Carbon footprint analysis of SV faculty refrigeration equipment

Refrigerators and freezers:
What reduction potential?

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Abstract

The electricity consumption of laboratories plays a significant role in their climate footprint and therefore is key to the sustainability strategy of the School of Life Sciences (SV) at EPFL. Among the main contributors are the refrigeration equipment at +4°C, -20°C and -80°C, accounting for more than 1000 pieces within the Faculty. This study is therefore being conducted by the School's sustainability office in order to better map the climate impact of this category of equipment and to draw concrete recommendations for reducing CO_2 emissions.

This report presents a possible categorization for a fleet of refrigeration equipment, a carbon accounting method based on a previous LCA as well as possible actions for the sustainable management of such a fleet. The study quantifies a total climate impact of the equipment of 219 tons of CO_2 equivalent (tCO_2.eq) per year within the School. Observations of lifecycle emissions coupled with economic considerations lead to the interpretation that the replacement of -80°C freezers can be justified after 15 years. In addition, a sensitivity analysis identifies significant potential gains for each degree increase in setpoint temperature or for each degree decrease in room temperature. Finally, larger equipment models are more efficient per useful volume than smaller ones, thus it is recommended that they be favoured while sharing storage space to avoid over-equipping the faculty with refrigerants.

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1. Introduction

The activities of the Faculty of Life Sciences (SV) require the refrigerated storage of many products.
More than 1000 refrigeration equipment intended for the conservation of biological or other products intended for research are installed in the SV faculty.

Their energy consumption represents a significant part of the laboratories' electricity consumption.
A previous study conducted by the Zero Emission Group revealed that for most laboratories it represents nearly a quarter of the electricity consumption.

Therefore, a study to identify the emissions from refrigeration equipment appears relevant.

2. Purpose of the study

Only the following storage equipment are considered in this analysis:

- Storage equipment at +4°C
- Storage equipment at -20°C
- Storage equipment at -80°C

Cryogenic equipment (-180°C) and any other equipment with a refrigeration system not intended for storage are not included in this study (ice machines, refrigerated incubators, etc.).

List of equipment considered

A precise inventory database of all refrigeration equipment was not available, so the identification of equipment was done by visiting the laboratories in December 2020.
A systematic survey of each equipment model was impossible due to the inaccessibility of the nameplates on many appliances.

It was therefore decided to make an inventory by families and categories of equipment that have similar CO_2 emission characteristics, mainly the type of equipment, their consumption, their generation, and their refrigerants.

<u>Four categories of refrigeration equipment have been identified:</u>

Families			
	 		
+ 4°C fridges and + 4°C/- 20°C combined fridges	+ 4°C cold cabinets and cold rooms	- 20°C freezers	- 80°C freezers

For each family, two categories of equipment can be distinguished: commercial (household) appliances and professional appliances.

For each of these two categories, "commercial" and "professional", we will also distinguish between old appliances of more than 15 or 20 years, equipped with fluorinated or halogenated refrigerants (CFC, HCFC and HFC) and the new generations equipped with hydrocarbons (HC). The latter having a lower impact on the greenhouse effect and whose CO_2 emissions due to the refrigerant are negligible, are not considered in our calculations.

Commercial equipment (household)

It is household equipment for the general public and small businesses.

									
Small + 4 < 170 litres > approx. 15 years or non HC	Small + 4 < 170 litres < approx. 15 years HC	Large + 4 170 to 500 l > approx. 15 years or non HC	Large + 4 170 to 500 l < approx. 15 years HC	+ 4 / - 20 combined fridge < approx. 15 years HC	+ 4 / - 20 combined fridge > approx. 15 years or non HC	Small - 20 < 150 litres > approx. 15 years or non HC	Small - 20 < 150 litres < approx. 15 years HC	Large - 20 150 to 500 l > approx. 15 years or non HC	Large - 20 150 to 500 l < approx. 15 years HC

- *> approx. 15 years* and *< approx. 15 years*: the age of the equipment has been estimated according to the dates of installation (laboratories or buildings)
- HC: Hydrocarbons, green refrigerants, with low GWP 0 < GWP < 5
- Non-HC: CFC, HCFC et HFC, refrigerants with high GWP 1'430 < GWP < 13'396
- GWP: Global Warm up Potential (kg CO_2 eq/kg)
- Source: [High-GWP Refrigerants | California Air Resources Board]

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Professional equipment (laboratories)

These devices are intended for medium-sized businesses and laboratories in the medical or research fields. Contrary to commercial equipment, these devices usually have higher power and consumption levels. Their carbon emissions are therefore significantly higher.

Small + 4 < 170 litres > approx. 15 years or non HC	Small + 4 < 170 litres < approx. 15 years HC	Large + 4 170 to 500 litres > approx. 15 years R134a ou R404	Large + 4 170 to 500 l < approx. 15 years HC	+ 4 / -20 combined fridge < approx. 15 years HC	Refrigerated cabinet + 4 > 1000 litres	Cold room + 4 > 5 m3	Small - 20 < 150 litres < approx. 15 years HC	Large - 20 150 to 500 litres < approx. 15 years HC	Small - 80 < 150 litres HC	Large - 80 > > 400 litres > 10 years or non HC	Large - 80 > 400 litres eco or HC	Large - 80 > 400 litres eco or HC

Summary of family and category choices

Families			
+ 4°C fridges and + 4°C/- 20°C combined fridges	+ 4°C cold cabinets and cold rooms	- 20°C freezers	- 80°C freezers
			

	Categories			
Commercial	Small +4°C, < 170 litres, > 15 years or non HC	/	Small -20°C, < 150 litres, > 15 years or non HC	/
Commercial	Small +4°C, < 170 litres, < 15 years and HC	/	Small -20°C, < 150 litres, < 15 years and HC	/
Commercial	Large +4°C, < 170 litres, > 15 years or non HC	/	Large -20°C, 150 to 500 litres, > 15 years or non HC	/
Commercial	Large +4°C, < 170 litres, < 15 years and HC	/	Large -20°C, < 150 litres, < 15 years and HC	/
Commercial	Combined fridge +4°C and -20°C, > 15 years or non HC	/	/	/
Commercial	Combined fridge +4°C and -20°C, < 15 years and HC	/	/	/
Professional	Small +4°C, < 170 litres, > 15 years or non HC	Cold cabinet +4°C, > 15 years or non HC	Small -20°C, < 150 litres, > 15 years or non HC	/
Professional	Small +4°C, < 170 litres, < 15 years and HC	/	Small -20°C, < 150 litres, < 15 years and HC	Small -80°C, < 150 litres, < 15 years and HC
Professional	Large +4°C, < 170 litres, > 15 years or non HC	Cold room +4°C, > 15 years or non HC	Large -20°C, 150 to 500 litres, > 15 years or non HC	Large -80°C, > 400 litres, > 10 years or non HC
Professional	Large +4°C, < 170 litres, < 15 years and HC	/	Large -20°C, < 150 litres, < 15 years and HC	Large -80°C, > 400 litres, < 15 years and HC
Professional	Combined fridge +4°C and -20°C, > 15 years or non HC	/	/	/
Professional	Combined frige +4°C and -20°C, < 15 years and HC	/	/	Large -80°C, horizontal, > 400 litres, < 15 years and HC

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3. Objectives

The objectives of this analysis are the following:

1. Identify the equipment stock in the SV Faculty buildings.
2. Determine their electrical consumption.
3. Quantify the annual and full life cycle CO_2 footprint.
4. Evaluate the different areas of emission reduction potential.

The numerous models of equipment and their various operating conditions (setpoint temperature, ambient temperatures, door openings, etc.) considerably complicate the task of accurate calculations.

Therefore, we will only take average values based on the data provided by the manufacturers and completed by punctual measurements in our laboratories.
This analysis does not pretend to provide exact figures but to give us a representative picture of the situation in our Faculty.

4. Methods and baseline data

For each category the main characteristics related to their emissions have been identified or acknowledged according to the following sources:

4.1. Emissions : production – transportation

The accepted CO_2 emission value for production, transport and packaging (cradle-to-gate, or before the use phase) is as follows:

241 kg CO_2 eq for a refrigeration unit of **56 kg**

Source : Study from the University of Bologna whose method is itself taken from Ecoinvent.

The emissions of all equipment are calculated from this value. The emission values will be obtained by extrapolation according to the weight of each equipment. We assume that all equipment families are made of the same proportion of materials (steel, aluminium, copper, plastic, polyurethane foam, etc.). Therefore, the CO_2 emission value is considered linear with the weight of the equipment.

Note:
The University of Bologna's study only considers a refrigeration unit, without the insulation chamber, i.e. with an additional copper mass but without considering the polyurethane masses.
However, the emission calculations performed with Simapro for a refrigerator (refrigeration unit and insulation chamber) give us very similar overall results, despite the differences in polystyrene and copper masses.
We therefore consider that the assumption of extrapolation by mass of the results of the University of Bologna remains very close to reality and quite admissible.

4.2. Emissions : power consumption

-20°C and -80°C refrigerators and freezers
The values of electrical consumption of these devices correspond to the manufacturer's data increased by a coefficient of 1.3 for commercial devices and a coefficient of 1.5 for professional devices.
These coefficients are an average estimation which results from measurements made on several equipment of our Faculty.
Generally lower set point temperatures and higher ambient temperatures are the reasons for applying these coefficients.

Cold room and refrigerated cabinets
The power consumption of the cold rooms was measured on three of our installations, i.e. on rooms of 48 m^3, 37.5 m^3 and on a fixed refrigerated cabinet of 4.2 m^3. The weights were estimated according to new installations currently on the market.

Annual consumption values: (measured values EPFL VPO SE)

- 48 m^3 cold rooms: 6 units, annual consumption: 5'460 kWh/year
- 37.5 m^3 cold rooms: 4 units, annual consumption: 3'391 kWh/year

Average value/cold room calculated: 4'632 kWh/year
Average weight/cold room with furniture: 1'840 kg

Our cold rooms having different masses, these values are taken in proportion to their weight.

- Fixed cabinets: 26 units, 1'792 kWh/year (valeurs mesurées EPFL VPO SE)
- Mobile cabinets: 7 units, 3'000 kWh/year (average values provided by manufacturers)

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Average value/rack: 2'048 kWh/year

Average weight/cabinet with shelves: 380 kg

It should be noted that the annual electrical consumption values of the fixed cold rooms and refrigerated cabinets are significantly lower than the values found in the literature, due to the use of water condensers on these installations. The use of water from Lake Geneva allows to reach temperatures on the condensers of about 12°C and thus significantly increases the coefficients of performance (COP) of these refrigeration machines. Due to lack of data and by simplification, the energy used to transport the lake water is not considered in the calculations, we consider that it has little or no impact on the CO_2 emissions.

Electricity mix

The ratio between carbon emissions and kWh consumed varies according to the production systems of each country or region.

The CO_2 emission value per kWh accepted for EPFL is **181 gr CO_2/kWh**, (source OFEV 2018) corresponding to the Swiss electricity mix.

Other CO_2 emission values for comparison:

Fuel oil/Diesel	265	gr CO_2 eq/kWh
Gasoline	266	gr CO_2 eq/kWh
Natural gas	202	gr CO_2 eq/kWh

4.3. Emissions : refrigerants

4.3.1. HC Hydrocarbons

The identification of the equipment fleet has allowed us to establish that more than 90% of the small equipment, refrigerators and -20°C freezers are equipped with green refrigerants **(HC)** with a warming potential (GWP) lower than 5 kg CO_2 eq.

For these devices with a gas charge of less than 300g, the CO_2 emissions are very low in proportion to the other emissions and are therefore not considered in our calculations.

4.3.2. Halogenated and fluorinated refrigerants CFC, HCFC, HFC

-20°C old refrigerators and freezers

It is admitted an average gas charge of 100 g of R134a refrigerant for small appliances and 200 g of R134a refrigerant for large appliances which corresponds to the vast majority of these old equipment; the GWP R134a is **1'430 kg CO_2 eq/kg**.

We also admitted that only half of the quantities were considered because 50% of the refrigerant is recovered or recycled at the end of the appliance's life, so 50% of the refrigerant is unfortunately dissipated in the atmosphere.

For these devices, the CO_2 emission due to the refrigerant is therefore 50% from 100g to 1'430 kg CO_2 eq, i.e.: 71.5 kg CO_2 eq for small ones and 143 kg CO_2 eq for large ones.

Refrigerated cabinets

The average values considered are:

- Refrigerants: 1.46 kg of R404 (GWP 3900 kg CO_2 eq/kg)

For these less tight installations, we have allowed a loss of 10% per year (Study from the University of Bologna) of the initial charge, over the entire life of 30 years.
When the installation is finally decommissioned, it is assumed that the gas charge is fully recovered, and therefore does not generate refrigerant leaks at the end of the equipment's life.

For these devices, the CO_2 emission due to the refrigerant is therefore 10% of 1.46kg at 3'900 kg CO_2 eq/kg x 30 years, that is **17'082 kg CO_2 eq.**

Are considered in the category of refrigerated cabinets:

- Fixed cabinets installed (R404a) during the construction of the buildings, i.e. 26 units.
- The mobile cabinets (mainly R404a) of more than 1000 litres old generation, that is 7 units.

