European Commission DG ENTR

Preparatory Study for Eco-design Requirements of EuPs

[Contract N° S12.515749]

Lot 1

Refrigerating and freezing equipment:

Service cabinets, blast cabinets, walk-in cold rooms, industrial process chillers, water dispensers, ice-makers, dessert and beverage machines, minibars, wine storage appliances and packaged condensing units

Task 3: User behaviour

Final report

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3.1. INTRODUCTION

The location of refrigeration equipment, and the way in which it is installed, used and maintained, can have a significant impact on its energy consumption and environmental impacts. Product design and product information to some extent influences user behaviour, as could information campaigns and mandatory/voluntary standards. The aim of this task is to explore the user behaviour aspects and their influence on the energy and environmental performance of the ENTR Lot 1 products.

Due to the nature of the products, refrigeration contractors might for certain product groups be considered as 'users', as they can be involved in the design, location, assembly or maintenance of the products (often through formal tendering and servicing contracts). The main underlying issues to consider are:

- heat loads – putting higher demand on the refrigeration system or affecting system efficiency through variable loads;
- incorrect use of the product – unnecessary increase of consumption through misuse or incorrect setting of controls;
- refrigerant leakage – leading to release of refrigerant gases into the atmosphere and reducing refrigeration system efficiency;
- product durability – impacts on the lifetime of the product and potential early replacement.

The objective of this section is to describe user behaviour, covering the best practices in sustainable product use. Firstly, the user types for ENTR Lot 1 products are identified, then the major sources of potential impact are discussed. User behaviour during the installation and use phase is discussed, then product and system design, followed by maintenance and repair practice, and finally end-of-life user issues are identified.

A number of governmental agencies and organisations[1] provide recommendations for smarter use of refrigeration equipment. Such strategies to reduce energy use aim to reduce the amount of cooling needed. This can be achieved through better equipment settings and reduction of heat losses and gains. An analysis of the influence of providing user information on real life efficiency of commercial refrigeration equipment is therefore provided.

3.2. USERS OF THE PRODUCTS

The refrigeration equipment identified in Task 1 is used by a wide range of users, and both consumers and contractors have an impact on product performance, for example:

[1] Such as the Government of South Australia Department of Transport, Energy and Infrastructure, Energy Smart Initiative (Australia), Natural Resources Canada – Office of Energy Efficiency oee.rncan.gc.ca/industrial/equipment/commercial-refrigeration/operation.cfm?attr=4

- poor location of the product or faulty installation may lead to increased heat infiltration (and increased heat load on the refrigeration system during use);
- during use, consumer maintenance might involve cleaning of the condenser heat exchanger during use, while installation and service contractors would carry out repair and refrigerant leakage testing.

The following tables provide a product-level description of users and the behaviours that may impact product performance.

Table 3-1: Consumer users of ENTR Lot 1 equipment

Equipment	Consumer users[2]
Service cabinets	Professional kitchens of all varieties, public and private catering facilities, hotels, light industrial food processing, and supermarkets
Blast cabinets	Restaurants, public and private catering facilities, hotels, light industrial food processing
Walk-in cold rooms	Professional kitchens of all varieties, public and private catering facilities, light industrial food industry, retail establishments of many kinds: butchers, pharmaceutical, florists[3]
Process chillers	Food processing, cold storage, and larger manufacturing processes[4] such as plastics moulding
Remote condensing units	To connect to remote equipment in restaurants, catering facilities, hotels, supermarkets, butchers

Consumer use impacts might come through use (e.g. use pattern, pre-cooling, loading, temperature selection) or maintenance (e.g. condenser cleaning).

Contractor impact could come at installation (e.g. avoiding air infiltration and refrigerant leaks, choosing a good location to avoid heat sources) or maintenance (e.g. checking for refrigerant leaks). For plug-in products, input from contractors is likely to be low (no expertise is needed for installation, components are integral and refrigerant leakage is relatively low), but high for remote products (installing pipes to circulate refrigerant, repairs and checking for leaks).

3.3. SOURCES OF IMPACTS

There are four major sources of impact that are affected by user behaviour, leading to greater energy consumption or reduced environmental performance.

[2] Deneen, Michael A.,Gross, Andrew C. The global commercial refrigeration equipment market. (Focus on Industries and Markets). 2002

[3] Health sector (the requirements are particularly special in medical premises: see **Annex 3-1**), mortuaries, testing laboratories are sectors in wich cold rooms are used, but these are not included in the scope of ENTR Lot 1.

[4] E.g. Plastics & Rubber; Lasers; Food & Beverage; Chemical & Pharmaceutical; Metal Working; Mechanical & Engineering; and Paper & Related Applications.

3.3.1. HEAT LOADS

Refrigerated equipment used to cool down and store foodstuffs requires constant refrigeration energy intake to offset:

- heat gains due to opening the appliance (convection) – this is true for service cabinets, walk-in cold rooms, dessert and beverage machines, and ice-makers;
- heat gains through insulated surfaces of the equipment (conduction);
- heat gains through the radiation from surrounding surfaces;
- heat gains due to the components included inside the equipment (lighting, fans, defrost system, warm foodstuff, etc.).

The efficiency of refrigeration systems can also be affected by varying loads, depending on its technical specifications (e.g. variable speed drives can be more efficient at part loads – please see Task 4 for more detail). As a rule, the cooling capacity of refrigeration systems should be designed to match their heat load. However, load can be heavily affected by use behaviour, for examplethrough overloading a system, or a refrigeration system may be 'over-designed' to account for extreme highs in loading (e.g. in summer months) and loaded to only a fraction of its capacity. Please see Task 4 for more discussion on system loading and technical solutions.

3.3.2. SYSTEM FUNCTIONALITY

The performance of service cabinets, blast cabinets and walk-in cold rooms can be impacted by improper stock loading, affecting air flows from the evaporator.

