Circular economy ecosystem to Recover, Recycle and Re-use F-gases contributing to the depletion of greenhouse gases -LIFE 3R

Deliverable: Market study

Action C4

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Contents

Introduction

This deliverable is a F-gas **market follow-up** at technical, economic, environmental and regulatory level concerning European Union (EU). Besides, Regulation (EU) No 517/2014 affects the whole HVAC-R value chain, aiming at industry awareness so that the greenhouse gas emissions to be reduced on time. LIFE 3R is considered to directly contribute to the EU's establishment as the first region to take such far-reaching steps to this direction. In this deliverable, special attention is paid on the market status of Hungary, Slovakia and Czech Republic which are selected to be the first 3 EU demo-countries, with the prospect of being the reference for future implementation of the 3R ECOSYSTEM at an EU-wide level. Therefore, monitoring of project impacts on both environmental and socio-economic sector will be intensive during demos while extra requirements and customisation issues from the different stakeholders will be detected and tackled.

1 Refrigerant market status in the EU

1.1 F-gas legal framework

Certain F-gases have come into use since the 1990s for the replacement of ozone-depleting substances (ODS) that were phased out under the Montreal Protocol (UNEP Ozone Secretariat, 1987) and Regulation (EC) No 1005/2009 (EU, 2009). Until 2014, their use in many different applications, most prominently in refrigeration and air conditioning, not only had been increasing but also had considerable potential for further growth. Consequently, emissions of F-gases in the EU-28, of which more than 90% are HFCs, were increased by 72% between 1990 and 2014.

This absolutely alarming phenomenon activated the EU which has taken regulatory action to control F-gases since 2014, as part of its policy to combat climate change. Basically, a new **F-gas Regulation** (No 517/2014) was implemented in 2015, introducing additional requirements compared to the previous measures (Regulation (EC) No 842/2006). Although the new rules maintain the principles of the 2006 Regulation, they go much further as they introduce a completely new mechanism to ensure emission reductions. This mechanism is called the phase-down and will gradually reduce the consumption of HFCs. It will also massively change the way industry can use HFCs.

The phase-down is a step-by-step approach where the quantities of HFCs expressed in CO_2 equivalent that are placed on the market are gradually reduced through the allocation of quotas by the European Commission to producers and importers of bulk HFCs. As a result of the phase-down, HFC consumption will be reduced by 79% by 2030. This is an unprecedented reduction and means that industry and users need to make the transition to refrigerants with a lower global warming potential.

Meanwhile, HVAC-R companies keep being obliged to report on produced, imported and exported quantities of F-gases and mixtures. However, the list of reportable F-gases is now extended beyond HFCs, PFCs and SF_6 to also include:

- unsaturated hydro(chloro) fluorocarbons;
- fluorinated ethers and alcohols;
- other perfluorinated compounds.

Due to the strong policy mechanisms adopted under the EU F-gas Regulation of 2014 which implements an EU-wide phase-down of HFC use, as well as measures taken by other industrialised countries, a momentum to the global development of HFC regulation was given. This culminated in October 2016 in Kigali, when the Montreal Protocol was amended to regulate HFCs. Both developed and developing countries have taken on mandatory commitments to reduce production and consumption of HFCs in the next three decades [(1)].

1. The Kigali Amendment regulates production and consumption, while reducing emissions of HFCs remains within the remit of the United Nations Framework Convention on Climate Change (UNFCCC) and the Paris Agreement.

