof, because the air volume above the habitable spaces gives already a considerable level of insulation.

2.2.2.2 Adding or increasing internal insulation in roofs.

Adding insulation on the inside of roofs is simple to execute and allows the use of thermal insulation materials of lower quality and lower cost than in the case of external insulation. In addition, lifting of the external roof (tiles or pavement), waterproofing, etc. are avoided.

2.2.2.3 Installation of a green roof

A green roof is an extension of the existing roof which is partially or completely covered with vegetation and a growing medium, planted over a waterproofing membrane and other additional layers such as a root barrier and drainage and irrigation systems. A green roof installed on a supermarket building IN WHERE? is shown in Figure 6.

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The vegetation acts as a solar radiation protection in summer, preventing overheating and the fluctuation of the temperature inside the buildings. In winter it works as an organic insulation that reduces internal heat losses. It is mainly used in flat and slightly sloping roofs.

Furthermore, it increases the environmental humidity and decreases the air temperature in the surroundings, due to the evapotranspiration process performed by the plants. In roofs, it protects the waterproof coating against solar radiation, sudden changes in temperature and mechanical stress. It also improves the visual impact from nearby higher buildings. On the other hand, vegetation requires some maintenance.

Figure 6 Green roof on a supermarket in the residential area of Linz (Austria) (Built to Bloom, 2015)

2.2.3 Retrofitting in doors and windows

Doors and windows in supermarket have to be as tight as possible in order to reduce infiltration. Thus, the HVAC system has to provide the necessary ventilation for an adequate thermal comfort in the supermarket. Still, doors and windows introduce some leakage, depending on their quality and their possible deterioration over time, which have a considerable effect on energy consumption.

There are several measures that can be taken in doors and windows retrofitting, not only to reduce air infiltration (e.g. improve existing joints) but also to decrease heat losses through their surfaces or thermal bridges.

2.2.3.1 Window replacement

This measure consists of the replacement of inefficient windows (e.g. aluminium frame without thermal break and single glazing) with more efficient models. Some examples are double glazing windows with wood frames, PVC frames, or aluminium frames with a thermal break. Further solutions include low emissivity glasses, solar control glasses, or triple glazing, enabling even better thermal properties. The thermal transmittance of the window can be reduced considerably to 2-3.5 W/m^2K, compared to the transmittance of inefficient windows which typically is higher than 4 W/m^2K (IDAE, ANDIMAT, 2008).

2.2.3.2 Vestibule entrance with two door sets

The measure consists in replacing single door entrance with a (vestibule) setup where two door sets are placed, such that there is a space between them (see figure 7). This action can be developed with either swing or sliding doors operated manually or with automatic openers. However, the replacement is not always feasible depending on space availability and reforms needed.

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This solution decreases the direct air exchange with the outside environment and, thus, reduces the energy required for heating and cooling loads and also increases thermal comfort. A reduction around 4 % in energy consumption in HVAC equipment can be achieved with this measure (National Renewable Energy Laboratory - NREL, 2012), depending on the climate and building parameters.

2.2.3.3 Installation of air curtains in openings

An air curtain is a device that creates a controlled stream of air and directs it across the full width and height of an opening to create an energy saving air seal. This seal separates different environments, allowing a smooth, unhindered flow of traffic and unobstructed vision through the opening.

Air curtains can be applied together with doors, however this measure is even more important where doors are not suitable for different reasons, allowing energy savings until 10 % compared with a conventional opening, depending on climate (Johnson & Thomas, 2001) or even up to 30 % with more efficient systems (Gil-López, Galvez-Huerta, Castejon-Navas, & Gomez-Garcia, 2013). An air curtain utilizing electric heaters implies an increase in energy use, but this is much smaller than the achievable savings in the HVAC system. The optimal case is that the air curtain is a part of the integrated refrigeration and HVAC system, hence utilizing excess heat from the refrigeration system.

Figure 7 Vestibule entrance with two door sets and air curtain (BERNER International Corp., 2014)

2.2.4 Installation of shading elements

The measure consists in installing a fixed or mobile external solar shading system, such as louvres and overhangs. The goal is to protect windows from solar radiation in summer, reducing the heat load, but to let in this radiation in in winter. It can reduce the energy required for cooling loads and increase thermal comfort, but it may reduce the contribution of natural light to the building.

The suitability and type of shading elements depends completely on the type of building. On south façade, louvres should be installed horizontally, meanwhile on East and West façade vertically. In the case of louvres, some maintenance is needed.

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2.3 Energy efficiency in HVAC systems

Heating, ventilating and air conditioning (HVAC) system is a set of facilities responsible for providing thermal comfort and acceptable indoor air quality within reasonable installation, operation, and maintenance costs. Most common system solution in supermarkets is a central air handling unit, supplying heating, cooling and ventilation to all zones of the store through an overhead distribution ductwork.

The energy consumption of the HVAC systems in food retail stores varies between 15 % - 25 % (Tassou, Ge, Hadawey, & D., 2011), depending on the heating system design, building features, geographic location of the store, operation and maintenance, etc.

Most HVAC equipment is not optimized. In supermarkets, equipment designed for office buildings is often used. The main actions to improve the energy efficiency in HVAC systems include equipment substitution, but significant improvements can also be gained through improved operation and maintenance, as described below.

2.3.1 Operation and maintenance

2.3.1.1 Store temperature

Store temperature has a major influence on the HVAC system energy consumption and also on the energy consumption of retail cabinets. The building temperature is greatly influenced by air spillage from open-fronted cabinets and infiltration through doorways.

In order to reduce energy consumption, the store temperature can be reduced in winter and increased in summer. In winter, to maintain a low but comfortable store temperature would allow energy savings in HVAC system, but also in display cabinets, as they would require less energy to reach the same temperature. On the other hand, raising the store by some degrees temperature in summer would produce considerable savings in HVAC system, although it will increase the energy used by the refrigeration system. A detailed analysis should be performed in order to establish the most efficient store temperature in summer.

Other possibilities for reducing energy consumption in HVAC systems is to use variable space temperature set points based on the outdoor temperature, as well as include zonal control to provide low temperature and low level of humidity close to the refrigerated display cabinets to reduce frosting and defrosting losses.

2.3.1.2 Store dehumidification

Reducing air humidity enables energy savings in open cabinets through reducing the latent load on the refrigeration system and, thus, reducing the compressor power needed. Reduced air humidity results in less condensation and frost formation, reduces the number of defrost cycles, decreases anti-sweat heater energy requirements and improves the temperature stability of products.

Store dehumidification is not widely implemented, although studies indicate that considerable savings, up to 22%, can be achieved by reducing relative humidity from 50 – 70 % to 35 - 55 %. Largest energy savings would occur in stores with low ceilings as less energy is required for dehumidification (Sharma & Fricke, 2011).

2.3.1.3 Control system with zone valves and temperature controls

In a hydronic heating or cooling system, it is possible to control the heat transfer fluid, such as water, supplied to the different zones by means of zone valves conducted with temperature controls. This is best accomplished with a floor heating system. In the interest of improving energy efficiency and customer comfort, the supermarket can be divided up into multiple zones with different temperature levels.

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This action enables lower power consumption, since the heat or cooling generation is completely adjusted to the demand. On the other hand, the system may be hard to design and introduces a number of components that require appropriate control and maintenance labour to make them operate properly.

2.3.1.4 Equipment maintenance issues

Proper maintenance of the HVAC system is crucial for minimizing the energy consumption. The main maintenance operations are:

- Upgrading and maintenance of the HVAC filters: Air filters are used to reduce the amount of dust that reaches the wet coils, keeping the HVAC system clean. Dust on the wet coils and ducts reduce the heat transfer and thus, the efficiency of the coils. Additionally, clogged filters reduce the air flow causing higher energy consumption in fans.

- Combustion analysis and maintenance of boilers: The efficiency of the combustion of a heating boiler is defined by the air-fuel ratio. This ratio is fitted in the regular maintenance of boilers through the adjustment and cleaning of the burners. It is necessary to perform flue-gas analysis periodically to verify that the combustion parameters are within the recommended values, in order to obtain the maximum efficiency of the boiler.

2.3.2 Integration of refrigeration and HVAC

When making a thorough retrofitting in a supermarket, one of the innovative solutions to be implemented is the integration of the refrigeration and HVAC systems, achieving important reductions in the energy consumption of the supermarket.