Additionally, inadvertent misuse of system controls can lead to increased energy consumption across all products, for example through incorrect setting of the thermostat.

3.3.3. REFRIGERANT LEAKAGE

Refrigerants and their impacts are discussed in detail in Tasks 1 and 4. The main impacts due to use arise through poor installation and maintenance of refrigerant circuit piping, leading to leaks – this is particularly problematic at joints in the piping, but user aspects (as opposed to technical aspects of refrigerant selection) can be addressed through good practice. In addition to the direct impact of high-GWP refrigerants escaping into the atmosphere, reduced refrigerant charges also affect system efficiency, leading to higher energy consumption.

3.3.4. PRODUCT DURABILITY

The durability of refrigeration equipment can be affected, and lifetime reduced, by damage to the refrigeration system or physical damage to the product.

3.4. LOCATION AND INSTALLATION OF PRODUCT

3.4.1. APPLIANCE LOCATION

Refrigeration equipment is often used in kitchens (near cooking appliances) without any air-conditioning systems, or can be used outdoors in potentially high ambient temperatures during summer (or direct sunlight). In industry, process chillers may be placed in areas of high ambient temperatures or located near heat sources such as industrial equipment.

Refrigeration equipment should be located in a cool and well-ventilated area to optimise its operation and reduce energy consumption. Remote condensation can also reduce energy consumption of refrigeration systems due to potentially lower ambient temperature at remote locations. Manufacturers recommend that plug-in equipment should be located in well-ventilated areas (with air-conditioning) to provide good ventilation (air flow) for the condenser coils and fans.

Avoiding direct sunlight, dusty areas (see §3.6.1.), and locations near heated units results in higher energy efficiency of refrigeration products, as does providing good ventilation.

3.4.2. Assembly and installation

Assembly and site installation can have a significant impact, particularly for remote product types and field-erected products such as walk-in cold rooms. If these products are installed in a sub-standard manner, the insulation housing may be poorly joined (leading to refrigerant leaks) or have reduced durability and a shorter lifetime. In the case of pumps, the performance of a water pumping system can be decreased by 28% to 56% due to poor installation[5].

Good installation is also crucial to avoid refrigerant leaks, when constructing the piping for the refrigerant circuit.

Stakeholders[6] have mentioned the importance of proper installation for chillers, due to which energy efficiency can vary from 50% to 85% (depending on the auxiliary equipment required by these machines), e.g.:

- Piping, which can reduce or increase pressure drops;
- pumps;
- heat exchangers (cooling towers or air coolers);
- water treatment plants, to avoid corrosion, biological contamination or biofilm formation.

Other stakeholder feedback has suggested that effective fine-tuning of a process chiller to its refrigeration system, and proper selection of water temperature, can save as much as 30% of energy consumed by better management of pumps and chiller operation at partial load. However, these gains depend on the operation conditions.

By setting the parameters of the system to match the actual load of the equipment, it will perform at its best efficiency. The different elements are not over- or sub-loaded, therefore no waste energy is produced.

Effective fine-tuning of refrigeration systems and controls could provide savings for other product groups.

[5] M. Merchat, *Mesure des performances énérgétique des systémes de refroidissement*, 2009

[6] Source: EUROVENT

3.5. PRODUCT USE

3.5.1. USAGE PATTERN

Little data is available in the literature on estimates of the typical usage patterns of products, however first estimates have been made and are described in Table 3-3.

Commercial refrigeration appliances such as professional service cabinets are typically used 24 hours a day, without interruption, even during the weekends. However, more specific products have more complex usage patterns, which will need to be further investigated.

Blast cabinets are used for batch chilling, and are activated only when they are required. The use patterns suggested by stakeholders are presented in Table 3-2. The use of these units will depend on the type of business in which they are installed. For example, a catering operation with a large customer base may use the equipment regularly for the high volume of food processed, while a restaurant may use the equipment only at meal-times and hence less frequently. The final use pattern is an average of these (Table 3-3). Stakeholders commented that although the products are often able to both chill and freeze, the freezing function is rarely used.

Process chillers used in the industry run only half of the day (see Table 3-3). However, process chillers used in food storage are meant to run 24 hours per day. It is estimated that process industrial chillers are more representative of the market, but no accurate data have been found regarding the proportion.

Table 3-2: Estimated blast cabinet use according to stakeholders

Stakeholder	Type of cycle[1]	Cycles per day	Days per year	Hours per year
1	Chilling	4-6	208	1,560
2	Chilling	3	180	810
	Freezing	2	180	1,440
3	Chilling	5	275	2,063
	Freezing	2	275	2,200
4	Chilling	2	-	
	Freezing	1	-	
5	Chilling	2	255	765
	Freezing	2	255	2,040
Agreement during stakeholder meeting[2]	Chilling	2	220	660
	Freezing	1	220	880
	Combined	1:1	220	1,210

[1]Chilling cycle = 90min, freezing cycle = 240min
[2]25th/10/2010. Brussels. Re-consulted with stakeholders absent from the meeting

Table 3-3: Usage pattern for ENTR Lot 1 equipment

Equipment	Source	
	UK Defra MTP[7] (h/year)	Estimate used (h/year)
Service cabinets	8,760	8,760
Blast cabinets	*N.A.*	Chilling models: 660 (two 90-minute chilling cycles per day, 220 days per year, an estimate based on stakeholder feedback)* Freezing models: 880 (one 240-minute freezing cycle per day, 220 days per year)* Chilling/freezing: 1,210 (one 90-minute chilling cycles plus one 240-minute freezing cycle per day, 220 days per year)*
Walk-in cold rooms	4,927.5	8,760
Industrial process chillers	4,380	4,380
Remote condensing units	*N.A.*	The use of the condensing unit depends on the product it is connected to, hence could vary from 1,650 for a blast cabinet to 8,760 for a walk-in cold room). The industry standard for the duty cycle is 16h/day, according to information provided by stakeholders. This means 5,840h/year.