1.2 Production and reclamation

It is important to be declared that "Production" refers to the production of virgin F-gases. Additionally, the F-gas Regulation defines "reclamation" as *the reprocessing of a recovered fluorinated greenhouse gas in order to match the equivalent performance of a virgin substance, taking into account its intended use*. Therefore, reclaimed HFCs do not count as placing on the market (POM) and are not subject to the limits of the HFC phase-down. Based on the last European Environment Agency Report for Fluorinated greenhouse gases (2020), some basic statistics about production and reclamation of F-gases in the EU are detailed below:

1.2.1 Production

Production of F-gases has seen a steady decline since 2012 (**Figure 1**). In 2019, a significant increase in the GWP of produced gases was reported, while the production volume by mass continued to slightly decrease as it was measured at 21.160 tonnes (from 21.787 tonnes in 2018). This effect is mainly due to the more complete reporting on the by-production of HFC-23 (GWP: 14.800), both amounts captured for destruction and amounts not captured. Explicit reporting on uncaptured amounts of F-gases was new in 2020, based on the 2019 amendment of the reporting questionnaire (EU, 2019). 97% of uncaptured HFC production in 2019 was reported to have been destroyed (96% of GWP).

Production of F-gases is dominated by HFCs, which are almost 90% of the total, with HFC-134a and HFC-365mfc accounting for the largest parts. Other HFCs produced in the EU are HFC-143a, HFC-227ea and HFC-23. The EU production of HFC-32 and HFC-125 ceased after 2013 and 2014, respectively [(2)]. For the sum of HFCs, 2019 production was 4% below 2018 in tonnes but 30% above 2018 in GWP. That is because HFC-134a production (GWP: 1.430) fell by about one quarter, while reported production of HFC-143a (GWP: 4.470) and HFC-23 (GWP: 14.800) approximately doubled.

While sulphur hexafluoride (SF_6) accounts for roughly 10% of EU F-gas production, it now constitutes about half of the total GWP of production. SF_6 production in 2019 rose by 6% compared with 2018 and thus returned to 2017 levels. Other F-gases produced in the EU are five perfluorocarbons (PFCs). The production of low quantities of HFC-1234yf had been reported for the period 2015-2017 and of hydrochlorofluorocarbon (HCFC)-1233zd for 2018. However, no production of these gases was reported for 2019.

2. Relatively small amounts of uncaptured production of HFC-125 were reported in 2019, however they were fully destroyed.

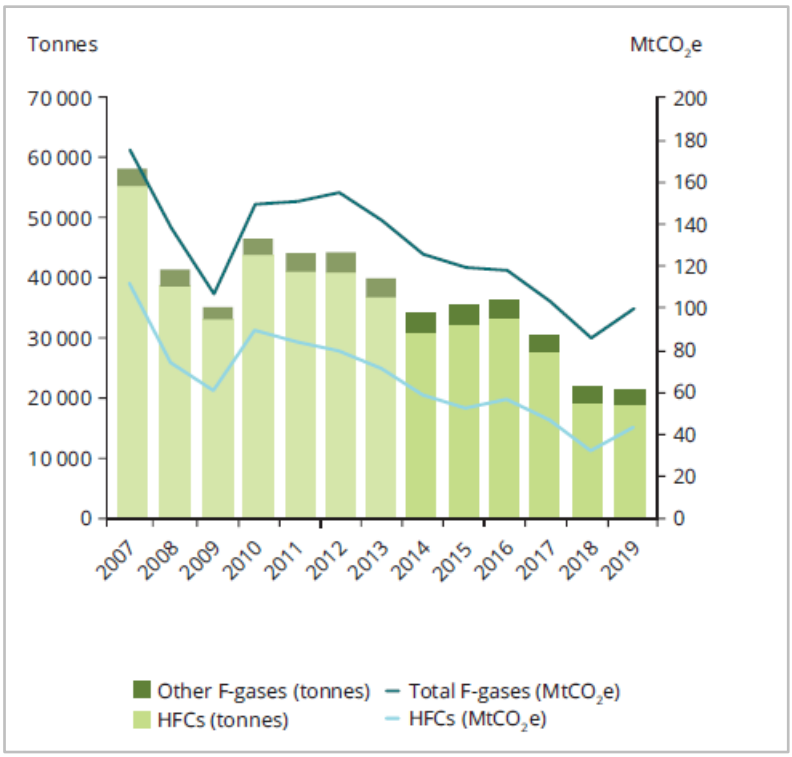


Figure 1: EU production of F-gases[3].