In this sense, this refurbishment should be accompanied by tools and support for this implementation. Please refer to D2.3 How to build a new eco-friendly supermarket,. (Kauko, Kvalsvik, & Hafner, 2016)

2.3.3 Equipment substitution or addition in Heat Pumps and Air Conditioning systems

2.3.3.1 Replacement of current equipment with high efficiency equipment

Recent models of heat pumps and air conditioning systems are much more efficient than old equipment, reaching COP values from around 2 to around 5 in advanced systems.

COP is highly dependent on operating conditions (i.e. cooling temperature, ambient temperature and cooling load) but also on the efficiency level of the HVAC machine. Main options for improving COP are related to different technologic improvements in design, manufacturing, materials, etc. that allows the reduction of the output temperature in the condenser and the increase in the input temperature in the evaporator. Some of these technological developments are based on increasing the size of pipes and heat exchangers, decreasing speed of fluid or improving thermal conductivity.

2.3.3.2 Free cooling systems

Free cooling implies using the cooling capacity of outside air to renew and cool the indoor air, reducing the energy consumption of the cooling equipment. The system only switches on extraction and air conditioning fans upon demand, avoiding starting up the compressor of the cooling equipment. The effectiveness of this measure is linked to environmental conditions.

Another option which is practiced in many countries in supermarkets is the free cooling through energy wells (please refer to D2.3. How to build a new eco-friendly supermarket (Kauko, Kvalsvik, & Hafner, 2016))

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2.3.3.3 *Evaporative cooling systems*

This system consists in cooling the supply air through evaporation of water, which can be done directly or indirectly. Direct evaporative cooling implies that air is humidified, what is the main reason why this solution is not advisable for supermarkets in many locations. In the indirect evaporative cooling the air is kept separated from the process of evaporation and, therefore, it is not humidified. In both cases, the energy consumption in the compressor is decreased. As a drawback, legionella regulations and maintenance operations to prevent the contamination of supply air have to be taken into account.

A simple scheme of the solution can be observed in Figure 8. Outdoor air (C) passes through a secondary air stream, it is isolated and it is indirectly evaporative cooled towards the space to be cooled.

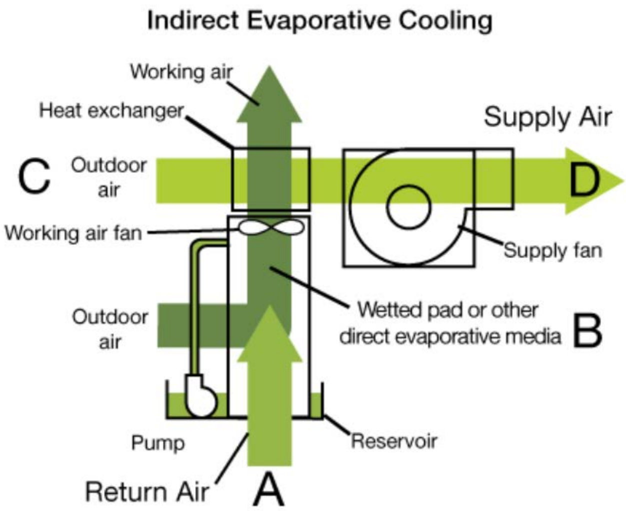

Figure 8 Indirect Evaporative Cooling (California Public Utilities Commission, 2014)

2.3.4 Equipment substitution in boilers

In those supermarkets where the heating demand is supplied by boilers, the following actions may be taken in order to improve the energy efficiency and reduce the environmental impact. However, the refurbishment of a supermarket with an eco-friendly view should address to a complete heat supply by means of a heat recovery from the refrigeration system, whenever possible.

2.3.4.1 *Replacement of fossil fuel boiler with biomass boiler*

A biomass boiler is equipment specifically designed to be powered with biomass, i.e. pellets, biomass chips, wood, and many others. Most of them have automatic ignition-regulation systems and some even removal of ashes. The boilers designed for pellets are very efficient and more compact than the rest of biomass boilers due to the characteristics of this fuel: high calorific value, compactness, low humidity, etc.

The CO_2 emissions of a biomass boiler are considered to be zero, since the emissions liberated in the combustion process are the same that had been absorbed by the plants during their life cycle.

On the downside, a biomass boiler requires more space than a conventional boiler, due to the necessity of storing fuel with a low calorific value compared to that of oil. Furthermore, certain amount of logistics is required in order to guarantee the biomass supply at competitive prices. In addition, specific safety measures are required and sometimes are difficult to achieve in the retrofitting of buildings.

Although the equipment is still considerably expensive compared to a conventional boiler, the replacement of diesel boilers with biomass are usually profitable, since biomass has significantly lower prices compared to diesel prices.

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2.3.4.2 Replacement of current boiler with condensing gas boiler

If possible, the replacement of a diesel boiler for a natural gas boiler is a very interesting option, since gas is a cheaper and less polluting fuel. In addition, in many places continuous supply of gas is available, removing the need for storage, which implies easier maintenance of the systems.

As a critical drawback, it is necessary that a natural gas distribution network is available next to the installation. In addition, the implementation involves adapting the boiler room for the new fuel and change of the burner or the boiler completely (depending on the type of existing boiler).

Within gas boilers, condensing models are the highest efficiency models. These boilers produce water at low temperatures (40-60°C), with high performance and low emissions of CO_2 and NO_X. Condensing technology allows the use of latent heat of the water contained in the flue gas, transferring part of this heat to the water in the primary circuit and achieving extra high efficiency, saving up to 20 % comparing with non-condensing models (Mukhopadhyay, 2013).

2.4 Energy efficiency in lighting

Lighting plays an extremely important role in supermarkets in attracting customers by presenting the products in the most appealing way. This is especially important in shop areas where meat, vegetables and other fresh products are sold. Moreover, choice of lighting is extremely important with respect to the energy efficiency, as lighting is responsible for up to 27 % of total electricity consumption in supermarkets. (Karampour, Sawalha, & Arias, 2016), (CIRCE. SME Energy Check Up project, 2014).

The most common technology for lighting is at present fluorescent tubes. Although these lamps are relatively efficient, new models and technologies have been developed with increased efficiency.

To perform a substitution of technology is important to consider the performance of the light source but also the entire luminosity, reflectance and switching. For instance, the average lighting level in supermarkets has to be about 1,000 lux and Colour Rendering Index (CRI) should exceed 85.

Savings between 25 %-35 % of the electricity consumption are possible by addressing the different energy efficiency measures discussed in the following.

2.4.1 Replacement of current lighting devices with high-efficiency fluorescent tubes

High-efficiency fluorescent lights are an interesting option in the short-term to reduce energy consumption in lighting, being less expensive (and less efficient) than LEDs, and reducing the energy consumption up to 35% when compared to standard fluorescents. Different options are available:

- Upgrading lighting to more efficient ones (T8 or T5 instead T12, see section 2.1.3.7), being a very quick measure with moderate savings.
- Upgrading power supply to electronic ballasts. It reduces energy consumption in a 20 %, since the losses in reactive power are eliminated.
- Installing high-quality light reflectors for fluorescent linear tubes that allows maximizing lighting levels without extra power.
- Replacing high-pressure sodium lamps by metal halide lamps, enabling moderate savings.

2.4.2 Replacement of current lighting devices with LED lamps

LED technology may reduce electric energy consumption in lighting by up to 66 % when compared to conventional fluorescent lamps. Furthermore, LEDs produce indirectly a reduction in energy consumption in air conditioning, since they have a negligible heat load contribution to the building.

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Although LED technology is still expensive, LED lamps have a longer operating life (up to 50,000 hours versus 18,000 hours for fluorescent lamps) and, thus, reduce the replacement cost in the long-term. In addition, this technology is still expected to reduce its cost in the next years.

Additionally, unlike other systems, start-up in LED lamps occurs instantly at 100% of its intensity without flicker or start-up periods; LEDs do not degrade by the number of starts, neither. These features make them excellent to apply lighting controls to switch them off or dim when no customers are present, achieving further energy savings.

However, lighting levels should be analysed when substituting conventional lighting with LED lights, since in some cases light level has been improperly reduced after the LEDs were fitted.

Typical replacement measures with LED lamps are the following (Philips, 2012):

- LED Tubes. The LED tube models are suitable to as a substitution where T8 or T12 fluorescent tubes are used.

- LED Ceiling Panels (mostly fluorescent replacement). A wide range of power levels is available and replacement costs are lower than with LED tubes (due to modular build and lower replacement frequency), although the initial cost is higher.

- LED Flood lights and accent lights (for meta-halogen replacement). They are aimed for product lighting, with higher energy efficiency and lower heat radiation than meta halogens.