N.A. : Not available at this stage
** Estimated average*

3.5.2. Loading efficiency

Commercial refrigeration appliances designed to store and cool foodstuff items, i.e. service cabinets, walk-in cold rooms, and blast cabinets, are affected by load efficiency. Good management of refrigeration needs can reduce the amount of cooling space needed. In the food distribution business, proper identification of requirements can enable less refrigeration. For example, one service cabinet with proper and full stocking is more efficient than two which are half-full.

3.5.2.1 Overloading

Most end-users fill their appliances with too much foodstuff, despite the "load limit" indications on the cabinets/storage rooms (load limit shows the maximum filling of the cabinet). In the case of service cabinets, blast cabinets, and walk-in cold rooms, overloaded refrigerated spaces decrease product quality and increase energy use by 10% to 20% per unit[8], by disturbing the internal air flow.

Bigger supermarkets and restaurants usually adhere to loading prescriptions more rigorously, due to stricter control from national health departments. Overloading is typically observed more frequently in small convenience stores/small users.

[7] UK Defra statistics available at whatif.mtprog.com
[8] Sacramento Utility District - www.smud.org/en/business/saving-energy/Pages/conservation-tips.aspx

Load limit indications on the cabinet/storage rooms (load limit shows the maximum filling of the cabinet/storage rooms) need to be clearly visible and understandable by the end-user. Additionally, users should be aware of the manufacturer's recommendations for shelf positions and sizes, to prevent increased refrigeration loads.

In the case of process chillers, users should be fully aware of the cooling capacity of the appliance, so as to choose the appropriate size to fit their cooling needs.

3.5.2.2 Foodstuff temperature

Foodstuff temperature, or water inlet temperature, is relevant to service cabinets, blast cabinets, walk-in cold rooms and process chillers. Please see Task 1 for a description of relevant national food hygiene regulation and HACCP.

The temperature of foodstuffs should be kept low when placed in the refrigeration equipment, as refrigeration products are designed to store foodstuffs at a low temperature and not to pull down warm temperatures. Pulling down the temperature of foodstuffs from the ambient temperature to the refrigerated temperature increases the energy demand. Blast cabinets are specifically designed to cool down products (but can also maintain the foodstuff at a low temperature if required), and energy savings are achievable through leaving foodstuff to cool in ambient air before loading into the blast cabinet.

Ambient pre-cooling is an option in those countries where the legislation allows this procedure. This step could be considered for blast and service cabinets in order to decrease the energy consumption of the equipment. However, this must agree with existing food safety legislation parameters.

Temperature at the time of loading into refrigeration equipment can also be an issue with non-perishable items, such as drinks, which are loaded at ambient temperature and therefore a significant increase in energy consumption is required to pull down their temperature. Users should be informed that storing goods in hot areas (e.g. in direct sunlight) should be avoided before they are loaded in refrigeration equipment, and that storing goods in a cool area and then loading the products could save energy. Pre-cooled products should be transferred as quickly as possible from one refrigerated area to another, to prevent their temperature from rising.

3.5.2.3 Loading duration/frequencies

The time taken to load the foodstuff, during which a refrigeration product’s door(s) is (are) left open, allows heat infiltration from the ambient warm air, and this can influence the energy consumption of refrigeration equipment. Service cabinets and walk-in cold rooms are subject to heavy usage; doors are opened hundreds of times during a day[9] which increases the heat infiltration. Information to raise awareness on the energy losses due to excessive door openings should be provided.

3.5.2.4 Abnormal use of blast cabinets

It has been mentioned by stakeholders that some blast equipment is used for steady-state cold storage, after the blast cycle (i.e. as a service cabinet). Although it can be used in this way, blast equipment is not meant to hold the foodstuffs for long periods of time. As blast cabinets are designed to rapidly cool hot food, the powerful refrigeration system is

9 Deneen, Michael A.,Gross, Andrew C. *The global commercial refrigeration equipment market*. (Focus on Industries and Markets). 2002

unsuited to the low demands of maintaining food temperature. Therefore this type of use has high energy consumption. No further information about the frequency of this type of behaviour has been found.

In addition, some chiller/freezer products do not include defrost systems, as they are thought to never be required to freeze product during “typical” use (this is according to manufacturers’ market research). When electric defrost systems are included, they are normally manually activated. Build-up of ice can increase energy consumption during use through reduction of heat transfer across the evaporator.

3.6. PRODUCT DESIGN AND SYSTEM CONTROLS

Other use characteristics can also influence the energy consumption of refrigeration equipment.

3.6.1. LOCATION OF EVAPORATOR AND CONDENSING UNIT

The location of the evaporator and condenser can affect ease of cleaning. For example, condenser heat exchangers can be more easily accessed and cleaned if located at the top of a service cabinet (please see § 3.7.1. and 3.7.2.). The location of the condenser is also important for system performance – poor quality of air flowing around it can lead to build-up of dust or grease, which reduces its heat transfer capacity.

3.6.2. TEMPERATURE SETTINGS

For refrigeration equipment designed for storage of foodstuffs, two levels of temperature exist: medium temperature (MT) (-2°C to +2°C), for preservation of fresh food, and low temperature (LT) (-18°C to -25°C) for preservation of frozen food.

Differences between the recommended temperature (fixed by food and safety regulations) and the actual working temperatures can sometimes be observed. For refrigerated cabinets, it is estimated that every degree below the required temperature increases the appliance’s energy consumption by 2% to 3%[10].