1.2.2 Reclamation

Reclamation of F-gases in the EU has fluctuated, but there was a steady increase from 2014 to 2018 (**Figure 2**). In 2019, however, the reported reclamation amount decreased by about 20% compared with 2018 (from 1.934 to 1.523 tonnes), due mostly to less complete reporting. Reclaimed HFCs as reported now make up 8% of the produced amount, or 3% of the EU supply of virgin HFCs (or 9% and 4%, respectively, as CO_2e). While 97% of reclaimed amounts are HFCs, SF_6 contributes to about 20% of the GWP of reclaimed gas.

3. *European Environment Agency (EEA): Fluorinated Greenhouse Gases 2020 Report.*

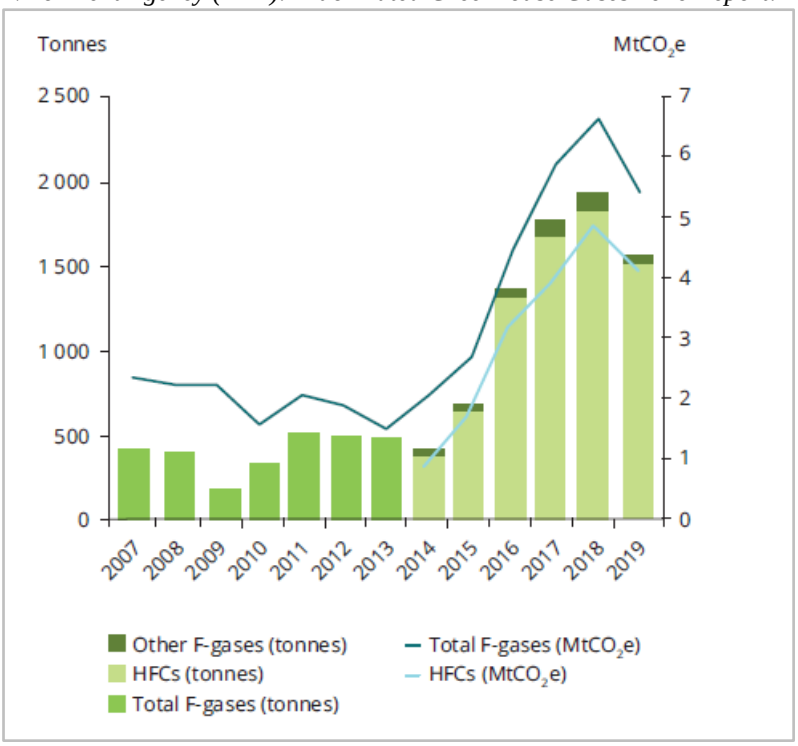


Figure 2: EU reclamation of F-gases[3].

It should be noted that the reporting on reclamation is considered to be incomplete, as no self-standing reporting obligation is in place for undertakings involved in reclamation. Reported reclamation amounts are based on the reclamation activities of undertakings that have a reporting obligation as gas importers.

1.3 Imports and exports

1.3.1 Imports

As it can be seen in **Figure 3**, imports of F-gases into the EU-28, including both bulk imports and imports contained in products and equipment [4], decreased by 14% compared with 2018 (from 98.223 to 84.284 tonnes). Basically, this is the combined result of a substantial reduction in bulk imports (from 87.221 to 73.478 tonnes) and a slighter decrease in products and equipment imports (from 11.002 to 10.806 tonnes). In terms of CO_2e, bulk gas and imports in equipment fell by 19% and 22%, respectively. In both cases, this reflects a switch to lower GWP gases. Indeed, imports of HFCs fell by 19% while imports of unsaturated HFCs/HCFCs increased by 6% (i.e.: the share of HFCs in total imports decreased from 79% in 2018 to 74% in 2019). With the low GWP of the unsaturated gases, the GWP of total F-gas imports decreased by 19%, too.