- LED High Bays. This type of lamp is the suitable model for direct substitution of different lamp technologies in a wide range of power levels: halogen lamps, metal halide lamps (MH), low pressure and high pressure sodium vapour lamps (LPS and HPS). However, high bay lighting is not common in supermarkets since the light flux is more concentrated and might cause unpleasant glare.

2.4.3 Presence detectors

Presence detectors are used to switch on or off the lighting of any space according to the presence of people. With this, the on and off control is performed automatically, so a light switch will only remain on when it is really necessary that the room is illuminated. Beyond switching on and off, also dimming can be performed, for instance with a modular configuration of light fittings (e.g. allow using only a percentage of the lamps during stocktaking or cleaning, reducing flux from 1000 lux to 250 lux).

These systems are not expensive and they are easy to install and configure. However, their profitability is usually limited to certain zones such as toilets, corridors and intermittent waiting room areas with low or medium people traffic. Energy savings of around 20 to 50 % of the typical consumption of sporadically used zones can be achieved (Mukhopadhyay, 2013).

2.4.4 Use of day-lighting

The objective of this measure is to increase the utilization of daylight without increasing the cooling demand by using transparent building elements. Suitable elements and examples of supermarkets using these are given in the SuperSmart report D2.3 (Kauko, Kvalsvik, & Hafner, 2016)(ref), The location of the elements should be analysed separately for each refurbishing project and climate conditions. The level of artificial lighting in the supermarket is in this case adjusted based on the level of daylight available, either through zone control or dimming.

In existing supermarkets, a preliminary study may be necessary in order to analyse the real possibilities and profitability, since it may imply a considerable re-location of different sections and products owing to increased heat load from the sun. In new supermarkets it should be taken in consideration at the very beginning of the project.

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2.5 Renewable energy systems

2.5.1 Photovoltaic systems

Photovoltaic (PV) systems convert solar radiation into electric power ready to use. The PV systems applied in supermarkets are usually connected to the electric grid, although they can also constitute isolated systems.

The PV system can work mainly in two different ways depending on the national regulation and the will of the owner: selling all the electricity production and buying all the electricity consumption or auto-consuming the electricity production when possible, and buying the amount of electricity that could not be covered by the PV system.

The size of the system depends on the available surface exposed to the sun. Moderately tilted roofs oriented to the south (in the northern hemisphere) are the optimal surfaces for PV systems, but also flat supermarket roofs, where it is easy to install structures to reach the required inclination (depending on the latitude).

PV systems are especially well suited for refrigeration purposes, since the period with maximum cooling demand matches the period with higher electricity production.

2.5.2 Micro-wind turbine systems

Micro-wind turbine system consists of a small turbine and other equipment installed on top of a building in order to produce electric power from the wind energy. The systems can be connected to the grid or isolated, just like with PV. The vertical-axis turbines are the most suitable for urban areas, mainly for roofs, since they are less noisy than horizontal-axis turbines; however, the latter have higher efficiency, but, on the other hand, they are not dependent on the wind direction and work well also in turbulent conditions (often the case in urban areas) . (Windpower Engineering magazine, 2009)

Main disadvantages are that there are restrictions regarding the area where the micro-turbine can be installed, and permit restrictions that can hinder the installation process. Furthermore, wind turbines may be a little noisy, especially at high wind speeds.

2.5.3 Cogeneration and trigeneration systems

Cogeneration or combined heat and power production (CHP), is the simultaneous production of useful heat and electric power from a single source, in a system close to the point of use. These units meet the demand for space heating and hot water production whilst producing electricity to supplement or replace the grid supply. However, CHP is not sustainable when based on fossil fuel technology; biofuel is preferable.

Trigeneration systems or combined cooling, heat and power production (CCHP), refers to the simultaneous generation of electricity and useful heating and cooling from the combustion of a fuel or by using a solar collector.

These systems are not widespread in supermarkets, since they are only profitable in processes that require big amounts of heat, which is not the case in retail stores. However, for supermarkets that are situated in the same building as, or close to, other industries/services requiring heat, a cluster sharing the outputs from the trigeneration could be beneficial for all parts. The regulation for grid connection and electric power use is as with PV, and may be different for different countries.

2.5.4 Geothermal systems

Geothermal energy systems use the ground as a heat source for air conditioning and refrigeration cycles

Because of its temperature stability, the subsoil, and bedrock through energy wells, can be used both in winter and in summer for HVAC systems (please refer to D2.3. How to build a new eco-friendly supermarket, (Kauko, Kvalsvik, & Hafner, 2016)). The most recommended geothermal heat pump is a water-water system, with a COP around 4 which releases and absorbs the heat to/from the ground.

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A geothermal system implies a high initial investment, depending on the type and characteristics of the soil, but it could enable energy savings around 40 % of the HVAC energy consumption (Abdeen Mustafa, 2008)

2.5.5 Biomass

Biomass can be used in supermarkets where heat demand is supplied by boilers. This issue has been already discussed in section 2.3.4.Equipment substitution in boilers.

2.6 Energy management and certifications

Energy management systems are computer-based systems that help to manage, control and monitor the energy consumption of building energy systems (refrigeration, HVAC, lighting etc.), and other related parameters (humidity, temperature, etc.). They provide the information and tools needed to understand the energy usage of a supermarket and to control and improve its energy performance.

Different level of monitoring can be addressed, from simple energy consumption measurement in the main equipment up to the implementation of an energy management system like ISO 50,001 or similar.

In any case, energy management systems imply an increased energy efficiency for the refrigeration equipment, better supermarket operation by staff members and improved indoor conditions. However, energy management systems require skilled operators and commitment at all levels to obtain maximum effectiveness.

Energy management systems for supermarkets are discussed in more detail in a dedicated report, D2.6 Eco-friendly operation and maintenance of supermarkets. (Ciconkov & Ciconkov, 2016)

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3 NON-TECHNICAL BARRIERS

Lack of awareness	
Barrier	**Solution**
Lack of awareness of available technology at decision making level	• Demonstrating and documenting the reliability of new solutions with direct reference to existing/running systems linked with economic benefits for the new solutions (usually obtained through an energy audit, previously developed to analyse the current and possible future energy performance before the refurbishing).
Lack of awareness of financial support (by banks, financial bodies or governmental funding) or reward schemes for energy efficiency	• Informing about financing possibilities and bodies which centralize this support to organisations willing to improve their energy performance. • Involving financing entities to the refurbishing project with other stakeholders such as ESCOS (as an example, please check (Santi, Caiazzo, & Nigro, 2015)
Lack of awareness of possible financial savings from energy efficient solutions	• Documenting and demonstrating annual savings in operational costs, and the reduction in total cost of ownership (usually obtained through an energy audit previously done to analyse the feasibility of the systems before the refurbishing). • It is of great importance to document that the investments reduce the operational costs, otherwise, there is no future for new energy efficient technologies.
Lack of awareness of the environmental benefit of energy efficient systems	• Documenting and demonstrating annual environmental benefits, connected with the benefits coming from the customer's perception and the supermarket's image and competence improvement, as the environmental factor is gaining more and more importance for the purchasing decision.
Lack of awareness of possible alternatives to F-gases when planning the future installations	• Demonstrating and documenting the reliability of new solutions with direct reference to existing/running systems linked with economic benefits for the new solutions (usually obtained through an energy audit previously done to analyse the current energy performance before the refurbishing).
Lack of knowledge	
Barrier	**Solution**
Lack of training material and programs	• Centralising all the available material and courses through a platform which will be strongly disseminated across Europe, and supported by an educational program. • For training opportunities, visit the SuperSmart website, http://www.supersmart-supermarket.info/
Lack of experienced trainers	• Creating a certification or specialization for potential trainers to become specialist in Energy Efficient Systems (including specific topic of Supermarkets). •
Lack of education material for different technical knowledge levels	• Ensure availability of training material for different levels. •
Lack of training interest	• Establishing basic requirements for the workforce for technical, commissioning services, etc. services.