These differences can occur when the cabinet thermostat is set to food safety temperature values and not to manufacturer’s recommended values, due to the position of the control temperature probes inside the service cabinet. The displayed working temperature of the cabinet (thermometer) can be slightly different from the real temperature inside the refrigerated volume of the cabinet (higher or lower depending on the probe position).

Unnecessarily low temperatures waste energy and do not provide any benefits. For maximum energy savings, temperatures should be set and kept at the maximum authorised temperature. As temperatures are often set lower than necessary a regular check of the temperatures could help to reduce energy consumption.

In this situation, manufacturers should give the right information regarding the correlation between the displayed temperature (set by the thermostat) and the real cabinet working temperature.

[10] Government of South Australia - Energy SA Advisory Service

A possible measure to avoid this might be to require all products to provide straightforward and accurate display of internal temperature, and allow its control, to avoid confusion.

3.6.3. LIGHTING CONTROL

Use of lower wattage light bulbs helps in reducing the amount of heat released and thus saving equivalent refrigeration energy. Switching off lights when unnecessary (e.g. during lunch hours) may result in overall reduction of energy consumption.

Lights bulbs are not normally used in blast cabinets, but are used in service cabinets and walk-in cold rooms.

3.6.4. ANTI-SWEAT HEATERS AND HEATING COILS CONTROL

Anti-sweat heaters and heating coils ensure that no condensation occurs and are often used in appliances with doors, such as service cabinets and in walk-in cold rooms (either remote or plug-in), to reduce condensation around the door seals. They commonly stay on at full load for 24 hours a day, and the heat generated by these components adds to the required cooling load. They are typically used 24 hours per day in low temperature cabinets (frozen) and 12 hours a day in chilled refrigeration equipment[11].

The use of anti-sweat heaters can be controlled by switches responding to local dew point or humidity conditions. Appropriately placed sensors can measure the dew point and allow the heater to switch off when not required. For example, energy savings can be achieved by reducing the use of such heaters when the ambient air is colder and has a lower humidity.

Heating coils could also be replaced by a hot gas line running from the compressor to the door frame (for plug-in products only).

3.7. MAINTENANCE AND REPAIR PRACTICES

The objective of this section is to describe user behaviour in relation to the use phase, covering real-life maintenance and repair practices.

No information has been found to describe typical EU practices in terms of product repair.

Regular basic maintenance on refrigeration equipment, which should be carried out approximately twice a year, includes the following practices[12]:

- cleaning the evaporator;
- cleaning the condenser;
- checking the compressor;
- maintaining the door/compartments seals;
- cleaning and sanitising equipment.

[11] Arthur D. Little, Inc., *Energy Savings Potential for Commercial Refrigeration Equipment Final Report*, Building Equipment Division Office of Building Technologies U.S. Department of Energy, June 1996. www.eere.energy.gov/buildings/info/documents/pdfs/comm_refridg_equip.pdf

[12] Mitchell, N. Annual Systems Inspections Reduce Electric Energy Consumption. *ASERCOM Symposium*, Nuremburg. 2000

These practices do not apply across all refrigeration equipment covered in ENTR Lot 1.Table 3-4

Table 3-4 identifies the correspondence between appliances and their maintenance practices.

Table 3-4: Different basic maintenance practices across ENTR Lot 1 products

	Maintenance practice	Service cabinets	Blast cabinets	Walk-in cold rooms	Industrial process chillers	Remote condensing units
Energy efficiency issues	Evaporator cleaning	x	x	x	x	
	Condenser cleaning (for appliances incorporating a condenser only)	x	x	x	x	x
	Maintaining door/compartments seals	x	x	x		
	Compressor check (for plug-in appliances only)	x	x	x	x	x
Health issues	Cleaning and sanitising equipment (once a month)	x	x	x		

The different maintenance practices and their impacts on the product performance are described below.

3.7.1. EVAPORATOR CLEANING

Cleaning the evaporator coils every month and keeping them unobstructed can improve energy efficiency. Blocking or partial blocking of the fin coils and oil logging (oil escaping from the compressor) will reduce the evaporator temperature, which reduces the cooling capacity. The desired cooling temperature might therefore not be reached.

Specially formulated cleaning solutions are available to clean the specific sediment that can collect over time in evaporators. Cleaning the evaporator annually can prevent the sediment from building up, and increase energy efficiency. However, cleaning the evaporator requires the power to be shut off and the drain tube to be disconnected. The bottom pan of the evaporator coil can then be unscrewed and removed, and the components accessed for cleaning.

3.7.2. CONDENSER CLEANING

The cleanliness of the surface of the air-cooled condenser is very important. If condenser coils get too dirty, the compressor discharge pressures can get high enough to make the compressor cycle off under the action of the high pressure cut-out switch in a short period of time. A regular check on this component can prevent reaching high discharge pressures, resulting in higher efficiency.

In the case of an air-cooled condenser, even if the condenser is located in a ventilated area, if the air cannot directly contact the heat transfer surface because of dust and dirt (see **Figure 3-1**) the condensing temperature will rise. Keeping the condenser coils clean will help reduce the electricity consumption. For example, in the case of beverage merchandisers, manufacturers recommend that the condenser should be cleaned at least twice a year.

A case study[13] in the UK showed that electricity savings of as much as 8% could be achieved for a top-mounted plug-in vertical freezer service cabinet, located in a canteen, just by cleaning the condenser.

Figure 3-1: Top-mounted condenser on plug-in service cabinet before/after cleaning[13]

In the case of water cooled condensers[14], the condenser should be checked in case of corrosion and scale formation. Tube scaling and fouling can be monitored by logging pressure drops across the condenser bundles.

Cleaning the condenser fan blades also ensures increased energy efficiency.