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Cold rooms

The average values considered are:

- Refrigerants: 3 kg per cold room (mainly R134a, GWP 1'430 kg CO_2 eq/kg)

For these installations, which are also less tight, we have assumed a loss of 10% per year of the initial charge, over the entire life of the equipment, i.e. 30 years.
As for the cabinets, at the time of the final decommissioning of the installation, it is assumed that the gas charge is entirely recovered, and thus does not generate additional emissions at the end of the equipment's life.
For these installations, the CO_2 emission due to the refrigerant is therefore 10% of 3 kg at 1'430 kg CO_2 eq/kg x 30 years, or **12'870 kg CO_2 eq**.

-80°C cold freezers

These appliances are equipped with two types of refrigerants (R404 and R508). Their average GWP (ratio-quantity) is 7'534. The quantity of refrigerants on these devices is 0.964 kg on average.
We also assume that a part is lost during usage (leakage) and another part during the end of life. As for the -20°C freezers and refrigerators, we have also admitted that only half of the quantities were considered because, once again, 50% of the refrigerant is recovered or recycled at the end of the appliance's life, so 50% of the refrigerant is unfortunately released into the atmosphere.

For these devices, the CO_2 emission due to the refrigerant over the life of the appliance is therefore 50% from 0.964 kg to 7'534 kg CO_2 eq/kg, i.e., **3'631 kg CO_2 eq**.

4.4. Emissions at the end of the equipment's life

- The accepted value is: **14 kg CO_2 eq** for a **56 kg** device.
  Source : Study from the University of Bologna

In this study, the end-of-life includes the recovery of the coolant, manual disassembly of the cooling unit, shredding, material separation, recycling of steel, aluminium and copper (with a rate of 37%, 32% and 22% respectively). 20% of the plastic and residues are incinerated, while 80% are sent to landfill.

To define the end-of-life emissions of each equipment, an extrapolation of this value (14 kg CO_2 eq) is applied according to the weight. The end-of-life CO_2 emission factor can therefore be defined as **0.25 kg CO_2 eq/kg equipment**.

4.5. References

References taken for our analysis:

Equipement	Weight	Production	Transportation packaging	Cradle to gate	Elimination EOL	Method/source
	Kg	Kg CO_2 eq	Kg CO_2 eq	Kg CO_2 eq	Kg CO_2 eq	
Refrigeration system Refrigeration unit only	**56**	**232**	**9**	**241**	**14**	Study from the University of Bologna

Other references for comparison:

Equipement	Weight	Production	Transportation packaging	Cradle to gate	Elimination EOL	Method/source
	Kg	Kg CO_2 éq	Kg CO_2 éq	Kg CO_2 éq	Kg CO_2 éq	
Refrigerator 250 liters	54	-	-	237	-	ADEME - Site Bilans GES
Refrigerator	60	228	-	-	-	Simapro Impact 2002+ V2.15 ecoinvent

Other reference consulted:

Study from the University of Michigan

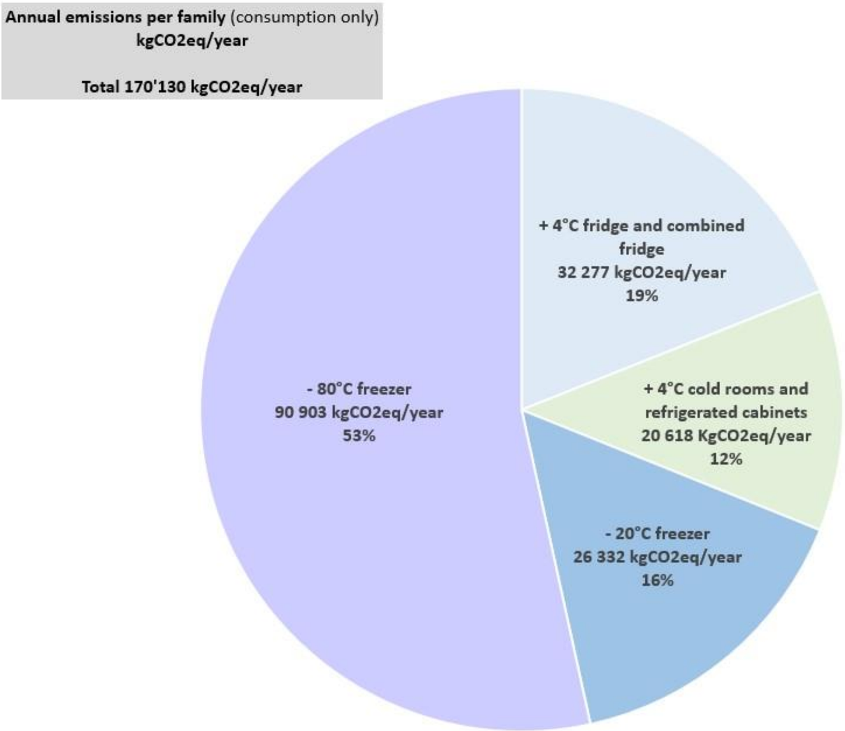
4.6. Estimated uncertainties

Values	**Uncertainties + / -**
Number of devices	1%
Category	2%
Age	20%
Power consumption	20%
Lifetime	30%
Device weight	30%
Quantity of refrigerants on small equipment	30%
Initial quantity of refrigerants on the cold rooms	20%
Loss of refrigerants (leaks)	Depending on device
Grey energy, construction + transport (cradle to gate) and end-of-life emissions	According to Study from the University of Bologna

The uncertainties are relatively large, but we stress again that the objective of this analysis is to provide a uniquely representative picture.

5. Main Results

5.1. Annual figures by family: carbon emissions from electricity consumption



Commercial and Professional

Annual values by family
Consumption only

Equipement	no. of appliances	kWh/year/fam	KgCO2 eq/year/fam (x 0.18 Mix)
+ 4°C fridge and combined fridge	438	164 233	32 277
+ 4°C cold rooms and refrigerated cabinets	43	113 912	20 618
- 20°C freezer	447	145 480	26 332
- 80°C freezer	85	502 229	90 903
Totals	**1013**	**925 854**	**170 130**

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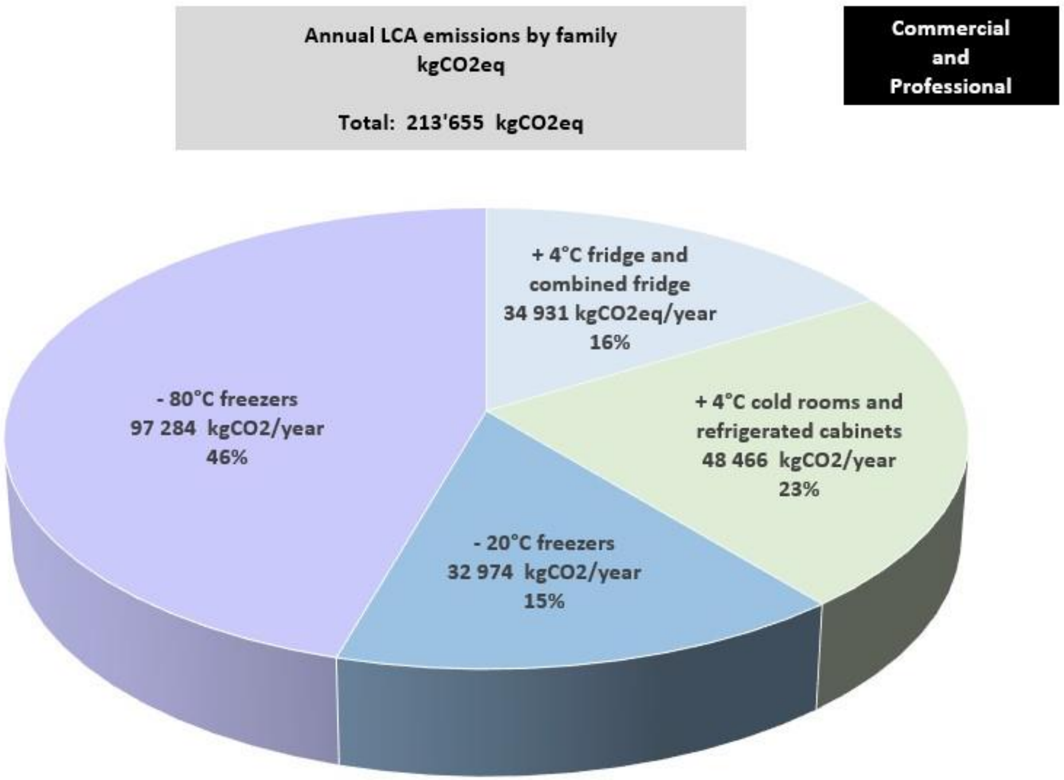
5.2. Annual carbon emissions from all life cycle emissions: LCA

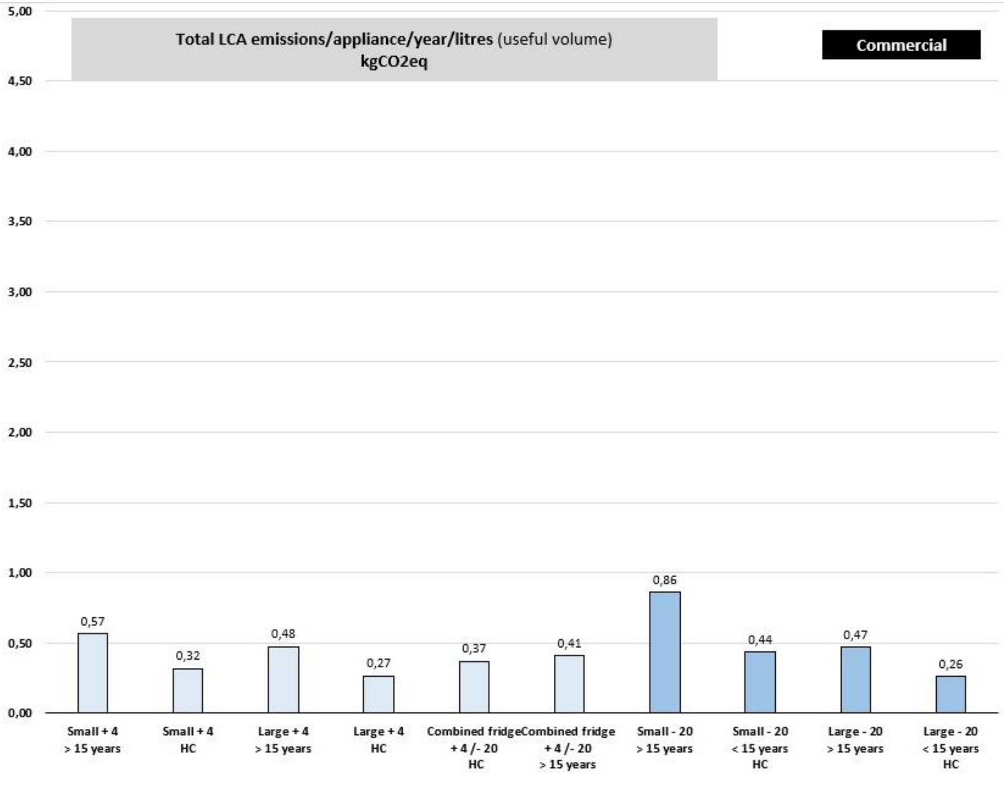
This is calculated by dividing all emissions by the lifetime

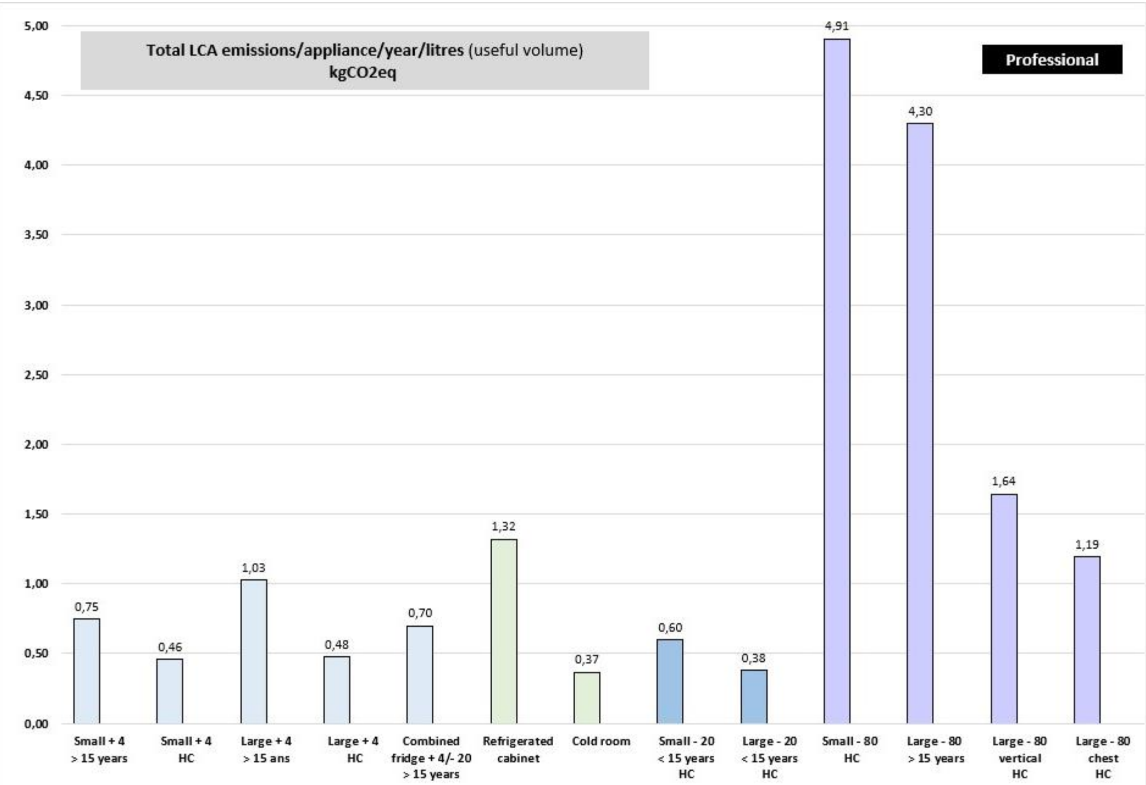


Average life expectancy

Families	Lifespan
+ 4°C fridge and combined fridge	20 years
+ 4°C cold rooms and refrigerated cabinets	30 years
- 20°C freezer	20 years
- 80°C freezer	17 years