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Lack of unbiased third party data to compare alternative technologies and methodology for comparing different systems under the same boundary conditions	• Establishing an Energy Efficiency Key performance Indicators system for benchmarking European supermarkets
Lack of specialized stakeholders in designing, commissioning and servicing the plant	• Establishing a contractual relationship between the end user and the service along a period of time. This implies updating their knowledge and the commitment to utilize specialized technicians.
Social barriers	
Barrier	**Solution**
Concern about possible investment increase and long payback time as well as financial conflict of interests	• Demonstrating and disseminating success stories on refurbished eco-friendly supermarkets with decreased operating costs and increased revenue. • Informing about financing opportunities.
Concern about new solutions leading to too many technical changes at the same time	• Increasing the level of confidence in new solutions by showcasing that technical changes are supported by training programs and technical sessions. • Promoting interaction amongst stakeholders for mutual support.
Concern about new systems being less reliable than H(C)FC ones	• Demonstrating and disseminating success stories on refurbished eco-friendly supermarkets and solutions with alternative refrigerants with low GWP, from different climatic conditions.
Concern that energy efficient systems do not perform as promised	• Registering and disseminating energy consumption of new systems vs old ones using well-known performance indicators (e. g. kWh/m^2) and clear figures.
Concern about higher maintenance for new solutions or increased installation time	• Increasing the availability for training programs and technical support. • Increasing stakeholders' awareness on the support available from suppliers and technical and research organisations, to cope with the first installation and learn from it. • Demonstrating and disseminating success stories on refurbished eco-friendly supermarkets with decreased maintenance costs and increased revenue.
Concerns about availability of trained technicians for installation/maintenance of the new systems or solutions	• As above • Promoting networking among stakeholders.
Concerns about consumers not appreciating and valorising improved environmental impact of supermarkets.	• Disseminating the negative environmental impact of H(C)FC-based solutions to a wider audience. • Disseminating success stories on energy-efficient supermarkets where the improved food safety and consumer comfort has led to increased revenue. • Making consumers aware and responsible for the environmental footprint deriving from their shopping habits, using mass media.
Organizational barriers	
Barrier	**Solution**
Conflicting interests of stakeholders involved in planning or operation of a supermarket	• Legislation on building integration and waste heat recovery. • Possibility for supermarket owner to sell the heat, for nearby buildings/users and to the DH grid ("prosumer" schemes in DH). • Promoting the concept that energy systems can be a part of the contractual obligations amongst the involved stakeholders.
Lack of an “Energy Manager” for supermarket life time	• Create the figure of the Energy Manager or work with the model with ESCOS (for more innovative solutions see Santi et all, 2015)

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Lack of distributed responsibility chain for setting up an "integrated, efficient solution"	• SuperSmart – to bring all parts of the chain together to create holistic, integrated solutions.
Lack of an energy rewarding/payback scheme between system owner and system operator	• Set-up proposal for valorising energy solutions and make them a part of contractual obligations (e.g. rental fee, etc).
Short term view for energy efficiency investments	• Documenting reduced total cost of ownership in new energy-efficient supermarkets • Increasing awareness on financing possibilities •
Legislative barriers	
Lack of legislation considering the supermarket system as a whole	• New EU Ecolabel on supermarkets may eventually lead to such legislation. • Emphasise that legislation for parts of the supermarkets exist, like the F-gas Regulation.
Complexity in keeping record of HFCs systems, as no harmonised procedures are ready yet	• Standard procedures for keeping record of HFC systems, comparable across Europe
Lack of qualified personnel for system servicing	• Increasing the availability for training programs and technical support • Increasing stakeholder awareness on the support available from suppliers and technical and research organisations to cope with the first installation and learn from it.
Lack of/limited availability of suppliers for HFC-free systems	• Creating a platform or network for suppliers, demanders of HFC-free systems, which promotes training and support for manufacturers and end users.

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4 BEST PRACTICES AND CASE EXAMPLES

4.1 Turkey

KurtKöy-Millennium Carrefour Express		
Opening year	2010	
Location, country	Istanbul, Turkey	
Size [m²]	765	
Type	Hypermarket, Food & Department Store	
Energy efficiency measures implemented	Transition from High-GWP refrigerant R-404A to CO_2. Retrofitted refrigeration system (fridges and freezer) using CO_2: Technical features: • 13 showcases for chilled (medium temperature, MT) products, and two for frozen (low temperature, LT) products (33 meters of refrigeration displays) • Compressor racks are used to provide cooling for these showcases at various temperatures. Capacity of 40 kW for MT compressors, and 4 kW for LT compressors. • Pipe fittings have been improved, reducing by 75% the refrigerant leaks.	
Reduction in energy demand and CO_2 emissions (when applicable)	15% of energy efficiency improvement in refrigeration system Energy bill reduction by 7%	3400 times less pollutant in terms of CO_2 emissions, comparing with the previous technology
Total investment and payback (when applicable)		
Financing solution (when applicable)		
Link for more information	(Shecco, 2012)	

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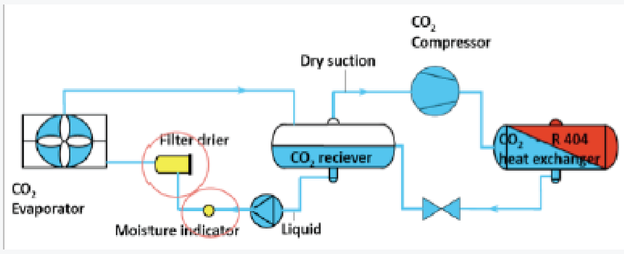
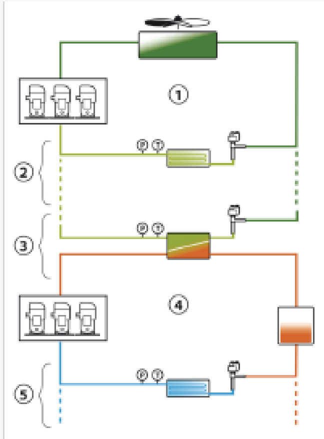
<table>
<tr><td colspan="2">The Bahçelievler Store</td></tr>
<tr><td colspan="2">




Above / Right: System Scheme CO_2-R404 cascade system
Right: 1 - R404a rack; 2 - MT units;
3 - LT condenser/condensers;
4 - CO_2 rack; 5 - LT units
</td></tr>
<tr><td>Opening year</td><td>2009</td></tr>
<tr><td>Location, country</td><td>Adnan Kahveci Bulvan E-5 Yolu Yani Bahçelievler Istanbul no:227</td></tr>
<tr><td>Size [m²]</td><td>7,778 (total sales area), 12,001 (net constructed area)</td></tr>
<tr><td>Type</td><td>Refurbished</td></tr>
<tr><td>Energy efficiency measures implemented</td><td>

- CO_2-R404a Cascade System, using CO_2 as refrigerant in its deep freeze zone and in one island refrigeration system.
- MT refrigeration units and the CO_2 condenser are supplied with R404a, and LT units with CO_2 (R744).
- High temperature (HT) rack and cascade system bringing together MT and LT units.

<table>
<tr><td>Rack</td><td>No. of comps.</td><td>Capacity steps</td><td>Inverter</td><td>Show cases</td><td>Cold rooms</td></tr>
<tr><td>HT</td><td>3</td><td></td><td></td><td></td><td>10</td></tr>
<tr><td>MT</td><td>5</td><td>1 comp with 3 steps</td><td></td><td>56</td><td>14</td></tr>
<tr><td>LT</td><td>3</td><td></td><td>1</td><td>14</td><td>1</td></tr>
</table>

- A capacity controlled compressor for the MT units and an inverter-driven compressor for the LT for further stabilisation of the installation because of the dynamic cascade solution.
-
- A management and electronic monitoring system to control the floating evaporation temperature of the CO_2 depending on the outside climatic conditions.

</td></tr>
<tr><td>Reduction in energy demand and CO_2 emissions[1] (when applicable)</td><td>Savings of 115.7 kWh per day, and 41.7MWh per year.</td></tr>
<tr><td>Total investment and payback (when applicable)</td><td>40,000 €</td></tr>
<tr><td>Financing solution (when applicable)</td><td></td></tr>
<tr><td>Link for more information</td><td>(Jump Start Project, 2010)</td></tr>
</table>