3.7.3. MAINTAINING DOOR/COMPARTMENT SEALS

Regular checks to verify that the door seals are providing sufficient insulation can also result in energy savings, by preventing heat leakages. In busy situations gaskets are prone to damage. They should be checked on a regular basis and replaced when needed.

3.7.4. COMPRESSOR CHECK

Compressor maintenance includes the following practices:

- vibration analysis;
- checking all alignments to specifications;
- checking all seals;
- checking the oil system (oil and filter);
- checking all strainers, valves, etc.

3.7.5. CLEANING AND SANITISING THE EQUIPMENT

In the case of ice-makers, the ice produced is consumed by customers; therefore the ice-maker is considered a food contact surface area. Following manufacturer's instructions, the appliance should be cleaned and sanitised at least once a month. Cleaning will remove scale/lime build-up and other mineral deposits and sanitising will remove harmful

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13 Mark J. Swain . *Energy use in the catering sector, Case study – Refrigeration at the Langford canteen.* University of Bristol. 2009 www.frperc.bris.ac.uk/defraenergy/docs/catr-casestudy.pdf

14 FEMP 2004. O&M Best Practices Guide 2.0., FEMP 2002. Continuous Commissioning Guidebook for Federal Energy Managers.

bacteria, algae and slime growth. This also applies for other appliances which have a direct food contact area (dessert and beverage machines, and water dispensers).

Service cabinets, walk-in cold rooms and blast cabinets do not come directly in contact with foodstuffs, but also need to be regularly sanitised and cleaned. In service cabinets and blast cabinets, the condensate drain lines can be blocked by spillages and debris (resulting from defrost operations), causing leaks and generating a possible health risks. Indeed, the drains and condensate trays are a breeding ground for bacteria which can multiply at a very fast rate. Correct condensate tray and drain sanitisation and regular cleaning will initially remove the bacterial growth[15].

Hygiene in walk-in cold rooms is important, particularly if dealing with fresh meat and produce, as fatty deposits from foodstuff can contaminate and restrict the airflow. Regular sanitisation with a food-safe sanitiser will break down and remove fatty deposits stuck on evaporator fins, and ensure that hygiene levels are maintained. Walk-in cold room walls, floors, ceilings and internal shelves also require cleaning and sanitising.

3.7.6. Refrigerant leaks prevention and correction

Refrigerant leaks have been reduced slightly in the last years, due to the refrigerant charge reduction, according to information received from stakeholders, but the average annual leakage rate is around 10%. In remote systems, where professional installation and pipes connections are needed, this leakage is higher than in plug-in applications.

These refrigerant leakages directly affect the efficiency of the product and the environmental impact, when the refrigerant's GWP or other environmental impacts are not negligible. Indirectly, the energy efficiency also affects the total environmental impact of the product throughout its life cycle.

There are some voluntary agreements in the industry regarding refrigerant leakage prevention, i.e. the UK Institute of Refrigeration (IOR) published a revised "Minimisation of refrigerant emissions code"[16] in 2009. This covers all the commonly used refrigerants and gives recommendations regarding F-gas and ODS regulations.

3.7.7. Additional maintenance practices

Additional maintenance practices[17] that are recommended to be performed at least twice a year include:

- verifying the electrical connections (insulation, tightness of electrical connections, fuse check, electrical contacts, etc.);
- checking the defrost, or anti-sweat, system (control and heaters);
- checking any water pipes and waste water pipes for leaks; and
- oiling accessible moving parts such as door hinges.

[15] Myddleton Maintenance Services Ltd
[16] IOR, Minimisation of Refrigerant Emissions Code. 2009
[17] APEX Commercial Refrigeration & Air Conditioning Ltd.

3.8. PRODUCT LIFE

3.8.1. ECONOMIC PRODUCT LIFE

The economic product life, in the case of refrigeration products, is assumed to be less than the technical life. Hence in real-life, a product may be replaced for cost, hygiene or aesthetic reasons, even if the technical components continue to function properly.

Section 2.3.4 in Task 2 provides preliminary average economic product life estimates which will be used in LCC calculation during Tasks 4 and 6.

3.8.2. END-OF-LIFE BEHAVIOUR

Commercial refrigeration equipment is often replaced for either economic, aesthetic or hygiene reasons, even though it is still operational.

There are three main routes for end-of-life:

- selling the product on the second-hand market;
- sending the product to the manufacturer for proper recycling and disposal; sending the product to a specialist plant for recycling and use of scrap metals.

In EU refrigeration equipment recycling facilities, less than 1% of the appliances are commercial equipment. Most of the commercial refrigeration equipment is therefore refurbished and introduced into the second-hand market. The used equipment is generally sold in East and Central Europe or in African/Asian countries.[18]

Other practices also exist. For example, when the equipment is not suitable for second hand use, some retailers sell the old equipment to scrap metal dealers. Valuable materials such as copper, aluminium and steel are then recovered.

3.8.2.1 Service cabinets

Professional service cabinets fall under the WEEE Directive, and due to their small size they can be disposed of within the domestic refrigeration waste stream. However, compliance with this may vary greatly depending on in which Member State the manufacturers are located[19]. It is estimated that over the life of the product, 100% of its refrigerants will be released to the atmosphere[20].

Best practice for recycling would include[21]:

- **Arrival of Product & Inspection**.
- **Removal of parts, shelving, castors and microprocessor** – Parts removed sent to re-processors. All re-processors are licensed by the Environment Agency as Treatment Facilities.
- **Refrigeration system de-gassed and oil removed into separators** – Refrigerant gas placed in pressurised containers. High temperature incineration converts it to harmless salts. Compressor oil is reclaimed & sent to 'Energy from Waste' (EfW) – a process which recovers energy from waste materials in a controlled and

[18] Stakeholder feedback
[19] Source: Gram, ECOS
[20] Source : ECOS
[21] As provided by Foster Refrigerator

regulated environment. This is supplied to the National Grid to support 'Green electricity'.