5.3. Annual LCA emissions per volume unit





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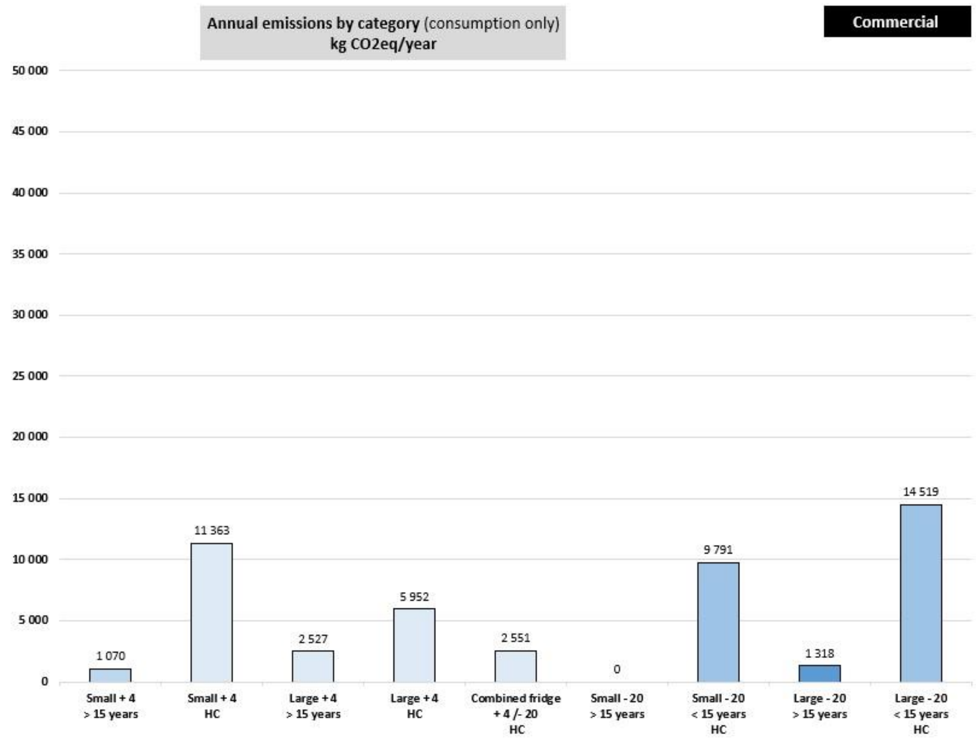
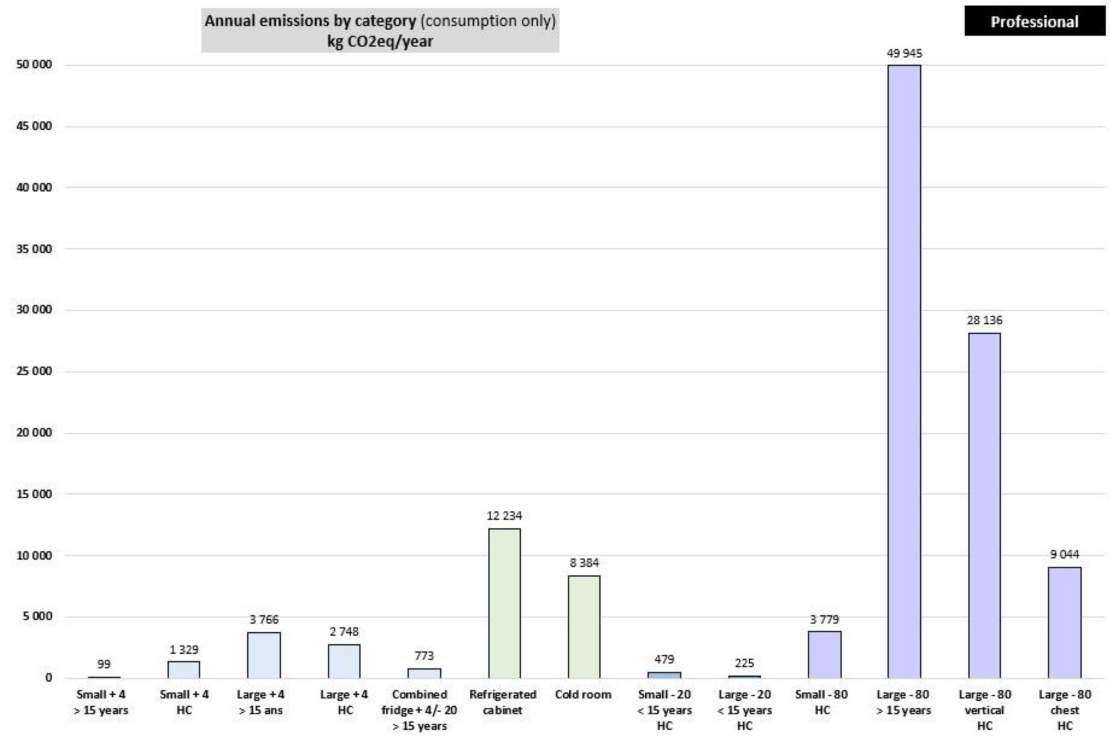
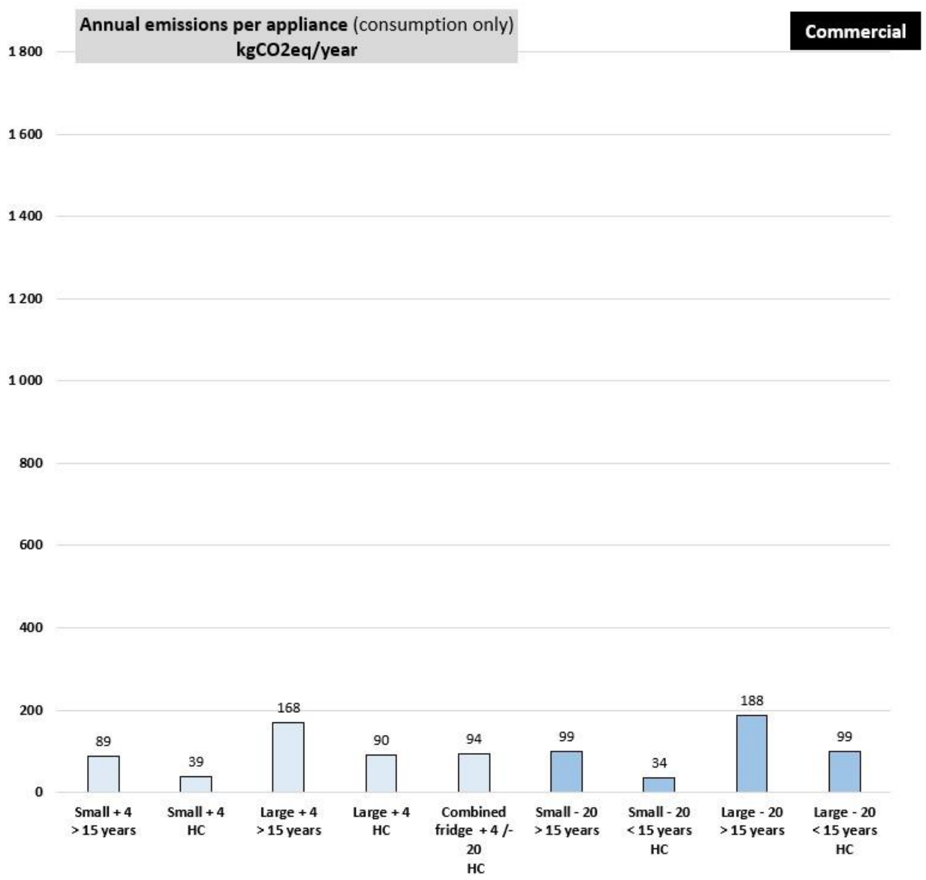
6. Annual emissions

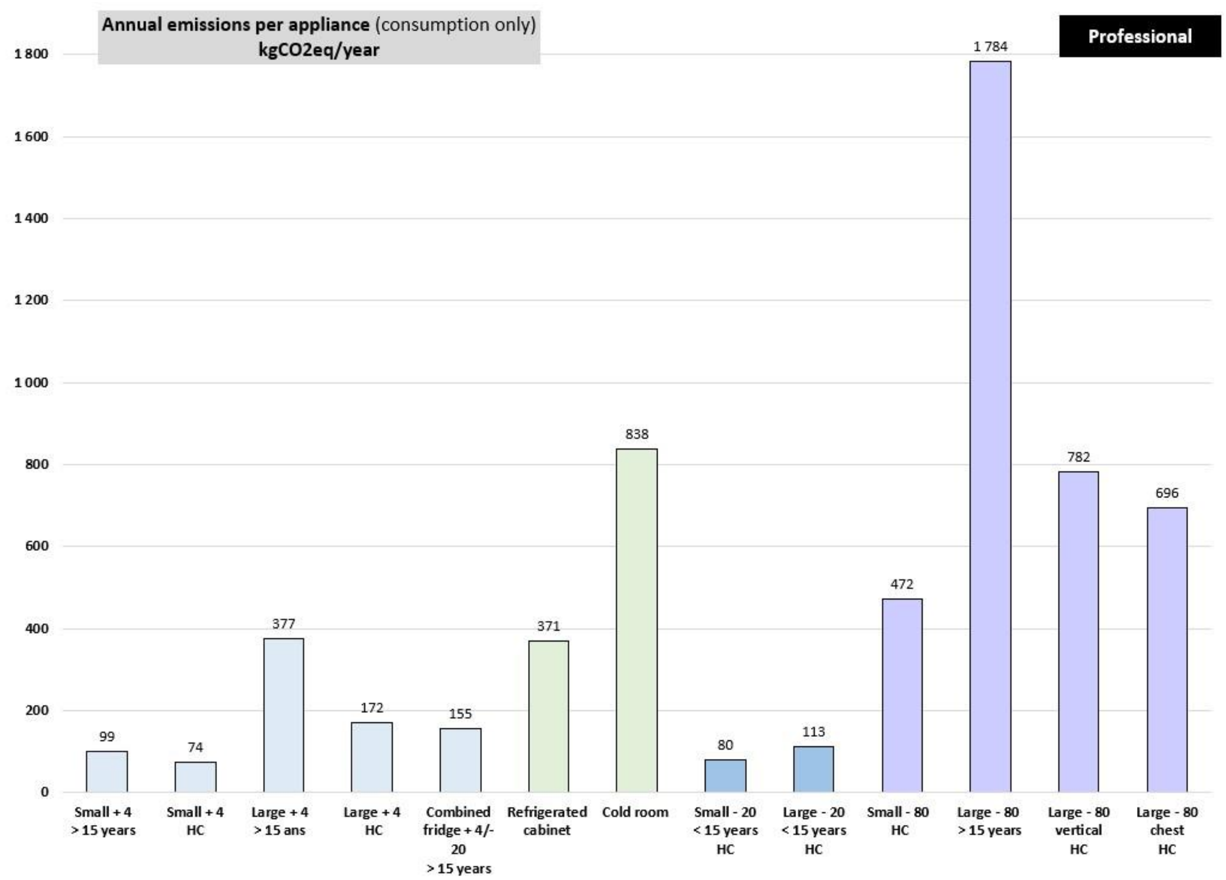
6.1. Annual emissions by category, all equipment, electricity consumption only