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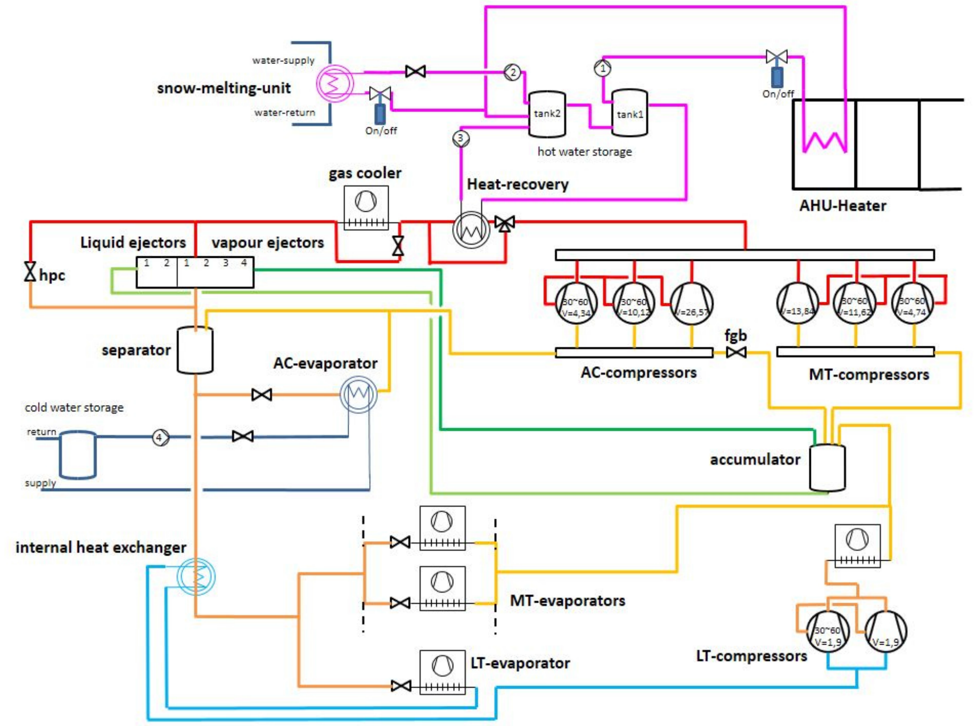
4.2 Norway

REMA 1000 Prinsens gate



Opening year	2015	
Location, country	Trondheim, Norway	
Size [m²]		
Type	Part of a building complex	
Energy efficiency measures implemented	• Integrated CO_2 refrigeration system with heat recovery at multiple temperature levels, equipped with ejectors • Provides AC for the entire building (including the offices above) • Excess heat utilized in the air handling unit to provide heat for the entire building as well as in snow melting	
Reduction in energy demand and CO_2 emissions[1] (when applicable)		
Total investment and payback (when applicable)		
Financing solution (when applicable)	The project received 600 000 NOK from Enova	
Link for more information	Not available yet.	

4.3 Romania

Mega Image in Obor		
Opening year	1995	
Location, country	Obor, close to the centre of Bucharest, Romania	
Size [m²]	200	
Type		
Energy efficiency measures implemented	Substituting the R-404A refrigerant for the frozen food cabinets in the store and the frozen storage facility in the back room by R-448A and filters, without changing any equipment, but with higher cooling capacity of 10 % in average and 6 % higher COP, with less refrigerant load required.	
Reduction in energy demand and CO_2 emissions[1] (when applicable)		
Total investment and payback (when applicable)		
Financing solution (when applicable)		
Link for more information	(Climalife)	

4.4 Spain

Carrefour hypermarket, L'Ametlla del Vallès		
Opening year		
Location, country	L'Ametlla del Vallès	
Size [m²]	3,200	
Type		
Energy efficiency measures implemented	• Carrier CO2OLtec CO_2 transcritical with ejector & parallel compressor • Retrofit of a 25-year old store. Store remained open throughout the installation. • System management and monitoring. • Pressure of 25 bars for LT, 45 bars for MT and 120 bars for HT • 90 % of the refrigeration equipment centralised, 10 % plug-in cabinets. • Centralised system uses 3 variable speed compressors, for high, medium and low pressure, respectively. • Refrigeration cabinets feature doors, LED lighting and electronic ventilators to reduce energy consumption. • Communication to customers on the use of HFC free refrigerants	
Reduction in energy demand and CO_2 emissions[1] (when applicable)	46 % more efficient than previous direct expansion systems using F-gases	
Total investment and payback (when applicable)		
Financing solution (when applicable)		
Link for more information	(Williams, 2015)	

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SIMPLY City Torrero		
Opening year		
Location, country	Zaragoza, Torrero	
Size [m²]		
Type		
Energy efficiency measures implemented	• LED lighting in sales room (lighting standard for new stores since 2011) • Taking advance of the natural lighting when possible and reducing lighting with respect to traffic (?) with a control system including presence sensors. • Floating pressure in condensation and evaporation • Variable speed drive compressors • Heat recovery for space preheating	
Reduction in energy demand and CO_2 emissions[1] (when applicable)	96,01 MWh annual reduction (28%) comparing with the previous installation	-37 tonsCO_2/year (-31 %)
Total investment and payback (when applicable)		
Financing solution (when applicable)		
Link for more information	(Asensio, 2015)	

4.5 Switzerland

Migros Supermarket		
Opening year		
Location, country	Grenzbacherstrasse, Basel city centre	
Size [m²]	600	
Type		
Energy efficiency measures implemented	• Modular LED lighting • Integrated CO_2 air conditioning/refrigeration system • Glass covers for self-service refrigeration units	
Reduction in energy demand and CO_2 emissions[1] (when applicable)	30% less energy consumption in the refrigeration system	
Total investment and payback (when applicable)		
Financing solution (when applicable)		
Link for more information	http://www.bjb.com/index.php?productid=399694	

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4.6 United Kingdom

Sainsbury's Beckton		
Opening year	1993	
Location, country	Beckton, London	
Size [m²]		
Type		
Energy efficiency measures implemented	• Reuse, onsite or locally, of materials in the reconfigured car parking areas and other areas of hard landscaping (1600 m^2 of cladding panels, 160 m^2 of aluminium curtain walling, and all of the standing seam roof system (14,700 m^2)) • Prefabricated roof and wall systems including integral insulation • PV panels • Ground source heat pumps • Cold aisle retrieval system • Water use monitoring	
Reduction in energy demand and CO_2 emissions[1] (when applicable)		40% of CO_2 emissions avoided (from PV panels, ground source heat pumps and cold aisle retrieval systems)
Total investment and payback (when applicable)		
Financing solution (when applicable)		
Link for more information	http://www.wrap.org.uk/construction	

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5 GOLDEN RULES AND CHECKLISTS

An **energy audit** according to regulation is a good starting point, in order to assess energy performance of the supermarket, as well as to detect inefficiencies and identify parts of the system where improvements are needed. A longer term option is establishing **an energy measurement and tracking system**. Refrigeration and lighting account for more than the 50% of the total energy use, and are hence the most obvious parts of the system to start checking and retrofitting (Energy Star, 2008).). The main measures are the following:

1. **Maintenance** plan to keep the equipment working correctly, assuring its life expectancy.

2. **Temperature** control and thermostat settings for the different operation conditions (including night operation and different seasons).

3. **Utilization of daylight** to reduce artificial lighting consumption.

4. **Occupancy sensors** to control the light when no necessary in less busy areas.

5. **Energy efficiency in refrigeration systems**
   a. Replacement or addition of equipment in the refrigeration system, such as equipment enabling floating head and suction pressure, evaporative condensers or heat recovery systems.
   b. Refrigerant change to lower GWP refrigerants, preferably natural refrigerants (CO_2). Depending on the type of system, more modifications than replacing the refrigerant may be necessary.
   c. Efficiency measures in cabinets, especially in doors and lighting.

6. Energy **efficiency in building envelope retrofitting and HVAC** systems

7. More **efficient lighting** systems or technologies

8. Use of **renewable energy**.

Furthermore, knowledge building, at different organizational levels might be necessary to ensure safe, efficient and reliable operation of the systems, from design to installation, commissioning, operation, service and maintenance of the supermarket.

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6 CONCLUSIONS

When analyzing the annual budget for supermarkets, energy expenses are one of the highest after the labor costs. For this and other reasons, such as the targets established in the EU, or the customers' interests, saving of energy together with reduction of CO_2 emissions are becoming one of the most important strategic goals of grocery stores.

In this report different solutions have been proposed both for retrofitting and refitting supermarkets to improve its energy performance, covering refrigeration systems, building envelope, HVAC systems, as well as lighting, accompanied with case examples from different parts of Europe.

For refrigeration systems, varying the head pressure allows the compressor to operate at the minimum pressure necessary at all ambient conditions, reducing the energy consumption in compressors and their maintenance and progressive wear. In this purpose, the use of Variable Frequency Drive (VFD) to modulate the condenser fans and compressors is the most efficient control system.

Additionally, heat recovery systems is a very advisable measure to implement when refurbishing supermarkets, but some conditions have to be taken into account when applying it: the waste heat temperature must be high enough for the heating application, and the operating time of the refrigeration machine must be close to the working period of the heat consumer. Main applications of this technology are: hot-water preheating, preheating of the supply ventilation air and reheating of dehumidified air. Moreover, floor heating is a good way to utilize low-temperature waste heat.

Furthermore, refrigerant replacement to natural refrigerants such as CO_2 has a significant effect on the environmental impact of supermarkets, not only due to reduction in the energy consumption, but mainly because of a lower global warming potential of the refrigerants and a reduction of direct emissions owing to refrigerant leakage.