- **Removal of compressor** – Empty compressors sent to re-processing metal plants.
- **Remainder of product crushed.**
- **Crushed products placed in sealed chamber filled with Nitrogen Gas** – The product is then shredded into small pieces.
- **A magnetic separator collects all the ferrous metal.**
- **An eddy current separator collects all the non ferrous metals.**
- **Polyurethane foam is treated with heat and mechanical pressure is applied to release more CFC/HCFC gas** – Gas is removed and rapidly cooled in liquid nitrogen. This turns the removed gas into a liquid. It is stored in pressurised containers and re-processed. Foam pellets are produced & recycled for plastic plate manufacture, oil spill absorbents or used in Energy from Waste (EfW).
- **Plastic separated out and sent to re-processor** – Plastic is recycled into horticultural products.

3.8.2.2 Blast cabinets

Blast cabinets should comply with the WEEE Directive. This equipment should be dismantled by specialist companies. Blast cabinet manufacturers recommend taking the following measures at the end-of-life:

- not disposing of the equipment directly into the environment; removing doors and locking systems, in order to avoid potential accidents;
- roughly dismantling the appliance by taking away wiring, and any removable parts;
- recycling oil and refrigerant;
- delivering the equipment to specialised collection and destruction centres.

It has been mentioned by stakeholders that a large share of the machines manufactured in the EU is sold outside the EU.

3.8.2.3 Walk-in cold rooms

Little information is available on the end-of-life practices for walk-in cold rooms. Stakeholders have stated that smaller products using packaged refrigeration systems are likely to be disposed of without treatment. Therefore, refrigerant charges are thought to be disposed of at the end-of-life. Larger systems with larger charges are thought to have a proportion of their charge recovered, due to its value and greater perceived consequences of its release[22]. On average, assuming that there is annual leakage and refilling of the charge, it is estimated that over the life of the product more than 100% of its original refrigerant charge will be released to the atmosphere[23].

It is thought that the panels and other enclosure components are disposed of, given that the insulation will degrade over life, and that the system and other electronic components

[22] Source: ECOS, GR Scott
[23] Source : ECOS

are either refurbished for resale or recycled for scrap metals. Some insulation panels are constructed to allow disassembly and reassembly for re-use[24].

In addition, well-preserved cold rooms can be sold second-hand, but remote condensing units need to be in very good, “current” condition to be re-sold after first use.

3.8.2.4 Process chillers

According to stakeholders (Daikin, Trane, 2010), chillers are almost 100% recycled at the end-of-life, due to the large amount of valuable metal that they contain. Only the electronic parts are wasted, representing about 0.1% of the total weight of the appliance. Some comments have indicated that the price of a 4MW process chiller to be sold at the end-of-life can reach between € 5,000 and € 10,000. Due to the large amount of materials within these units, they are not likely to be dumped without proper treatment and refrigerant recovery. However, opinions regarding this point are not consistent; the proportion of refrigerant disposed of at the end-of-life ranges from 10 to 80%[25]. An average of 50% is being considered for this value.

3.8.2.5 Remote condensing units

It is assumed that remote condensing units are either refurbished for resale or recycled for scrap metals. The greater part of remote condensing units is usually recyclable (metals, plastics), and waste treatment facilities sell the mixture of copper and aluminium to motor manufacturers.

During correct end-of-life management, the refrigerant is reclaimed and the rest of the product is shredded, separating the different materials for recycling by air-vacuuming and magnets. Approximately 70% of the content is ferrous metals, with the rest being non-ferrous metals, plastics and others.

However, estimations of real practices regarding the reclamation of refrigerants at the end-of-life show that between 50% and 95% of the refrigerant charge is released to the atmosphere, depending on the country[26].

3.9. INFORMATION AVAILABLE FOR USERS

The objective of this section is to analyse whether providing users with information regarding the product’s sustainable use and ecological profile would have a significant positive environmental impact.

For example, information related to refrigeration appliances can have a significant impact on the equipment’s energy efficiency as **improving simple operational and maintenance practices can reduce energy consumption by 15 % or more**[27]. Strategies to reduce energy use and refrigerant leakages are described below.

Stakeholders have discussed how the initial capital cost of products is the main concern for end users. There is also a significant difference between the types of end user. Large corporate consumers of refrigeration equipment may have well organised maintenance

[24] Source: Smeva

[25] Source: ECOS

[26] Clodic et al. Global inventories of the worldwide fleets of refrigerating and air conditioning equipment in order to determine refrigerant emissions. The 1990 to 2006 updating.

[27] Australia Energy Smart Initiative - www.sedo.energy.wa.gov.au/uploads/comm_refrig_28.pdf

departments who are able to perform necessary tasks to ensure high product performance. However, many users are small and may not have the technical understanding of the products to be aware of the maintenance needs and impacts of poor maintenance. This also depends on the type of the product: products requiring installation (such as remote condensing units, compressor packs, industrial chillers, walk-in cold rooms) are bought by the contractor/installer and the end user does not decide on the energy efficiency of the machine, whereas small plug-in products can be directly purchased by the end user and a higher efficiency could be a driver in the purchase decision.

Energy labelling would therefore be beneficial to highlight the significant variability in products' energy consumption, particularly plug-in products that are sold directly to consumers (such as service and blast cabinets, and for small walk-in cold rooms) and the resulting life cycle cost.

For remote and more complex products, such as process chillers, larger (remote) walk-in cold rooms and remote condensing units, an energy label would be more challenging to implement and may be less effective. These products, often used for applications requiring more specific performance (i.e. process chillers), would either be sold to more knowledgeable users or a refrigeration contractor/installer who are aware of performance issues. Therefore, a high efficiency guarantee label (without necessarily covering energy consumption but ensuring use of high performance components) may be more appropriate for these products, to demonstrate to the end user that the product has been designed to be energy efficient.