4.The figures before 2014 include only bulk imports.

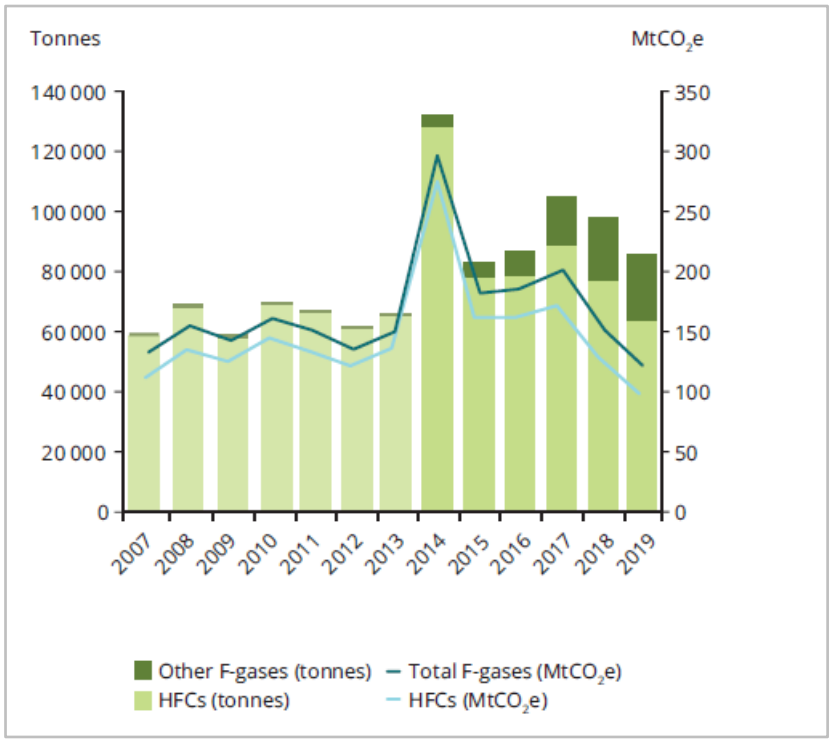


Figure 3: EU imports of F-gases[3].

1.3.1.1 Bulk imports

New reporting details necessary under the Kigali Amendment to the Montreal Protocol (MP), which entered into force in 2019, include country-specific reporting on imports and exports of bulk HFCs [5]. This means that HFC imports and exports need to be distinguished by country of origin/destination. **Figure 4** shows the countries of origin for bulk imports by mass:

5. Country-specific reporting is not required for the reporting of non-HFC imports.

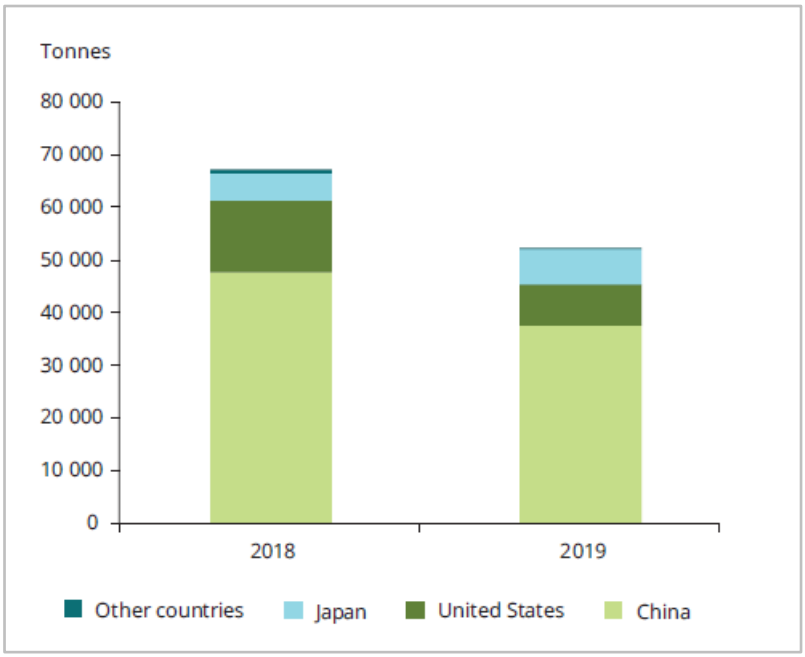


Figure 4: Origin of bulk HFC imports by mass[3].

Likewise, the origin of bulk HFC imports in relation to their GWP is displayed in **Figure 5**. Generally, in both 2018 and 2019, 99% of all imports originated from three countries: China, the United States and Japan, with China being the largest supply country of EU HFC imports. While overall bulk HFC imports in 2019 decreased by about 20% compared with 2018, Chinese imports followed the same trend. US imports decreased by about 40% while imports from Japan increased by 30%. Figure 5 also shows that HFC imports from China have a slightly higher GWP.

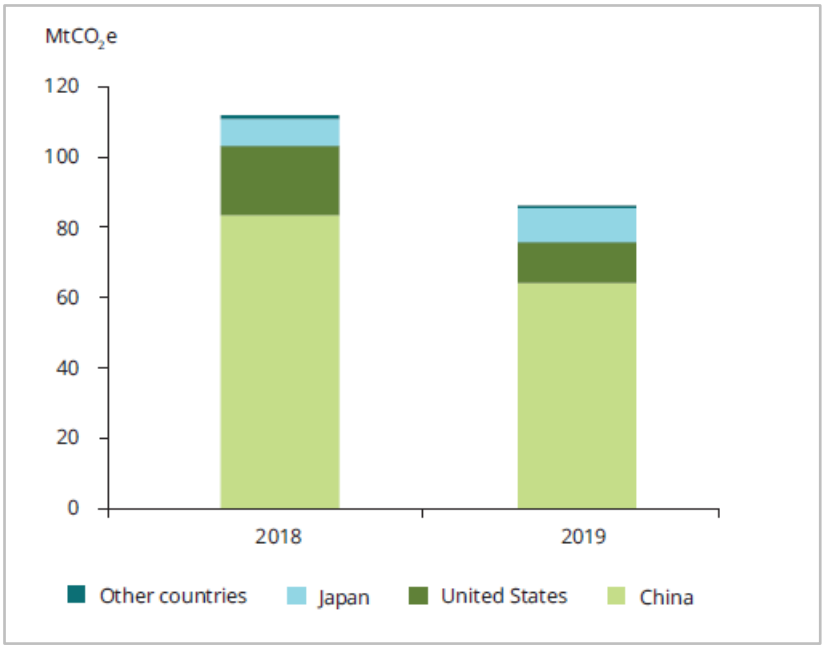


Figure 5: Origin of bulk HFC imports in relation to their GWP[3].

It should be noted that bulk imports presented in Figures 4 & 5 do not include imports of pre-blended polyols and are thus compatible with the MP definition. In addition, the geographical scope of applied data is the EU-28.

1.3.1.2 Imports contained in products and equipment

Imports of F-gases contained in products and equipment [(6)] have been subject to reporting since 2014, and reported amounts rose significantly until 2016. Part of the increases up to 2016 may be attributable to more complete reporting and not to actual increases in equipment imports. Starting in 2017, the relevant imports of F-gases appear to have levelled off when measured by mass. Nevertheless, the bars corresponding to the years 2018 and 2019 seem to be increased according to **Figure 6**. This is reasonable as imports of pre-blended polyols are also included since 2018. Basically, pre-blended polyols are included in the definition of bulk gases in F-gas Regulation (EU) No 517/2014. However, under the Montreal Protocol, they are considered products and are thus not covered.