Retrofitting of existing cabinets such as installing doors or night blinds on open-fronted cabinets, among others, are measures which are relatively cheap and easy to apply. Maintenance is also very important, to identify leaks and repair them during the refrigerant change and the operation, but also to maintain cabinets and refrigeration plant in right conditions to avoid increase in energy use.

Further described in the report are means of building envelope, HVAC and lighting systems retrofitting, as well as renewable energy systems integration in supermarkets.

Apart from the technical aspects, the report discusses the non-technical barriers for refurbishing supermarkets, as well as possible solutions to overcome these barriers. Increased investment costs and lack of full skilled technicians, are often regarded as the biggest non-technical barriers. Financing opportunities to overcome the financial barrier are therefore included for different European countries.

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A Appendix A Financing

A.1 EU and partner countries

NAME OF THE GRANT OR THE PROGRAM	BENEFICIARIES	WHAT IS FINANCED?	CALL DATES	COMPETENT BODY
LIFE	EU member states and some partner countries	"*The general objective of LIFE is to contribute to the implementation, updating and development of EU environmental and climate policy and legislation by co-financing projects with European added value" (European Commission 2016c)*. From 1992 till 2013, 3954 projects were funded, with together approximately €3.1 billion, or about €0.8 million per project on average. The programme is called the LIFE Multiannual work programme. The European Commission contains two sub-programmes, **Environment** and **Climate action**	Running for four-year-periods, The relevant programme is the 2014-2017-programme.	Executive Agency for Small and Medium-sized Enterprises (EASME). (Delegated by The European Commission - The Directorate General for the Environment and DG Climate Action)
LIFE – Environment (European Commission 2016b)		Projects focuses on management of the nature and resources in a good way, that is; utilizing the resources efficiently, reduce wasting of resources and pollution, especially CO_2, only use a sustainable part a the nature's resources, and ensuring safe operation and no health risks neither from operation/processes nor their environmental impact.	Continuously	
LIFE - Climate action (European Commission 2016a)		The programme has different priority areas, but the most recent are those of biodiversity and preservation of natural habitats, monitoring of resource use, possible technologies and their potential, network establishment, action plans/completing list for red listed species and birds listed in Annex I and II of the Birds Directive[1] on the one hand, and exchange of researchers, students and knowledge, increase awareness and recruitment to the field of LIFE and its work and results (European Commission 2014).	Continuously	

The European Commission funds "projects and initiatives that promote its policy priorities throughout the European Union and further afield." (European Commission 2015) There are opportunities for both implementing environmentally friendly technology and for innovation within the same field.

[1] Directive 2009/147/EC of the European Parliament and of the Council of 30 November 2009 on the conservation of wild birds. http://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:32009L0147.

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A.2 Germany

A.2.1 Call for project grants and financial support

NAME OF THE GRANT OR THE PROGRAM	BENEFICIARIES	WHAT IS FINANCED?	CALL DATES	COMPETENT BODY
Maßnahmen zur Nutzung erneuerbarer Energien im Wärmemarkt (Marktanreizprogramm) Heating with renewable energies	All sizes of companies and also individuals, freelancers, municipalities, local authorities and municipal syndicates and other legal persons of private law, in particular non-profit organizations or cooperatives.	Heat pump systems having up to 100 kW nominal power, but not air/air or direct to air heat pumps (BAFA 2016b). Additional funding is given to heat pumps: capable of load management ("Smart Grid Ready"); combination with a heat network or simultaneously established eligible solar collector or biomass plant; energy optimization of the heating system and hot water production in existing buildings in connection with the establishment of an eligible heat pump or optimizing a supported heat pump. Optimization of heating equipment can give additional funding in the following cases -building of a new, support worthy heat pump -Optimization of an earlier granted investment in a heating system or heat pump. If the installation of the energy system was more than 3 years ago, but less than 7 years, but the system has to be in the catalogue of the funding program. Cost below 100 are not funded. An analysis might have to be carried out (DIN EN 15378). -Optimization of a heat pump one year of operation, measurements after at least one year should be compared to calculated results and eventual improvements may be funded-	Continuously	BAFA[2] on behalf of the Federal Ministry for Economic Affairs and Energy (Bundeswirtschaftsministerium)
Richtlinie zur Förderung von Maßnahmen an Kälte- und	Businesses of any size, non-profit organizations, municipalities, municipal Authorities, syndicates and municipal enterprises, schools, hospitals and religious	Air-conditioning and refrigeration systems; Consulting measures; Renovation of existing systems; Installation of new systems; Installation of air handling units and absorption units; heat- and cooling integrated systems;	Continuously	BAFA on behalf of the Federal Ministry for the Environment, Nature Conservation, Building and Nuclear

[2] BAFA: Bundesamt für Wirtschaft und Ausfuhrkontrolle (Federal Office for Economic Affairs and Export Control)

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Klimaanlagen (Kälte-Richtlinie) Stationary refrigeration and air conditioning systems	institutions	Measures for using heat recovery from production processes and cooling units or refrigeration plants. The solution should use environmentally friendly refrigerants and be so efficient that environmental impacts are significantly reduced (Bundesministerium and für Umwelt 2015, BAFA 2016a).		Safety (Bundesumweltministerium)
Kraft-Wärme-Kopplung Power-heat-coupling	Storage system owners	Storages that have at least 50% of heat/cold for heating storage and cooling storage from CHP, is to be installed before 31.12.2020 and is a completely new, unused installation or an upgrade of an existing storage unit. €250 per m³ water equivalent can be funded, but maximum of 30% of the total investment costs or 5 million € per project (BAFA 2016c).	Continuously	BAFA

Project funding from BAFA is normally equity financing, that is, non-repayable grants. Application needs to be sent to BAFA and paying the grant is done after proof of the use of evidence. This should be an electronic application containing application documents, proof of installation of highly-efficient technologies, commercial registration and energy savings concept. Examples of funded projects include engines, pumps, ventilation, heat recovery systems, lighting. There is no funding for used machinery, measures that have to be done by law, cooling units, components and systems of the refrigerant circuit (not sure what way that means supermarkets).

A.2.2 Soft loans

BENEFICIARIES	WHAT IS FINANCED?	CALL DATES	COMPETENT BODY
Companies, that are mainly private owned, in **<u>both Germany and other countries,</u>** as well as in some cases, other institutions or individuals/ freelancers	Three main areas are funded: -Renewable energy: storage, solar, wells deeper than 400 m, fluid at least 20 °C, -Energy efficiency: heat recovery/utilization, efficient buildings, renovation of non-residential buildings (including heat/cold equipment, lighting, monitoring and controlling systems, ventilation…), -Environment and innovation: protection of resources and environment, water treatment, reduced waste, energy efficiency. Generally, planning and equipment can be financed. Spreading effects are important (KfW 2016).	Continuously	KfW
No requirements given	Initiatives sparing the environment, like the building of renewable energy plants and passive houses: They consider the entire life cycle: building, operation and demolition. Priorities are	Continuously	Umweltbank

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	solutions for organic development, clean nature and protecting the environment. No projects violating human rights or legislations are accepted. A set of positive criteria and excluding criteria are given on their webpage (UmweltBank 2016).		

Positive criteria (as listed on their webpage, both translated and in their own words in German):

• Energy saving measures • Renewable energy • (Wind energy, photovoltaic, solar thermal, biomass and biogas, hydropower) • Decentralized energy production/ energy recovery, CHP plant • Environmentally friendly buildings • (Low energy building techniques, passive houses, use of organic building materials, landscape protection/ reduction of area use, reuse of rainwater) • Organic agriculture and organic forestry • Cycling/circular processes/recycling (Reduction of waste, saving raw materials, and protecting resources, environmentally justifiable depositing, nature cleaning plant) • Reduction and Removal of emissions (Environmentally friendly transport, soil protection and restoration, noise reduction, prevention of air pollution) • Sustainable economic operation (Development, production and distribution of long-lasting, resource preserving, regional and thereby environmentally friendly products)	• Energiesparmaßnahmen • Regenerative Energie • (Windenergie, Photovoltaik, Solarthermie, Biomasse und Biogas, Wasserkraft) • Dezentrale Energiegewinnung/ Energierückgewinnung, Blockheizkraft/Kraft-Wärme-Kopplung • Umweltschonende Gebäude • (Niedrigenergiebauweise, Passivhäuser, Verwendung organischer Baustoffe, Landschaftsschutz / Reduktion von Flächenverbrauch, Regenwasserrückgewinnung) • Organische Landwirtschaft und Organische Forstwirtschaft • Kreislaufwirtschaft/Recycling (Abfallvermeidung, Rohstoffeinsparung und Ressourcenschonung, umweltverträgliche Entsorgung, Naturkläranlagen) • Schadstoffverringerung und -beseitigung (Umweltschonende Verkehrsmittel, Bodenschutz/ Sanierung, Lärmverminderung, Luftreinhaltung) • Nachhaltige Wirtschaftsweise (Entwicklung, Herstellung und Vertrieb von langlebigen, ressourcenschonenden, regionalen und damit umweltfreundlichen Produkten)