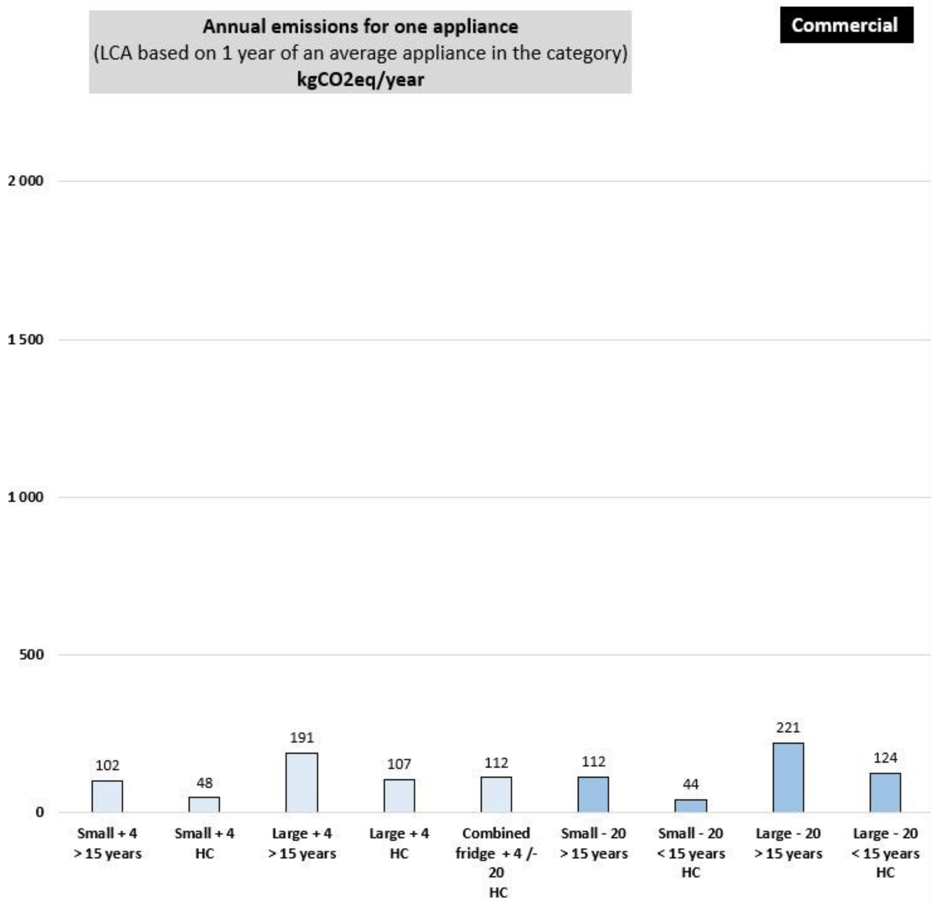
6.2. Annual emissions per appliance: an average appliance in the category, power consumption only

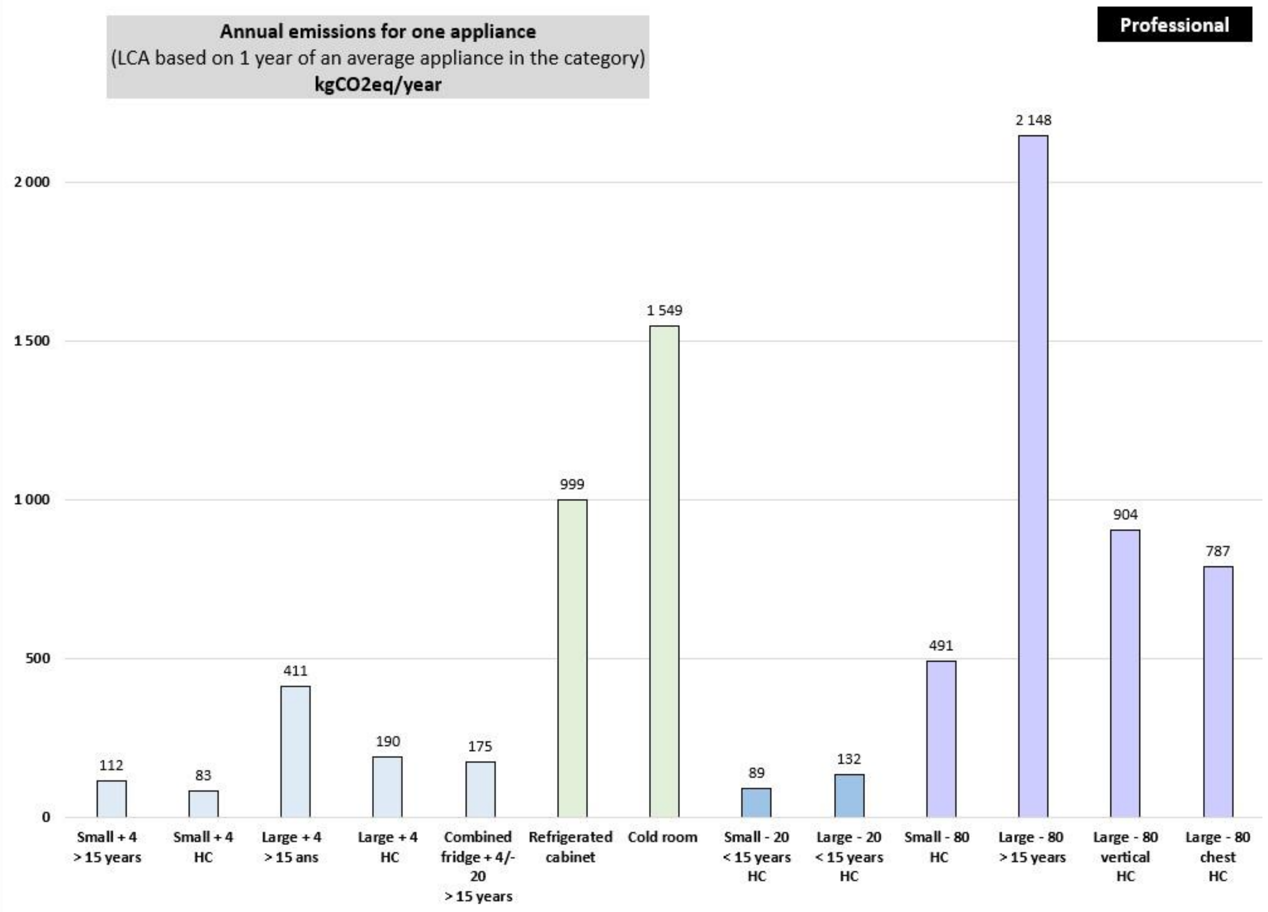




6.3. Total annual LCA emissions per device (production – consumption – disposal)

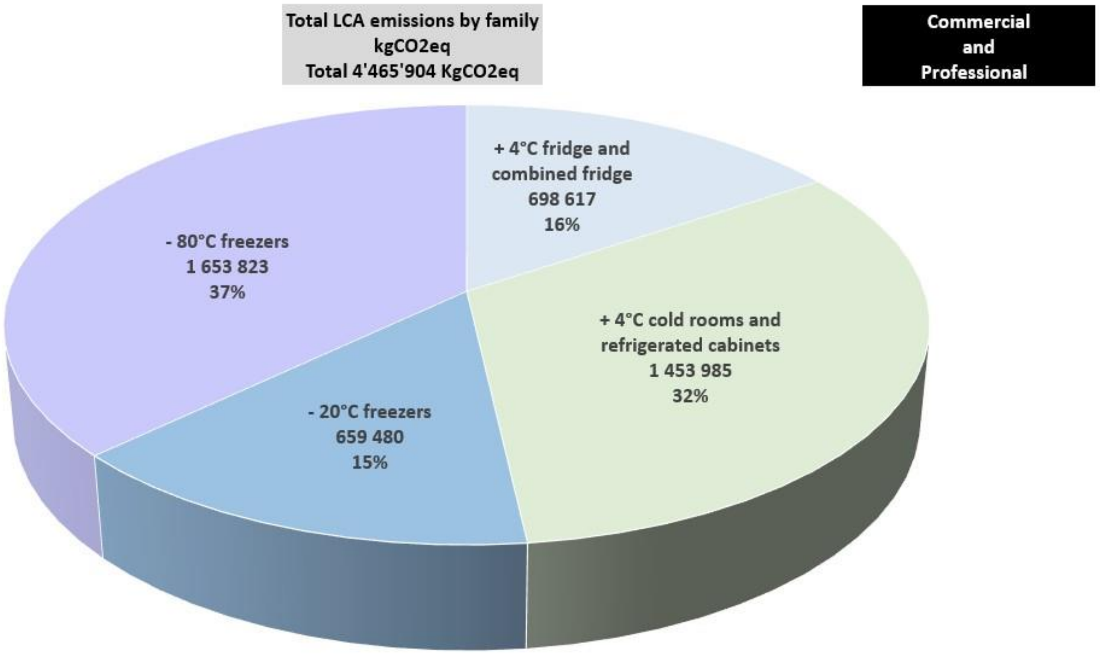
These emissions are calculated by reducing the emissions of the entire life cycle to one year.