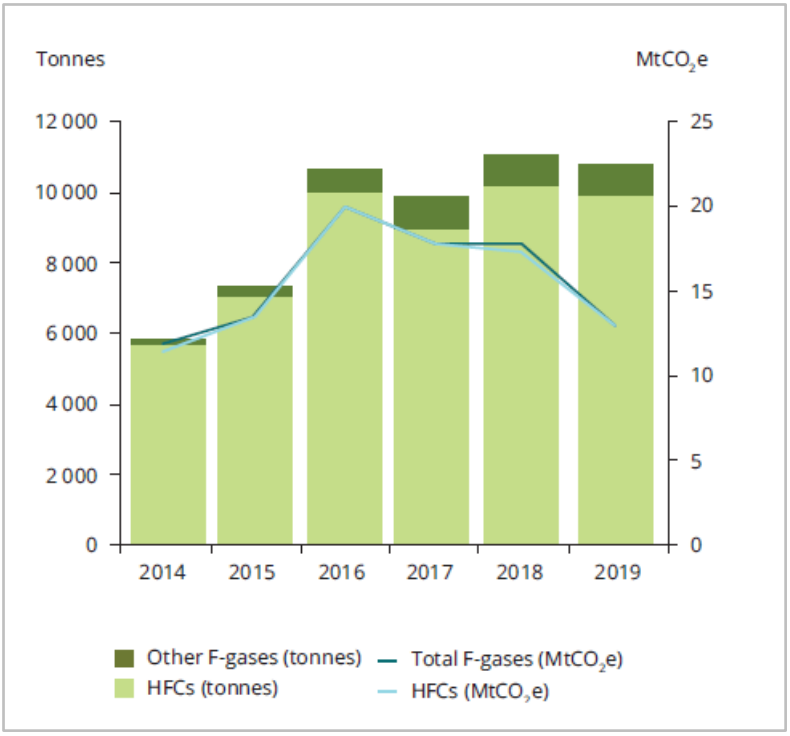


Figure 6: EU imports of F-gases within products and equipment[(3)].

6. Data reported by importers of products or equipment under the F-gas Regulation (EU) No 517/2014 are defined as including quantities imported and placed on the market. Products and equipment that are imported but not placed on the market (e.g., for re-export) are not to be reported. Considering this limitation, the import of gases within products and equipment presented here have been approximated using the reported data.

Thus, 2019 imports were reduced (10.806 tonnes) in comparison with those of 2018 (11.002 tonnes), returning almost back at 2016 levels (10.631 tonnes). Meanwhile, the strong

decreasing trend in CO_2e observed since 2016 reflects a shift to gases with lower GWPs given that HFCs contained in imported refrigeration, air conditioning and heat pump (RACHP) equipment have been covered by the HFC phase-down under the EU F-gas Regulation since 2017. Measured in CO_2e, 2019 equipment imports were 22% below 2018 or 38% below 2016 (see trend line of Figure 6).

HFCs make up more than 90% of F-gases imported in equipment, the remainder being almost completely unsaturated HFC-1234yf, used as the refrigerant in air conditioning equipment of vehicles. Stationary equipment for comfort cooling or heating (mostly air conditioning) is the most important category in equipment imports, representing about 80% of the total, both in tonnes and in GWP. Mobile air conditioning equipment, other refrigeration, air conditioning and heat pump equipment as well as other products and equipment are the rest of categories of EU supply in products and equipment of F-gases.

1.3.2 Exports

Bulk exports of F-gases from the EU-28 have been decreasing by almost 10% annually since 2017. Measured in CO_2e, the declining trend is less steep, with a 1% reduction in 2019 compared with 2018, following a 4% decrease the year before (**Figure 7**). There are different trends for different gases: 2019 HFC exports are about 25% lower than in 2017. For other gases, mostly SF_6 and unsaturated HFCs and HCFCs, 2019 exports are about 20% higher than in 2017. In particular, the rise in SF_6 exports compensates for reductions in HFC exports when assessing trends in total bulk exports on a GWP basis. Exports of F-gases contained in products and equipment are not subject to obligatory reporting.