Excluding criteria (as listed on their webpage, both translated and in their own words in German):

• Large power plants (brown/stone coal, nuclear power) • Weapon or military goods (production/trade) • Products or technologies harmful for the environment. (production/trade) • Violation of environmental specifications • Socially incompatible projects, e.g. child exploitation for production • Genetic engineering in agriculture • unfair trade practices, e.g. corruption, violation of human rights	• Großkraftwerke (Braun- / Steinkohle, Atomenergie) • Waffen oder Militärgüter (Produktion/Handel) • Umweltschädliche Produkte oder Technologien (Produktion / Handel) • Nichteinhaltung von Umweltauflagen • Sozial unverträgliche Projekte, z.B. auf Ausbeutung von Kindern basierende Produktion • Gentechnik in der Landwirtschaft • unfaire Geschäftspraktiken, z. B. Korruption, Menschenrechts-verletzungen

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A.3 Norway

A.3.1 Call for project grants and financial support

NAME OF THE GRANT OR THE PROGRAM	BENEFICIARIES	WHAT IS FINANCED?	CALL DATES	COMPETENT BODY
Støtte til konsept-utredning for innovative energiløsninger i bygg og områder (Enova 2016a)	Firms planning innovative energy solutions in one/more buildings, starting within three years	New energy solutions for building projects, which will start within three years; both new and established technologies; clusters/integrated systems, storage and peak shaving, heating, cooling, use of waste heat and free cooling (use of outdoor cold to cover cooling demands, completely or partially) and local energy production, insulation and solar panels, ventilation and other indoor equipment. The higher the degree of innovation, and the larger the further spreading effects the project has, the higher the chance for funding.	Continuously	Enova
Støtte til eksisterende bygg (Enova 2016b)	Owner(-s) and renter (-s) of existing residential and non-residential buildings	Implementation of measures for reduced energy demand and increased use of renewable sources in existing buildings and for upgrading to passive house or low energy standard (built after criteria in "NS 3701 - Kriterier for passivhus og lavenergybygninger, Yrkesbygg") which start within three years, giving at least 10 % energy reduction and having a follow-up system (Energioppfølgingssystem - EOS).	Continuously	Enova
Støtte til energieffektive nybygg	Those economically responsible for a building project after higher standards than required, reducing energy demand significantly	Projects leading to significant energy reductions, including innovative elements and fulfilling a set of minimum requirements (Enova 2016c). Applicant(s) must be economical responsible for the investments, and the application must include dynamic energy simulations, resulting energy demand and profitability, which other support the project receives, and description and documentation of new/rarely used technology to be included.	Continuously	Enova
Miljø-teknologi: tilskudd til fremtidens løsninger	Firms in all sectors in Norway can apply. However, SMEs and ventures in the districts are generally given priority.	Solutions that have lower impacts on the environment than those presently used, the applications with highest potential/spreading effects are prioritized. Additional costs compared to conventional solutions for new technology for the environment (with repeatable results and identified spreading measures) and **test plants are funded.** The solutions must enhance value creation in Norway	Continuously	Innovasjon Norge
Generell bedrifts- og prosjektfinansiering	Firms in all sectors in Norway can apply. However, SMEs and ventures in the districts are generally given priority.	Pre-projects/analyses resulting in a clear plan for implementation of energy efficient measures (a market growth potential should be documented); Use of consultant services; Buildings and equipment; "... profitable projects that include building expansions, modernizing, transition/adaptation to new external conditions, development or new establishments." (Enova 2016b)	Continuously	Innovasjon Norge

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A.3.2 Tax incentives

NAME OF THE GRANT OR THE PROGRAM	BENEFICIARIES	WHAT IS FINANCED? CALL DATES	COMPETENT BODY
Skattefunn	Enterprises	Skattefunn reduces the tax of businesses working with R&D that will benefit their operation, provided the money are all spent on R&D. There is a maximum border for tax refunding (≤2 million NOK per year, depending on conditions). SMEs can have 20 % covered, larger enterprises 18 % (Forskningsrådet 2016).	Innovasjon Norge

Enova funds investments in equipment and technology for lowering energy demand and reduced CO_2 emissions. The application must be written in advance of building start, and the expenses, also in terms of analysis and planning, project realization and results must be documented to receive financing. All buildings and sizes can receive funding, but high ambitions compared to requirements and high further impact is mandatory to achieve this. Enova funds additional costs, but not more than the extra costs for making the building more energy efficient than the legal requirements, and gives priority to higher savings for less money and sooner starts.

Similarly to Enova, Innovasjon Norge requires that an application is submitted to them before the project has started. They also offer loans and guaranties, in addition to funding. Innovasjon Norge will discuss with applicants to find the most suitable support for each case. The difference compared to Enova is that Innovasjon Norge is more focused on innovation projects and new development, whereas Enova is primarily focused on bringing the new technologies to the market, thus the research should (normally) already have been done. Yet, the programme *"Støtte til konseptutredning for innovative energiløsninger i bygg og områder"* also includes innovation, thus, there is some overlap in focus areas.

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A.4 Spain

A.4.1 Call for project grants and financial support

NAME OF THE GRANT OR THE PROGRAM	BENEFICIARIES	WHAT IS FINANCED?	CALL DATES	COMPETENT BODY
AYUDAS EEA-GRANTS (CDTI 2016)	Empresas establecidas en España. En el caso de proyectos en colaboración entre empresas españolas, Agrupación de Interés Económico (AIE) o consorcio regido por un acuerdo privado **Companies established in Spain. In the case of collaborative projects among Spanish companies, Economic Interest Group (EIG) or consortium must be governed by a private agreement**	Se financiarán proyectos empresariales de carácter aplicado para la creación y mejora significativa de un proceso productivo, producto o servicio, en el ámbito de las energías renovables, la eficiencia energética, el cambio climático y las tecnologías medioambientales. Pueden comprender tanto actividades de investigación industrial como de desarrollo experimental **Business projects for the creation and significant improvement of a production process, product or service in the field of renewable energy, energy efficiency, climate change and environmental technologies will be financed. They may include both industrial research and experimental development**	Última convocatoria: **10/02/2014 a 10/04/2014** **Last call: 10/02/2014 to 10/04/2014**	Centro para el Desarrollo Tecnológico Industrial (CDTI) **Centre for the Development of Industrial Technology**
Programa Estatal de I+D+i Orientada a los Retos de la Sociedad (Ministerio de Economía y Competitividad 2014)	Empresas, y asociaciones empresariales sectoriales, además de otros organismos tanto públicos como privados **Companies, and trade associations, and other organizations, both public and private**	Proyectos en cooperación entre empresas y organismos de investigación, con el fin de promover el desarrollo de nuevas tecnologías, la aplicación empresarial de nuevas ideas y técnicas, y contribuir a la creación de nuevos productos y servicios **Cooperation projects between companies and research organizations in order to promote the development of new technologies, business application of new ideas and techniques and the creation of new products and services**	Última Convocatoria: 23/12/2013 a 28/01/2014 **Last call: 23/12/2013 to 28/01/2014**	Dirección General de Innovación y Competitividad. Ministerio de Economía y competitividad **Directorate General for Innovation and Competitive-ness, Economy and Competitive-ness Ministry**