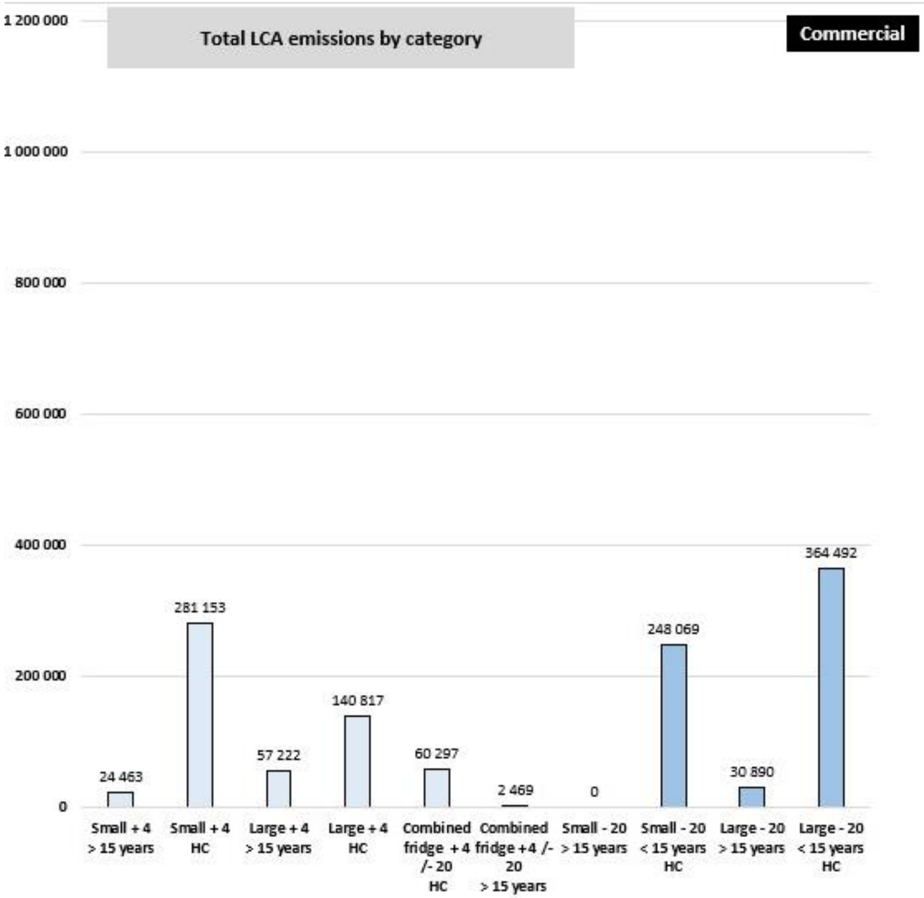
7. Lifetime emissions

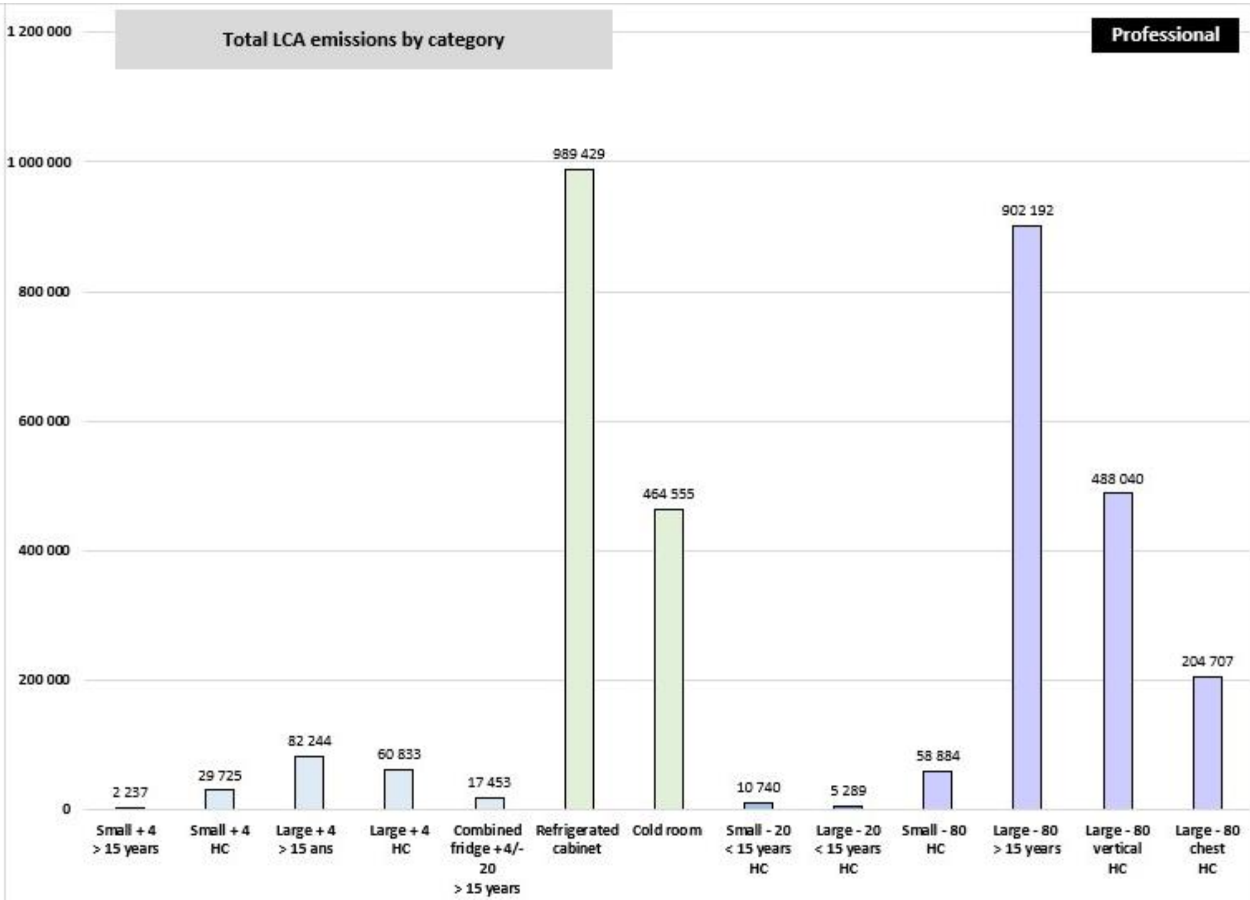
7.1. Total emissions by family



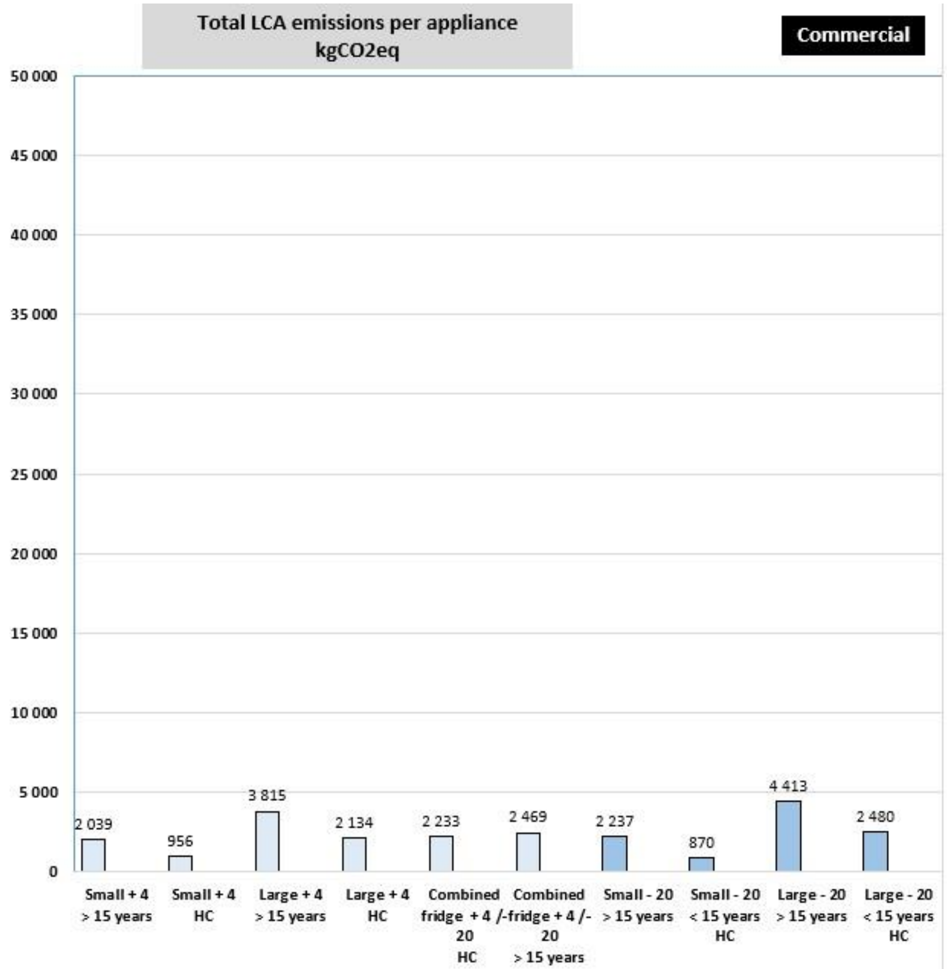
Families	Lifespan
+ 4°C fridge and combined fridge	20 years
+ 4°C cold rooms and refrigerated cabinets	30 years
- 20°C freezer	20 years
- 80°C freezer	17 years

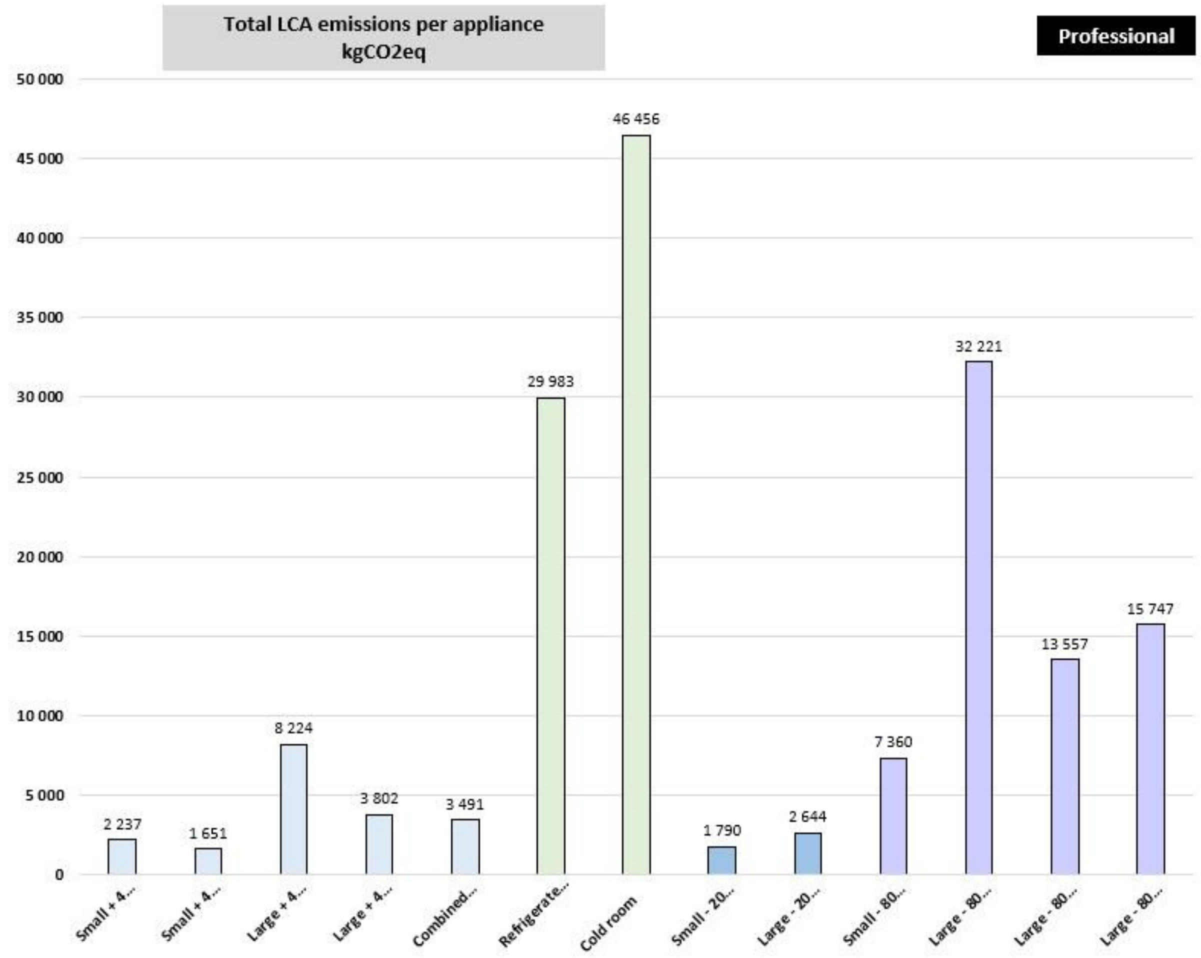
7.2. Total LCA emissions by category, over lifetime