User manuals should include information on best user and maintenance practices for all products, to maximise the potentially high energy savings that basic maintenance can allow. These alternative policy options will be further discussed in Task 7.

3.9.1. SERVICE CABINETS

Service cabinets are usually bought by end users and thus an energy labelling scheme or other energy information to the consumers could influence the purchase decision towards more efficient products.

Recommendations for energy efficient use to the end users in technical specifications brochures can also promote a more efficient use pattern, and in addition recommendations for best maintenance practices could improve product performance, resulting in lower energy consumption during the use phase of the product.

3.9.2. BLAST CABINETS

Blast cabinets are also usually bought by end users. An energy labelling scheme may be relevant, influencing purchasing decisions by differentiating products by energy efficiency.

Again, recommendations for energy efficient use and best maintenance could promote more efficient use patterns, resulting in lower energy consumption during the use phase of the product.

3.9.3. WALK-IN COLD ROOMS

A major concern for walk-in cold rooms is the proper installation of the room – however, this is usually carried out by a contractor. Best practice installation guidance for the product, or at industry level, may encourage improve installation quality, thereby reducing energy consumption – however, this would not be likely to be directed at the final end-user.

Open doorways are probably the biggest cause of concern regarding energy wastage. Training staff to close doors is paramount[28].

An energy labelling scheme for walk-in cold rooms is considered to be less practical than for other products, due to the variability of the products.

As for service and blast cabinets, recommendations in user manuals for best use and maintenance practice could result in lower energy consumption during the use phase of the product.

3.9.4. INDUSTRIAL PROCESS CHILLERS

Due to their complexity and variation in performance depending on location (ambient temperature) and application, it is considered impractical to establish an energy labelling scheme for chillers.

It may however be of benefit to provide end users with a standardised measure of performance (such as seasonal COP) to enable differentiation. In addition, recommendations to end users on best practice for use and maintenance of the chiller in order achieve best performance and efficiency could help to reduce energy consumption.

3.9.5. REMOTE CONDENSING UNITS

Remote condensing units are usually purchased by the contractor or installer, and the decision is usually driven by the initial cost more than by the energy performance of the product. When this kind of products is usually used in big stores, the savings associated to the performance of the product are negligible compared with the total energy consumption of the store.

Remote condensing units can be installed on different applications (walk-in cold rooms, display cabinets, etc) and thus the use pattern can be different depending on the system requirements. However, recommendations to end users on the correct adjust and maintenance of the condensing unit in order to get a correct performance and efficiency can help to achieve lower energy consumptions.

3.10. BENEFITS OF ECO-DESIGN AND ENERGY EFFICIENCY

3.10.1. EXISTING INITIATIVES

As seen in Task 1, in the EU there are very few energy efficiency programmes to promote efficient refrigeration appliances (apart from the UK Enhanced Capital Allowance scheme and Eurovent programme), and there are no incentives at the EU level to communicate the ecological profiles of commercial or industrial refrigeration products and the benefits of eco-design.

In the US, Energy Star[29] labels commercial refrigerators and freezers (i.e. service cabinets) that are more energy efficient (designed with components such as ECM evaporator and condenser fan motors, hot gas anti-sweat heaters, or high-efficiency compressors), and

[28] Source: Fermod

[29] US Energy Star www.energystar.gov

which will significantly reduce energy consumption and utility bills. Compared to standard models, Energy Star labelled commercial refrigerators and freezers can lead to energy savings of as much as 35% with a 1.3 year payback. Commercial ice machines that have earned the Energy Star are on average 15% more energy-efficient and 10% more water-efficient than standard models.

However, preliminary data on the improvement potential[30] through better design of the refrigeration equipment included in ENTR Lot 1 show that there could be room for product differentiation, based on product performance (in terms of electricity consumption).

The examples suggest that labelling efficient (eco-designed) products can communicate such advantages to consumers. However, in the EU, due to the absence of either voluntary or mandatory certification programmes to communicate on the performance of products, there is little incentive for manufacturers to improve their products. Section 3.10.2. further elaborates on the possible barriers for eco-design and take-up of more efficient products regarding environmental impacts.

3.10.2. POSSIBLE BARRIERS TO ECO-DESIGN

3.10.2.1 Lack of standard test procedures

One major barrier to the implementation of eco-design measures is the current lack of standard procedures to measure the energy use for certain product categories (see Task 1). Without harmonised standards, it is difficult to accurately compare and monitor the energy performance of different refrigerating equipment produced by different manufacturers. Furthermore, without the confidence in the data that harmonised standards provide, it is difficult to make energy efficiency incentives, schemes or policies a reality.

3.10.2.2 Focus on capital cost

Purchase decisions for refrigeration equipment are generally not made on life cycle cost (LCC) or payback considerations. Equipment buyers (small end-users, medium end-users or large supermarkets) normally select the equipment that meets specifications at the lowest capital (upfront) cost.

For medium-sized end-users and large supermarkets, the individuals in charge of selecting the equipment do not focus on energy efficiency as a choice criterion because they are generally not in charge of operating it, nor paying the final electricity bill. Additionally, instead of energy performance, end-users tend to focus on design, size, and additional functions at the time of purchase. The main reason for this is that end users are often unaware of how significant the difference in life cycle cost can be.[31]

3.10.2.3 Lack of financial initiatives

The UK ECA is the only programme identified which provides financial incentives for investment in energy-efficient commercial refrigeration equipment in EU.