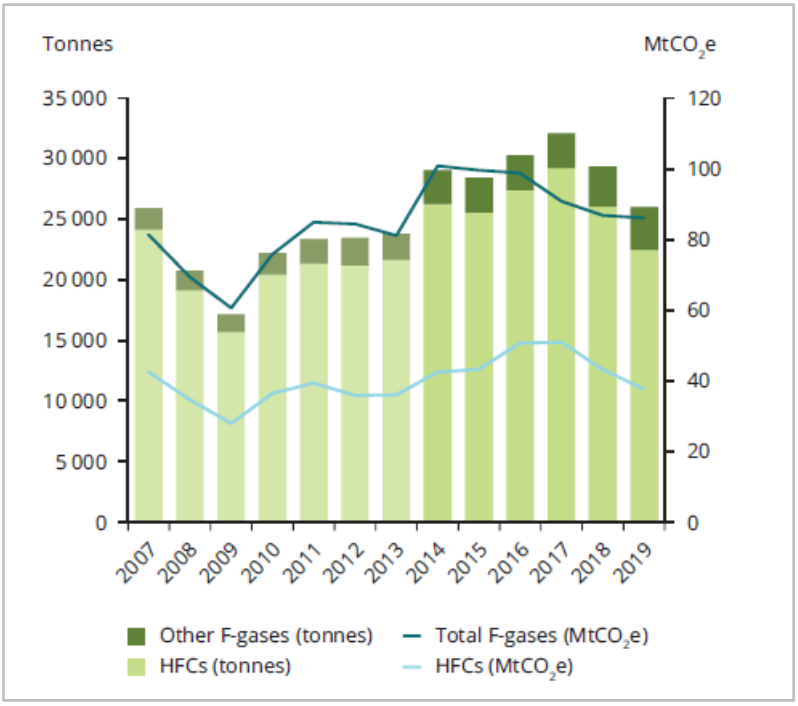


Figure 7: EU bulk exports of F-gases[3].

1.4 Progress of the HFC phase-down

Starting in 2015, the amount of hydrofluorocarbons (HFCs) being placed on the EU market annually is capped to a limited HFC quota, which is being progressively reduced ("EU HFC phase-down"). Companies deal in HFCs, they receive annual quotas which are transferrable only under certain conditions and, unlike emissions allowances under the EU Emissions Trading System (ETS), are not freely tradable [(7)].

Moreover, companies must have sufficient annual quota in order to legally place HFC bulk gases on the EU market. Hence, companies exceeding their quota face a penalty of twice the exceedance amount, applied to the subsequent quota allocation by the European Commission. Further consequences for non-compliant companies are subject to Member States legislation including criminal prosecution, depending on the severity of the non-compliance.

7. Quota allocations are set out in Article 16 and Annexes V and VI of the F-gas Regulation (EU) No 517/2014. Transfers and authorisations are regulated in Article 18. Penalties are covered in Article 25.

Quotas are expressed in carbon dioxide equivalent (CO_2e), rather than physical tonnes of gases, to create an incentive to use gases with lower GWPs. The initial total allocation in 2015 was 183,1 million tonnes CO_2e (EC, 2020). In 2016 and 2017, the first stage of reduction applied, and only 170,3 $MtCO_2e$ was allocated (93% of the 2015 allocation). Following a recalculation of the maximum quantity for 2018, which allowed for the subtraction of exempted gases as stipulated in Annex V of the F-gas Regulation (FGR), an HFC quota totalling 101,2 $MtCO_2e$ was allocated for 2018, about 40% less than for 2017. For 2019 and 2020, the maximum quantities were again recalculated to consider the latest available data on exemptions, resulting in allocations of 100,3 $MtCO_2e$ and 99,5 $MtCO_2e$, respectively (EC, 2020).