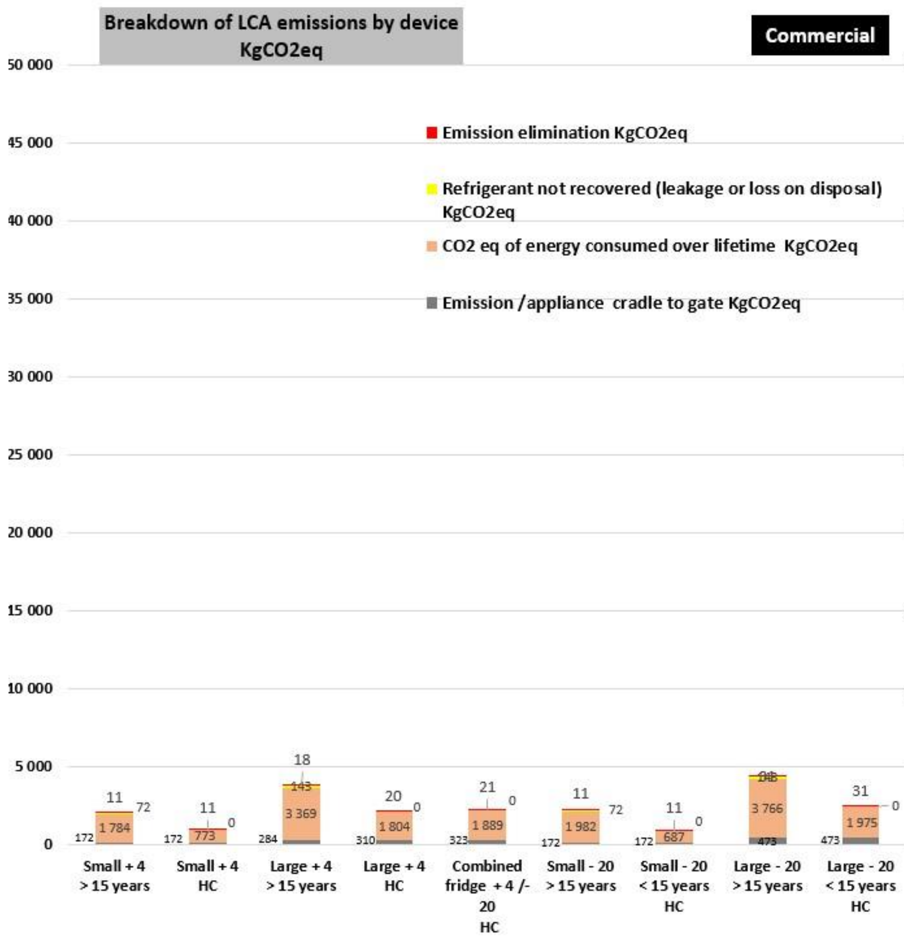


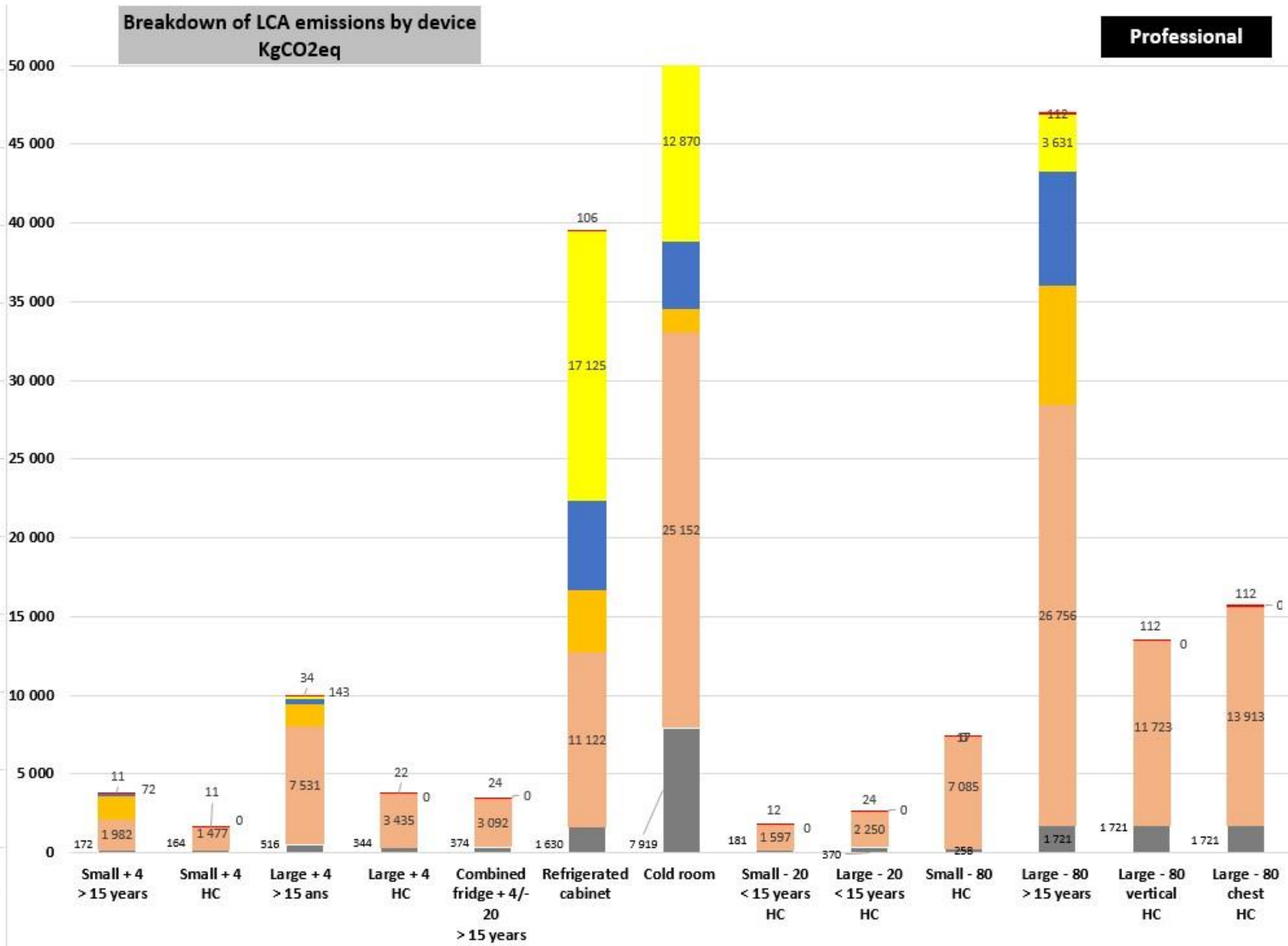
7.3 Total LCA emissions by appliance, over lifetime





7.4 Distribution of emission sources over the life cycle for each type of appliance





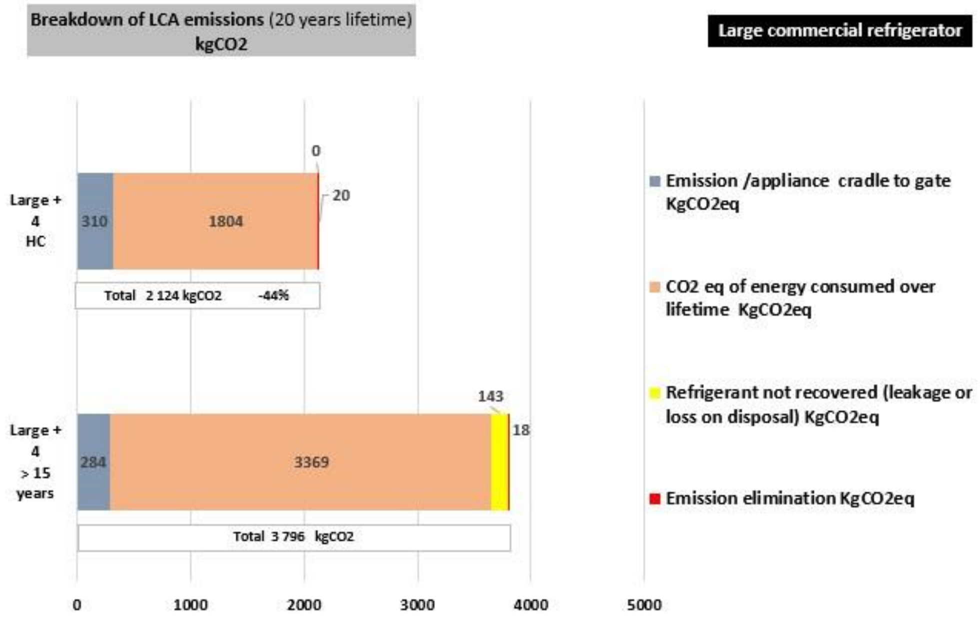
8. Comparison between old and new devices

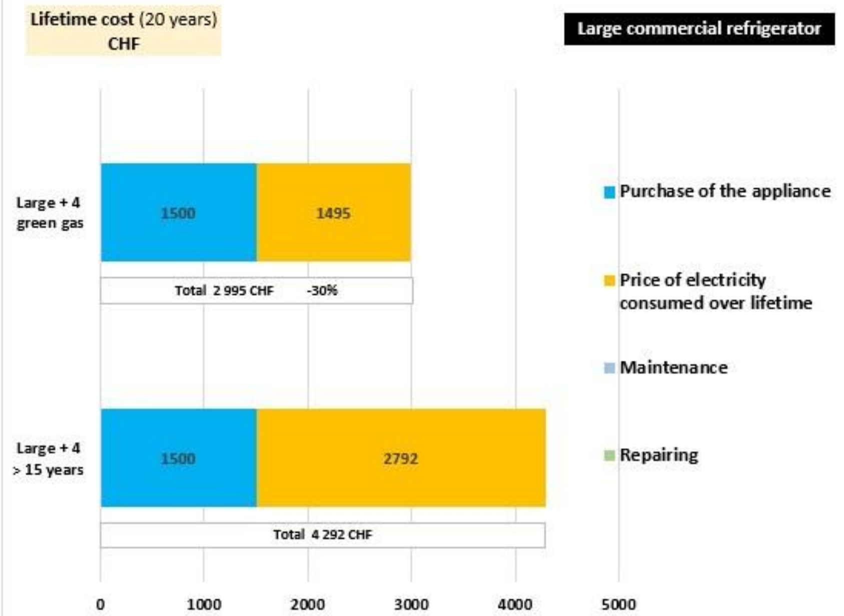
(electricity rate applied: 0.15 CHF/kWh)

Distribution of emission sources over the entire life cycle LCA

8.1. Commercial refrigerator

- Large +4°C HC: refrigerator about 400 liters, new generation (< 15 years) green refrigerants (HC)
- Large +4°C > 15 years: refrigerator about 400 liters old generation (> 15 years) fluorinated refrigerants (CFC, HCFC or HFC)





- CO_2 saving per year: 89 kg CO_2 eq. Grey energy is compensated in 4 years.
- Financial savings per year: 65 CHF. The purchase cost is compensated in 23 years.

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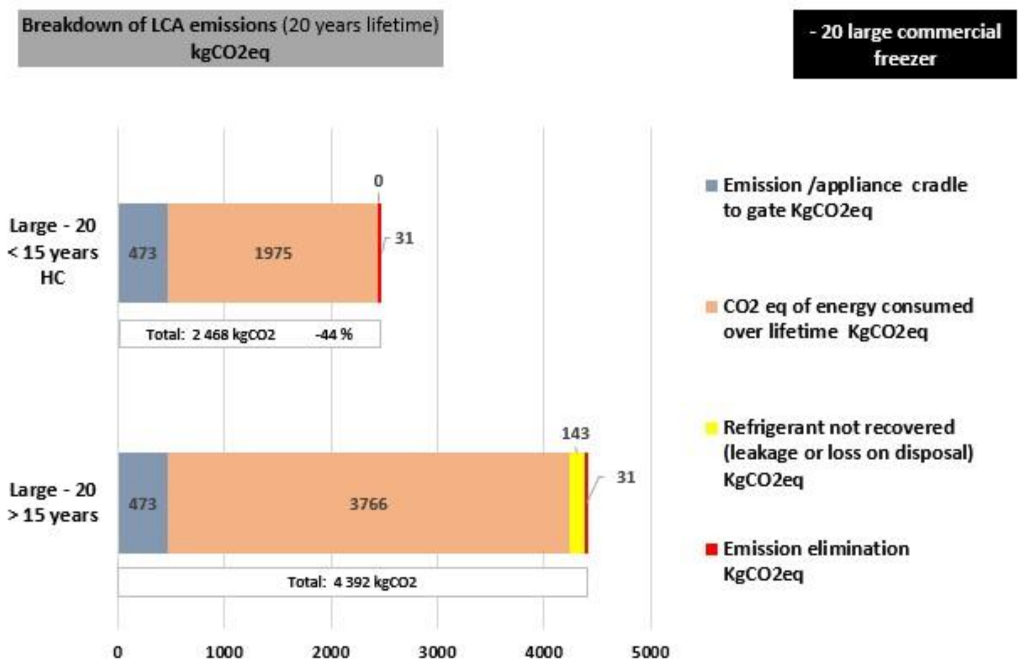
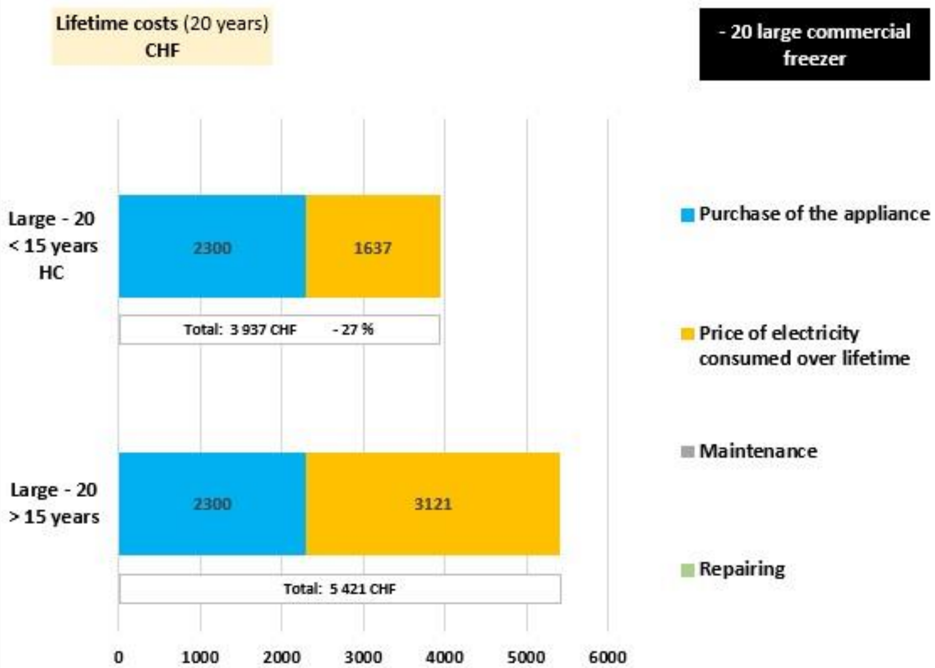
8.2. -20°C commercial freezer

- Large -20 °C HC: freezer about 400 litres, new generation (< 15 years) green refrigerants (HC)
- Large -20 °C > 15 years: freezer about 400 litres, old generation (> 15 years) fluorinated refrigerants (CFC, HCFC or HFC)





- CO_2 saving per year: 102 kg CO_2 eq. Grey energy is compensated in 5 years.
- Financial savings per year: 74 CHF. The purchase cost is compensated in 31 years.

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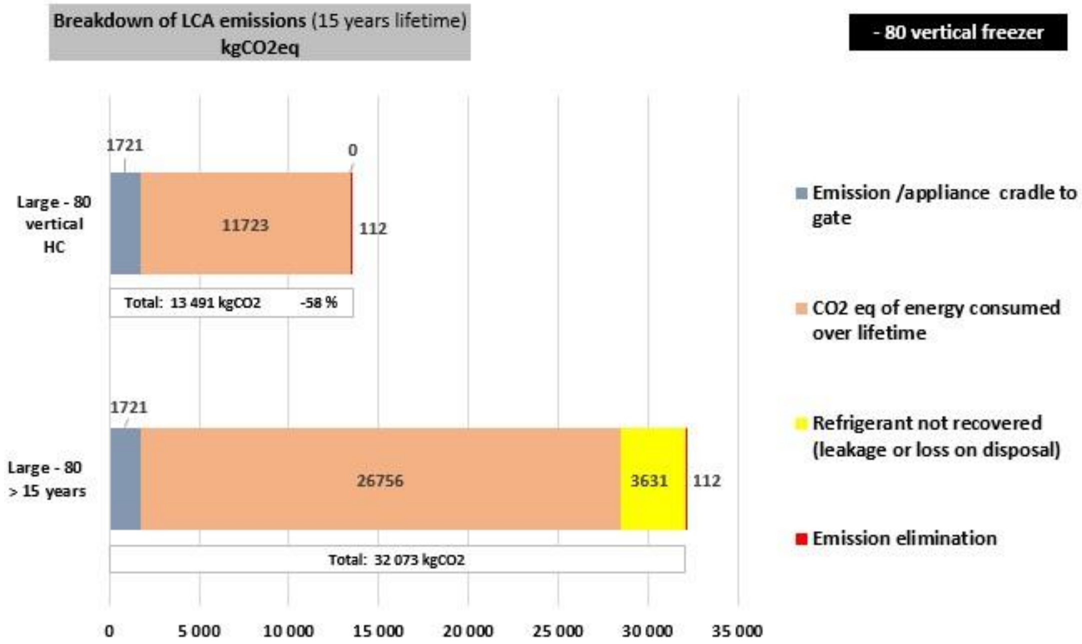
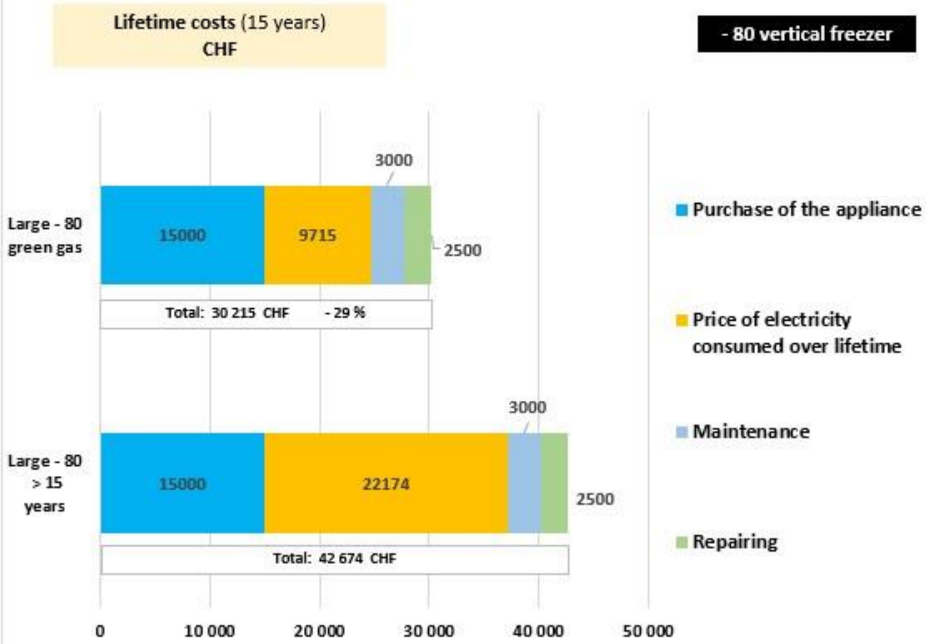
8.3. -80°C freezer