[30] See BIO Intelligence Service. *ENTR Lot 1 - Working Document on Task 1, published on 04/05/2009*. 2009. www.ecofreezercom.org

[31] T. Kubo and S.Nadel. Commercial Packaged Refrigeration: An Untapped Lode for Energy Efficiency. Report for the American Council for an Energy Efficient Economy. 2002

In the UK, end users can benefit from tax concessions when they choose to buy energy-efficient products. The full list of complying products is available online[32]. Among the products included in ENTR Lot 1, the ECA covers packaged chillers and professional service cabinets.

Compared with the energy thresholds presented by ECA and other MEPS, e.g. in the US or Canada, the ECA is less demanding.

3.10.2.4 Significance of energy costs relative to overall operating costs

Energy costs may be small compared to other operating costs (e.g. wages and other expenditures). This could increase the tendency to disregard energy efficiency when evaluating ("sales-boosting") design changes which can decrease initial capital cost of the equipment.

3.10.2.5 Preference for stabilised technologies[33]

Technologies diverging from current practice take time to grow into a significant portion of the market. Indeed, the switch to natural refrigerants for remote equipment requires that technicians know how to install and operate refrigeration systems with these "new" refrigerants. Therefore, training of technicians is a preliminary requirement (and expense) before the roll-out of these "new" refrigerants.

3.10.2.6 Design limitations

For service cabinets, blast cabinets, and walk-in cold rooms, an increase of the insulation thickness is undesirable. This would result in a decrease in storage volume, which would reduce sales capacity of a given unit. Hence this route to increasing energy efficiency of products is often undesirable.

3.10.2.7 Limited information

End users are often not aware of the differences in energy efficiency between competing products (potentially as a result of a lack of energy efficiency labels to differentiate the products). Some end users also lack information on the costs of operating their equipment. There is thus a lack of information available to end users to enable confident and accurate assessment of the available technology options and related energy saving potentials.

New equipment is often purchased only when old equipment fails, and there is no time to analyse in detail the purchase options (a particular issue for small end users). This can add to the difficulties of making an informed purchasing decision.

3.10.2.8 Lack of trained technicians

State-of-the-art systems require newly trained technicians to operate the equipment. Stakeholders estimate that there are not enough hydrocarbons and CO_2 trained technicians to supply maintenance or installation for a large number of systems like this.

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[32] www.eca.gov.uk/

[33] BIO Intelligence Service. *Eco-design Preparatory Study Lot 12. Final Report prepared for DG TREN*. 2007 – www.ecofreezercom.org

3.11. CONCLUSIONS

User behaviour has a significant impact on electricity consumption and environmental performance, of commercial refrigeration equipment. Improving simple operational and maintenance practices could provide significant energy savings (within a 15% range). Reducing heat loads, refrigerant leaks, ensuring good practice in installation, use and maintenance are all important in achieving reduced energy consumption and environmental benefits.

End-user barriers to eco-design have been identified and include lack of user information, cost being the main focus, and lack of financial incentives. These will need to be taken into account when focusing on improvement potential (Task 6).

The user patterns identified for the product groups in this task are an important input for analysis of the products in Task 4. For service cabinets and walk-in cold rooms, the use pattern is constant (24 hours per day), in that the products are constantly providing cooling for storage, The almost constant use of remote condensing units (approximately 16 hours per day) reflects the product group's predominant use for remote refrigerated storage. Blast cabinets are used in a different way, for pre-determined cycles to pull-down foodstuff temperature (estimates of use range from 810 to 2,200 hours per day). Chillers are used intermittently, at an estimated average of 12 hours per day, during industrial and commercial processes.

Barriers to eco-design related to the end user have been identified and will need to be taken into account when focusing on improvement potential (Task 6). They include lack of standardised testing, lack of financial incentives and market preference for trusted and reliable technologies over new developments.

Some recommendations to improve energy efficiency of products from sustainable consumer behaviour include:

- testing standard to be finalised or adapted for service cabinets, process chillers and remote condensing units and developed for walk-in cold rooms and blast cabinets; these need to replicate real user behaviour as closely as possible (e.g. door openings, loading pattern, ambient conditions);
- good practice schemes or legislation regarding assembly and site installation of walk-in cold rooms, to avoid sub-standard, inefficient 'shells', and remote condensing units, to minimise refrigerant leakage;
- to avoid user confusion, manufacturers must provide straightforward and accurate display of internal temperature, and a temperature control mechanism, in all products;
- load limit indications on the cabinet/storage rooms (load limit shows the maximum filling of the cabinet/storage rooms) need to be clearly visible and understandable by the end-user;
- user manuals should include information on best installation, user and maintenance practices.

ANNEXES

Annex 3-1: Refrigeration in the medical sector

The demands made on refrigeration equipment are particularly high in medical environments, where the long-term, trouble-free operation of equipment needs to be assured. As such, the most stringent reliability and safety standards apply to appliances used in both laboratories and the medical sector. These refrigerators (and freezers) allow hospitals, pharmacies and universities to store temperature-sensitive pharmaceuticals under optimal conditions.

Refrigerating appliances for medical applications are in the scope of World Health Organisation (WHO) specifications. WHO performance specifications exist for the following categories of equipment: cold rooms, freezer rooms and related equipment, as well as refrigerators and freezers. Since 1979, WHO in collaboration with UNICEF Supply Division, have developed and maintained a series of performance specifications and test procedures for cold chain equipment, injection devices, and other immunisation-related products, under the PQS system (Performance, Quality, Safety).

The refrigerators and freezers in the medical sector are mainly used to store blood (Blood Bank Refrigerators), vaccines, chemicals and organs. They operate at a wide range of temperatures, from -120°C to +22°C. They are also much more sensitive to temperature changes. The inner temperature measurement resolution is around +0.1°C. Additionally, mobile refrigerators exist for safe transportation of temperature sensitive chemicals, vaccines, blood and its components.