A.4.2 Soft loans

NAME OF THE GRANT OR THE PROGRAM	BENEFICIARIES	WHAT IS FINANCED?	CALL DATES	COMPETENT BODY
Financiación por terceros (F.P.T.) (IDAE 2016a)	Empresas industriales **Industrial enterprises**	Solución integrada técnica y financiera para inversiones en proyectos energéticos. IDAE realiza directamente la inversión y la amortiza con los ahorros energéticos generados **Technical and financial comprehensive solutions for investment in energy projects; IDAE makes directly investment and amortizes energy savings generated**	Continua **Continuosly**	Instituto para la Diversificación y Ahorro de la Energía (IDAE) **Institute for Diversification and Saving of Energy**
Fondo de Inversión para financiar proyectos de eficiencia energética y energías renovables. (IDAE 2016b)	-ESEs. -Otras empresas privadas. -Entidades público-privadas. -Entidades Públicas. **-ESCOs** **-Other private companies.** **-Public-private entities.** **-Public entities.**	Este fondo financiará todas las inversiones relacionadas con el aumento de la eficiencia energética y la utilización de energías renovables en entornos urbanos. Comunidades Autónomas: Andalucía, Islas Canarias, Castilla y León, Castilla-La Mancha, Ceuta, Comunidad Valenciana, Extremadura, Galicia, Melilla y Región de Murcia. **This fund will finance all investments related to increasing energy efficiency and renewable energy use in urban environments. Autonomous Communities: Andalusia, Canary Islands, Castile and Leon, Castile-La Mancha, Ceuta, Valencia, Extremadura, Galicia, Melilla and Region of Murcia.**	Vigencia: hasta el 30 de abril de 2015 **Validity: until April 30, 2015**	Instituto para la Diversificación y Ahorro de la Energía (IDAE) **Institute for Diversification and Saving of Energy**
Financiación de Proyecto y Arrendamiento de Servicios (IDAE 2016c)	Empresas **Enterprises**	Este tipo de financiación es aplicable a proyectos de inversión en materia de ahorro, eficiencia energética y energías renovables, que dispongan de un análisis previo de viabilidad técnico-económica. **This type of funding applies to investment projects in savings, energy efficiency and renewable energy, which have a preliminary analysis of technical and economic feasibility.**	Continua **Continuosly**	Instituto para la Diversificación y Ahorro de la Energía (IDAE) **Institute for Diversification and Saving of Energy**

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A.4.3 Tax incentives

NAME OF THE GRANT OR THE PROGRAM	BENEFICIARIES	WHAT IS FINANCED? CALL DATES	COMPETENT BODY
REAL DECRETO LEGISLATIVO 4/2004, de 5 de marzo, por el que se aprueba el texto refundido de la Ley del Impuesto sobre Sociedades. Artículo 39. Deducciones por inversiones medioambientales. (Ministerio de Hacienda y Administraciones Públicas 2004)	Empresas **Enterprises**	1. Las inversiones realizadas en bienes del activo material destinadas a la protección del medio ambiente consistentes en instalaciones que eviten la contaminación atmosférica procedente de instalaciones industriales, contra la contaminación de aguas superficiales, subterráneas y marinas para la reducción, recuperación o tratamiento de residuos industriales para la mejora de la normativa vigente (deducción en la cuota íntegra del 10 por ciento de las inversiones) 2. Adquisición de nuevos vehículos industriales o comerciales de transporte por carretera, sólo para aquella parte de la inversión que reglamentariamente se determine que contribuye de manera efectiva a la reducción de la contaminación atmosférica. 3. Aprovechamiento de fuentes de energías renovables consistentes en instalaciones y equipos con cualquiera de las finalidades que se citan a continuación: a) Aprovechamiento de la energía proveniente del sol para su transformación en calor o electricidad. b) Aprovechamiento, como combustible, de residuos sólidos urbanos o de biomasa procedente de residuos de industrias agrícolas y forestales, de residuos agrícolas y forestales y de cultivos energéticos para su transformación en calor o electricidad. c) Tratamiento de residuos biodegradables procedentes de explotaciones ganaderas, de estaciones depuradoras de aguas residuales, de efluentes industriales o de residuos sólidos urbanos para su transformaciónen biogás. d) Tratamiento de productos agrícolas, forestales o aceites usados para su transformación en biocarburantes (bioetanol o biodiésel). **1. Investments in active material for the protection of the environment consisting of installations to avoid air pollution from industrial plants, pollution of surface, ground and sea water; reduction, recovery and treatment of industrial waste to improve existing legislation (the total tax deduction of 10 % of investments)** **2. Acquisition of new industrial or commercial road transport vehicles, but only for that part of the investment determined by regulation that effectively contributes to reducing air pollution.** **3. Use of renewable energy sources in facilities and equipment consistent with any of the purposes cited below:** **a) Use of energy from the sun for conversion into heat or electricity.** **b) Use of municipal solid waste or waste biomass from agricultural and forestry industries, agriculture residues and forestry and energy crops as fuel for transformation into heat or electricity.**	Ministerio de Hacienda y Administraciones Públicas **Ministry of Finance and Public Administration**

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		c) Treatment of biodegradable waste from farms, from sewage treatment plants, industrial effluents or solid waste for biogas transformation stations. **d) Treatment of agricultural, forestry or oil products used for processing into biofuels (bioethanol and biodiesel).**	

A.4.3.1 Financing by means of energy service companies

La **Directiva 2006/32/CE** del Parlamento Europeo y del Consejo define la Empresa de Servicios Energéticos (ESE) "como una persona física o jurídica que proporciona servicios energéticos o de mejora de la eficiencia energética en las instalaciones o locales de un usuario y afronta cierto grado de riesgo económico al hacerlo. El pago de los servicios prestados se basará (en parte o totalmente) en la obtención de mejoras de la eficiencia energética y en el cumplimiento de los demás requisitos de rendimiento convenidos".

En este sentido, las ESEs tienen el objetivo final de ahorrar energía, lo que deriva en un ahorro tanto económico como de emisiones de CO_2. Su actividad se centra en el desarrollo de proyectos que garanticen una gestión eficiente de la energía, comprometiéndose económicamente con los resultados. El pago de los servicios prestados se basará (en parte o totalmente) en la obtención de mejoras de la eficiencia energética y en el cumplimiento de los demás requisitos de rendimiento convenidos. El cliente tiene la posibilidad de conseguir un beneficio económico de la optimización de su consumo energético a la vez que reduce el riesgo ante variaciones de los precios de la energía, todo ello sin tener que realizar ninguna inversión. En España existen varias asociaciones a las que recurrir para encontrar una ESE. Concretamente, y con el fin de facilitar el conocimiento de las empresas de servicios energéticos, el IDAE ha elaborado una base de datos que contiene información de contacto, servicios comercializados y su ámbito geográfico de actividad (IDAE 2016d).

Directive 2006/32/EC[3] defines the Energy Service Company (ESCO) "as a natural or legal person that delivers energy or improving energy efficiency in facilities or premises of a user services and facing some degree of financial risk in doing so. Payment for services rendered will be based (partially or entirely) in obtaining improvements in energy efficiency and the fulfillment of the other agreed performance criteria. "

In this sense, ESCOs have the ultimate goal of saving energy, resulting in both economic savings and CO_2 emissions. Its activity focuses on developing projects to ensure efficient management of energy, economically promising results. Payment for services rendered will be based (partly or fully) in obtaining improvements in energy efficiency and the fulfillment of the other agreed performance criteria. The customer has the possibility to get an economic benefit from optimizing their energy while reducing the risk to changes in consumer energy prices, all without having to make any investment. In Spain there are several associations that go to find an ESCO. Specifically, and in order to facilitate the understanding of energy service companies, the IDAE has developed a database containing contact information, services sold and its geographical area of activity (IDAE 2016d).

[3] Directive 2006/32/EC of the European Parliament and of the Council of 5 April 2006 on energy end-use efficiency and energy services and repealing Council Directive 93/76/EEC. http://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:32006L0032.

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A.5 Macedonia

A.5.1.1 Call for project grants and financial support

NAME OF THE GRANT OR THE PROGRAM	BENEFICIARIES	WHAT IS FINANCED?	CALL DATES	COMPETENT BODY
Western Balkans Sustainable Energy Financing Facility II Macedonia Serbia BiH Croatia	-Private businesses -Public Private bodies -Public bodies	- Modern technologies that cut energy consumption or CO_2 emissions by at least 20% - Retrofitting of buildings, provided the investment will make them at least 30% more energy efficient - Stand-alone renewable energy projects Businesses will receive investment incentives of 5% - 10% of the loan amount upon successful completion and verification of eligible projects.	Permanent till funds available	EU/EBRD European bank for research and development (EBRD 2016)

A.5.1.2 Soft loans

NAME OF THE GRANT OR THE PROGRAM	BENEFICIARIES	WHAT IS FINANCED?	CALL DATES	COMPETENT BODY
Western Balkans Sustainable Energy Financing Facility II Macedonia Serbia BiH Croatia	-Private businesses -Public Private bodies -Public bodies	- Modern technologies that cut energy consumption or CO_2 emissions by at least 20% - Retrofitting of buildings, provided the investment will make them at least 30% more energy efficient - Stand-alone renewable energy projects Businesses will receive investment incentives of 5% - 10% of the loan amount upon successful completion and verification of eligible projects.	Permanent till funds available	EU/EBRD European bank for research and development (EBRD 2016)

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