- Large -80 °C HC: freezer about 500 litres, new generation (< 15 years) green refrigerants (HC)
- Large -80 °C > 15°C years: freezer about 500 litres, old generation (> 15 years) fluorinated refrigerants (CFC, HCFC or HFC)



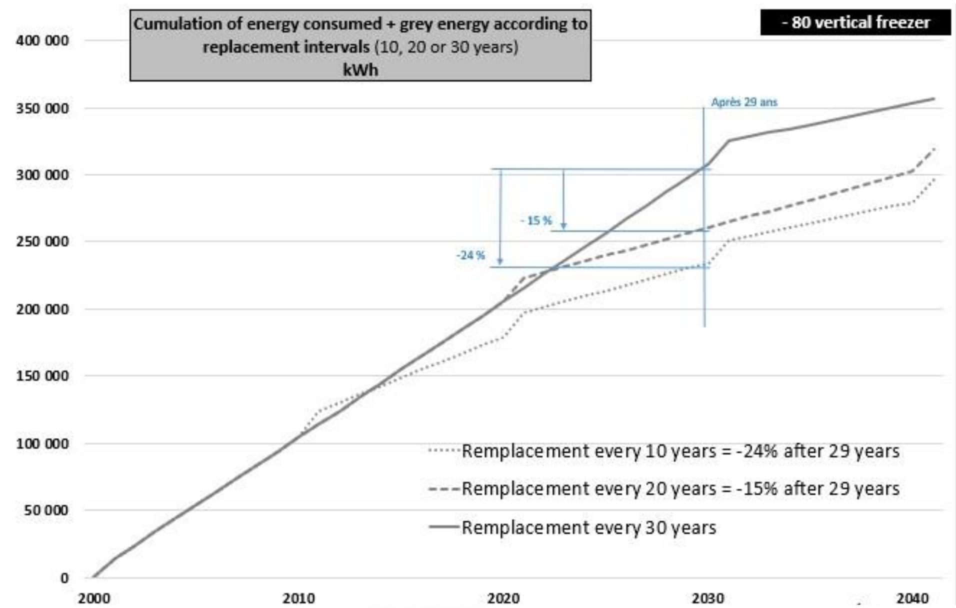


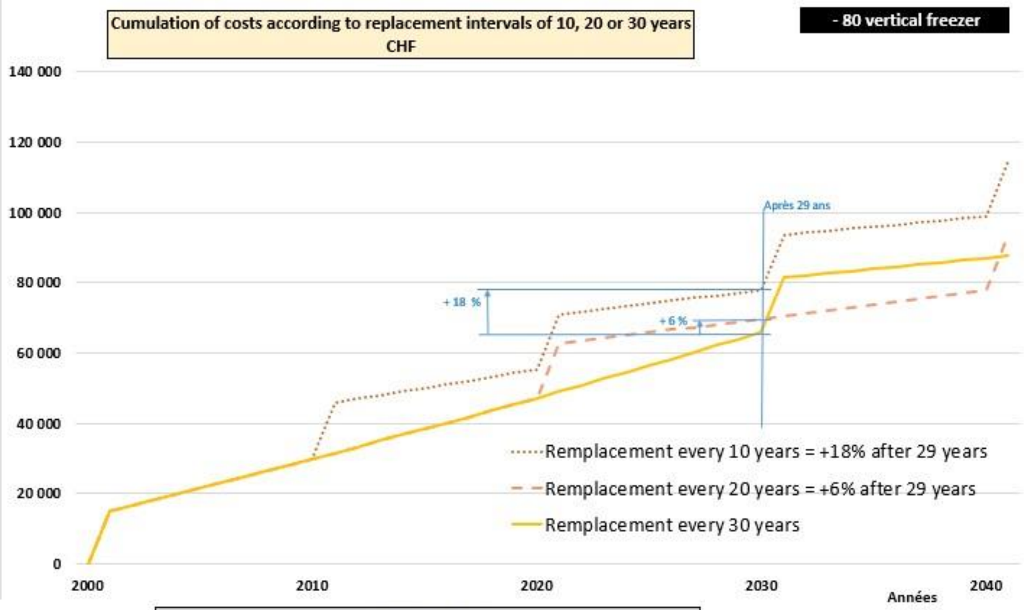
- CO_2 saving per year: 1 036 kg CO_2 eq. Grey energy is compensated in 2 years.
- Financial savings per year: 831 CHF. The purchase cost is compensated in 18 years.

9. When to replace equipment?

Simulation of CO_2 emissions and costs when replacing equipment

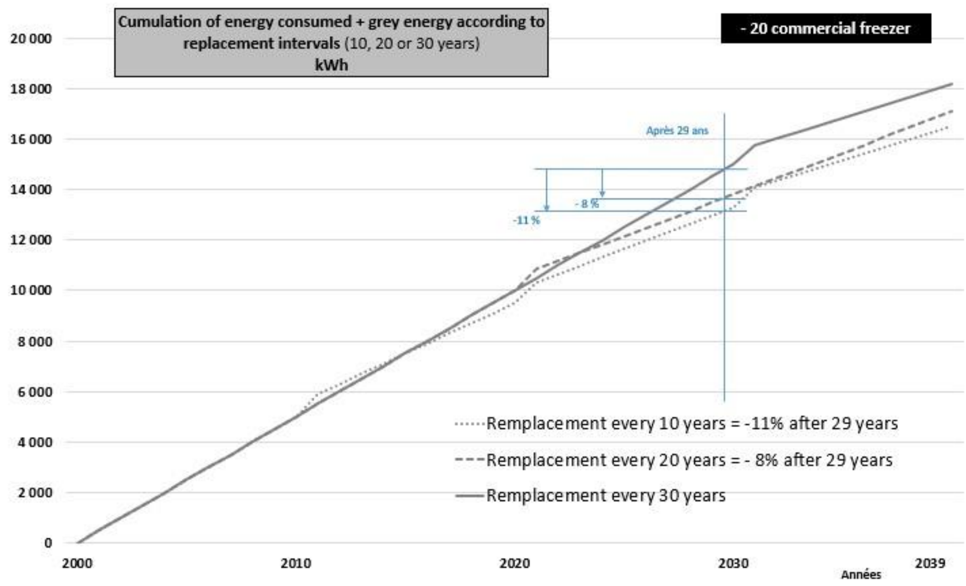
9.1. Example 1: Replacement of a -80°C freezer every 10, 20 or 30 years

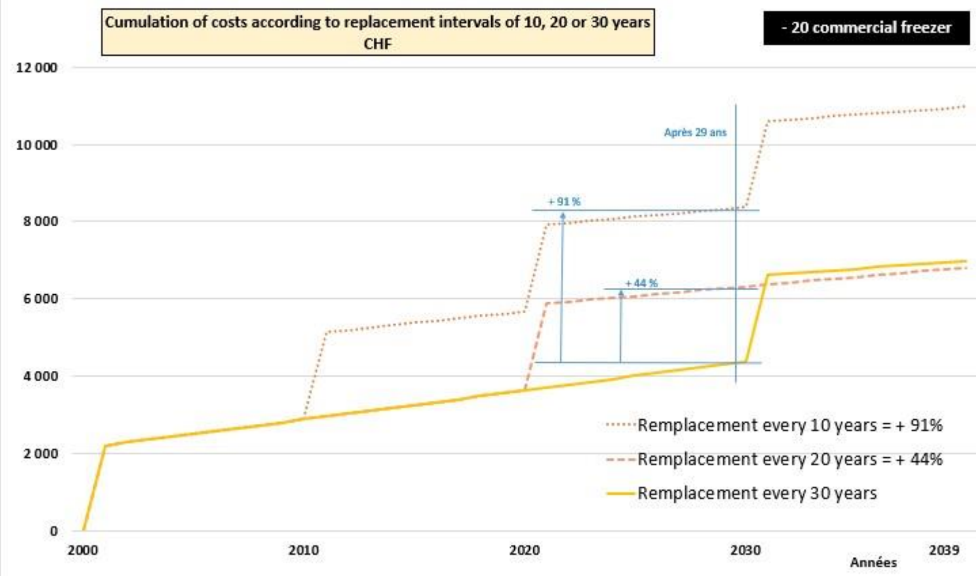




Hypothesis		Time periode			
		2000-2010	2011-2020	2021-2030	2031-2040
Energy consumption in relation to technological development	%	100%	60%	40%	30%
Purchasing price CHF (identical over the 3 time periodes)	CHF	15 000	15 000	15 000	15 000
Annual consumption according to purchasing periode	kWh/year	9 855	5 913	3 942	2 957
Annual energy cost : 0.15 CHF/kWh	CHF/year	1 478	887	591	443
A minimum of maintenance and related energy costs have been taken into account. The values taken are proportional to the age of the equipment but do not exceed 3% annually. Hardly noticeable on these curves. Important interventions with external technicians are not included in the calculations.					

9.2. Example 2: Replacement of a -20°C freezer every 10, 20 or 30 years





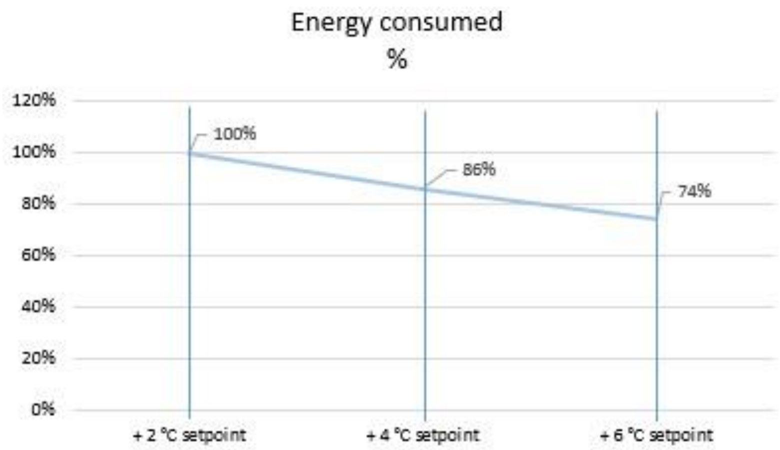
Hypothesis		Time periode			
		2000-2010	2011-2020	2021-2030	2031-2040
Evolution of energy consumption in %.	%	100%	80%	66%	54%
Purchasing price CHF (identical over the 3 time periodes)	CHF	2 200	2 200	2 200	2 200
Annual consumption according to purchasing periode	kWh/year	500	400	330	270
Annual energy cost	CHF/year	75	60	50	41
Energy corresponding to annual maintenance	kWh/year	0	0	0	0
Annual maintenance and repair costs	CHF/year	0	0	0	0

10. Parameters influencing energy consumption

10.1. Setpoint temperature

Example 1: +4°C refrigerator, Liebherr KPT 1750 type

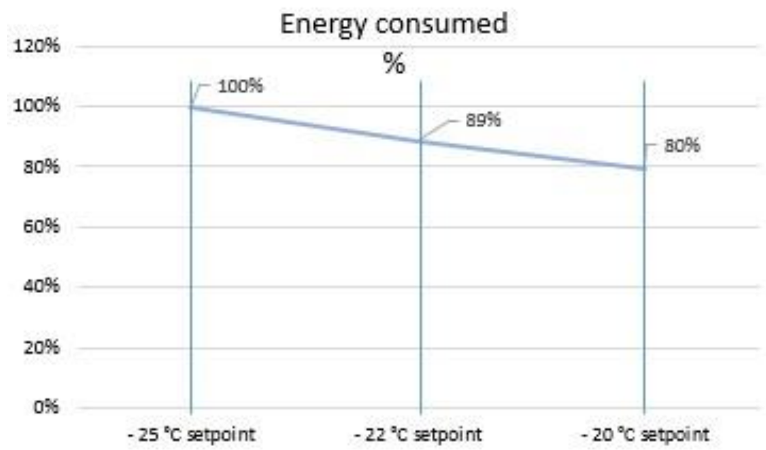
+4°C refrigerator	Energy consumption kWh/day	Energy consumption
+2°C setpoint	0.282	100%
+4°C setpoint	0.243	86%
+6°C setpoint	0.21	74%



Source : EPFL SV Measures

Example 2: -20°C freezer, Liebherr GG 5210 type

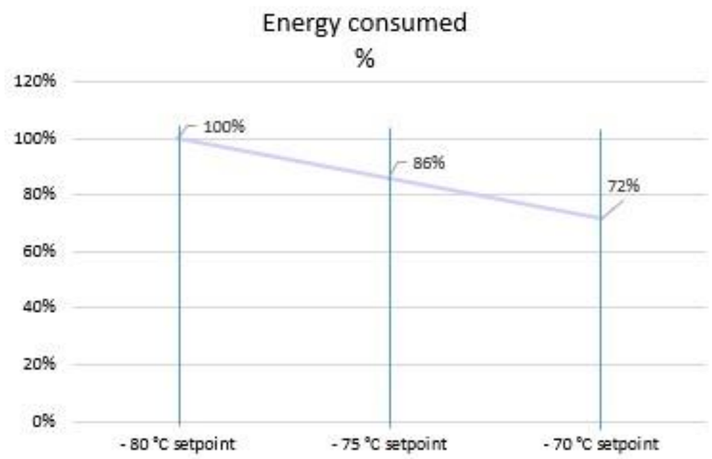
-20°C freezer	Energy consumption kWh/day	Energy consumption
-25°C setpoint	1.76	100%
-22°C setpoint	1.56	89%
-20°C setpoint	1.40	80%



Source : EPFL SV Measures

Example 3: -80°C freezer, Eppendorf 570h type

-80°C freezer	Energy consumption kWh/day	Energy consumption
-80°C setpoint	9.35	100%
-75°C setpoint	8	86%
-70°C setpoint	6.69	72%



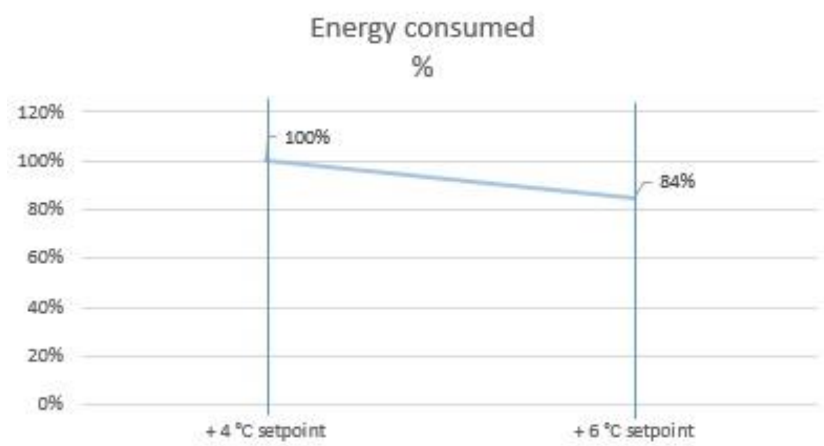
Sources:
- Etude Office of Sustainability University of California, Riverside

- University of California Office of the President, June 2016

- Confirmed by EPFL FSV measures

Example 4: Cold room, SV 2135

+4°C cold room	Energy consumption kWh/day	Energy consumption
+4°C setpoint	9.29	100%
+6°C setpoint	7.84	84%

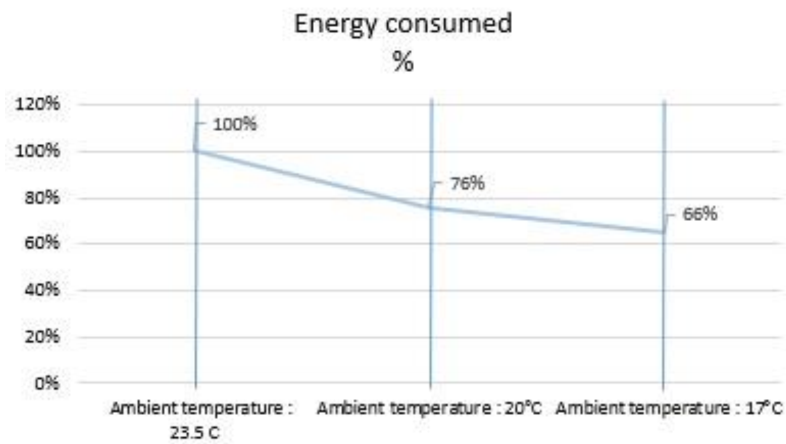


Source :
Values measured in EPFL VPO SE,
May - June 2021

10.2. Ambient temperatures

Example 1: Refrigerator, Liebherr FKS 5000 (EPFL)

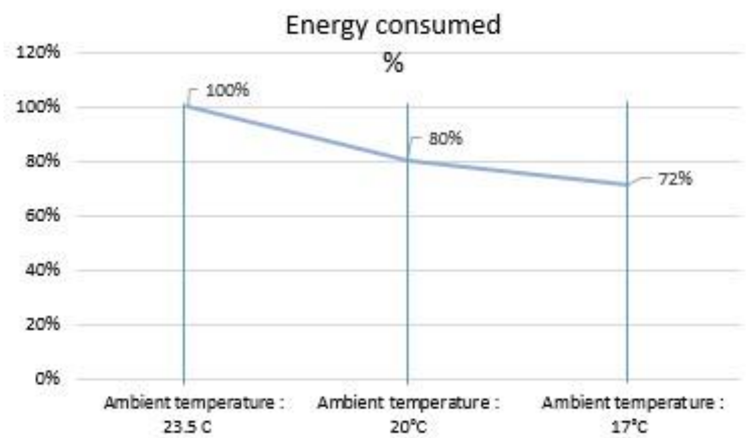
+4°C refrigerator	Energy consumption kWh/day	Energy consumption
23.5°C ambient temperature	1.121	100%
20°C ambient temperature	0.854	76%
17°C ambient temperature	0.735	66%



Source : EPFL SV measures Local AI 9134

Example 2: -20°C freezer, GG 5210 index 23 A (EPFL)

-20°C freezer	Energy consumption kWh/day	Energy consumption
23.5°C ambient temperature	1.23	100%
20°C ambient temperature	0.99	80%
17°C ambient temperature	0.881	72%

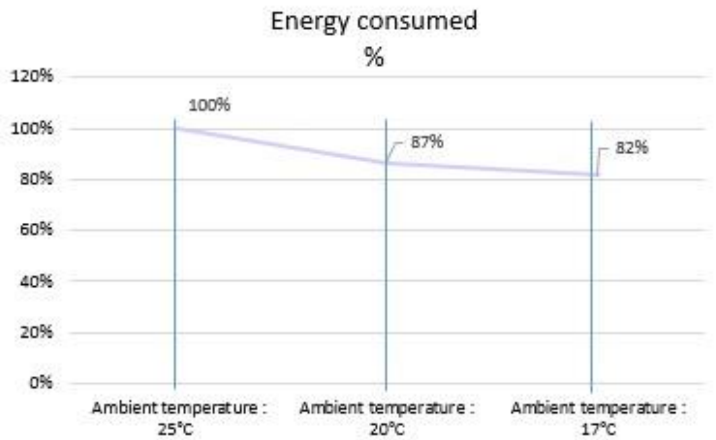


Source : Mesures EPFL SV Local AI 9134

Example 3: -80°C freezer, PCB MDF-DU702VH-PE VIP ECO (EPFL B072642)

-80°C freezer	Energy consumption kWh/day	Energy consumption
25°C ambient temperature	8.5	100%
20°C ambient temperature	7.36	87%
17°C ambient temperature	6.95	82%

Source : EPFL SV
Measures Local AI 9134



11. Indications for the heating and cooling systems of the buildings.

We must also consider that the heat releases from all these refrigeration units have two effects on the thermal balances of our buildings:

In winter:

The electrical consumption contributes to a direct heating input with a COP coefficient of 1. So it is an energy that is not entirely wasted, although it is also not an efficiently used contribution compared to the heat pump heating system in place on the EPFL site.

Considering that these water-to-water heat pump systems have high efficiencies (COP close to 5), about 20% of the electrical energy used by our refrigerated appliances replaces the energy that should be supplied by the heat pumps. As a consequence, the CO_2 impact of the electrical consumption of the refrigerated appliances is to be reduced by about 1/5 in winter.

In summer:

The heat input due to the electrical consumption must be partly compensated by the cooling of the premises. Nevertheless, the cooling of the EPFL premises is carried out by a "free cooling" system using water from Lake Geneva. Today, the CO_2 emissions generated by these installations are not yet known and therefore cannot be considered in the results of our study at this time.

It should be noted that this energy input in winter and this energy loss in summer are partially compensated and therefore influence our results to a lesser extent.

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12. Conclusions

12.1. Equipment selection

The choice of equipment used is important and emission ratios can vary from 1 to 3 between different models.

Conservation at +4°C

Cold rooms and large, recent commercial (household) refrigerators generate the least CO_2 emissions per useful volume.
It should be noted that the cold rooms installed in our faculty have refrigeration units equipped with water condensers, which gives them a high efficiency (COP). The temperature of the cooling water circuit is about 12°C thanks to the pumping of water from Lake Geneva.
The vast majority of these cold rooms, equipped with R134a refrigerant and installed in 2008, generate 19% and 61% less CO_2 emissions than commercial or professional refrigerators (large or small) for the same useful volume. (see page 16 chapter 5.3)

Refrigeration cabinets, most of which were installed in 2001, have two to three times higher emissions per unit volume than refrigerators or cold rooms. Although this equipment is, for the most part, equipped with condensers cooled with water from Lake Geneva, their low efficiency is mainly due to the refrigerant used (R404a, high GWP), as well as to their poor insulation (low wall thickness and glass doors).

Conservation at -20°C

Commercial (household) freezers are the appliances that generate the least CO_2 per useful volume. It is preferable to opt for volumes of 400 liters or more, whose carbon footprint is about 40% lower, still per useful volume.

Conservation at -80°C

The -80°C freezers have big differences in emissions between the old and new generations. Replacing older models will significantly reduce emissions in the short to medium term.
Chest freezers have the lowest impact due to their longer life.
Smaller -80°C freezers have the highest carbon footprint per usable volume of all forms of storage.

Note:

Ecological, qualitative, practical and financial issues when choosing equipment are often linked and cannot be separated from the CO_2 impact alone. It is therefore sometimes inevitable to purchase equipment with a high carbon footprint.

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12.2. Equipment replacement interval

In terms of CO_2 emissions, it makes sense to replace the most energy-intensive equipment. For refrigerators, -20°C freezers and -80°C freezers, the grey energy necessary for their manufacture and transport is compensated in 2 to 5 years.

Economically speaking, it is generally wise to keep these devices until their average or even maximum life span. Only old generation -80°C freezers should be replaced after 15 years.

In general, it is often difficult to compensate the purchase price by the energy savings because of the relatively low price per kWh at EPFL.

12.3. Influence of the setpoint temperatures

In the normal temperature range of use, the set temperatures have a significant influence on electrical consumption. For storage at +4°C and -20°C, the energy gain is 5 to 10% per degree Celsius of increase of the set point. It is approximately 15% for an increase of 5°C on -80°C freezers.

During the inventory of equipment, we noticed that the set point of many appliances is lower than the recommendations, especially for -20°C freezers.

12.4. Influence ambient temperatures

Ambient temperatures also have a significant influence on electrical consumption. These values are adjustable in some rooms, but in the majority of cases, the equipment is located in laboratory areas where the temperature cannot be lowered.

The data in this report and its conclusions apply to the equipment models installed in our faculty. The results could therefore be significantly different from one institution to another.

Several elements and parameters have not been considered in this analysis but would certainly have a significant influence on CO_2 emission reductions:

- Regular sorting of stored material,
- Mutualization of equipment in order to optimize the filling rate,
- Optimization of the volumes used in the equipment (optimization, boxes, racks, shelves),

- Use of -80°C freezers equipped with water condensers,
- Optimization of maintenance in order to extend the life of the devices.

The energy efficiency of appliances will certainly not be able to improve indefinitely, so it will be wise to keep equipment for as long as possible.

The important point to remember from this analysis is the significant impact of -80°C freezers. A -80°C freezer generates 8 to 12 times more CO_2 emissions than a commercial refrigerator, equivalent to the emissions linked to the average electricity consumption of a 4-person household. This is why refrigerated storage will be one of our priorities in the faculty for the years to come.

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