Figure 8 depicts the progress of the EU HFC phase-down [(8)] based on company-level data concerning amounts of bulk HFCs placed on the market and the quotas held by these companies. Beginning from 2017, the HFCs contained in RACHP equipment have also been covered by the quota mechanism. In order to import such equipment, importers must acquire authorisations to use quota from quota-holding companies. Notably, it is the sale of authorisations by the quota holder and not the actual import of RACHP equipment by the authorised party that counts as placing on the market (POM) for the purpose of the annual quotas.

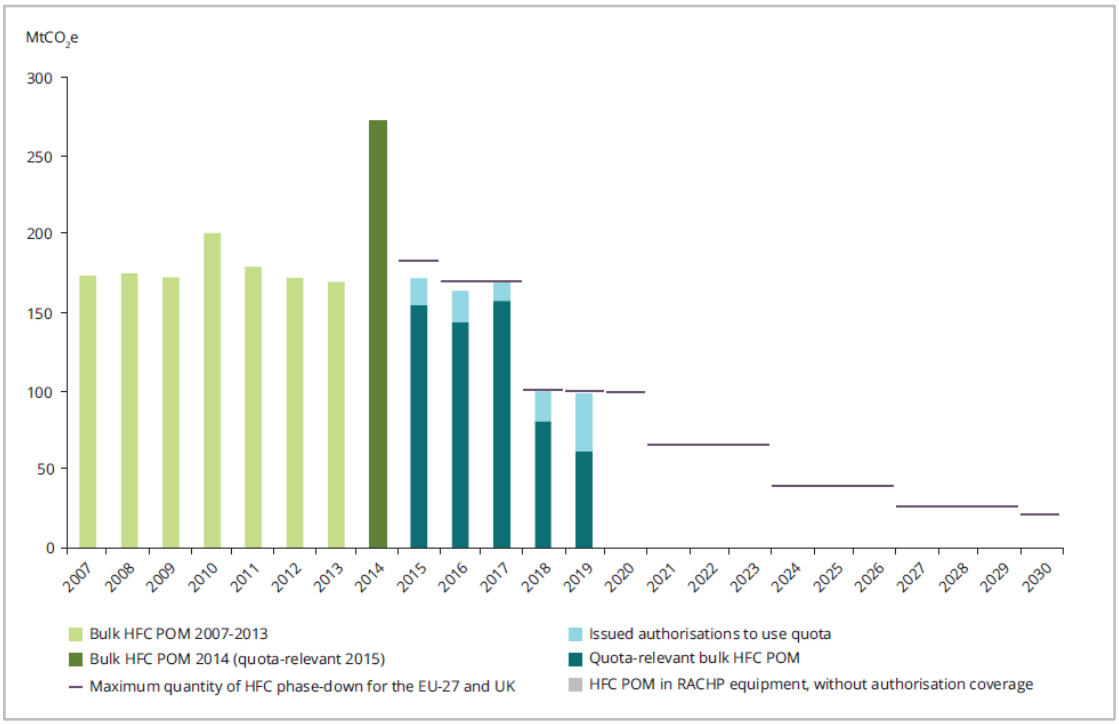


Figure 8: Progress of the EU HFC phase-down, including the imposed annual allocations[(3)].

8. After the United Kingdom's withdrawal from the EU on 31 January 2020 (Brexit), the F-gas Regulation and the EU HFC phase-down continue to apply in the United Kingdom until the end of the Brexit transition period (which is scheduled for 31 December 2020). For the period after the transition period, maximum quantities for the EU-27 will need to be recalculated.

Otherwise, authorisations do not expire at the end of a year and can be used in subsequent years [(9)]. Therefore, equipment imports can physically occur in a later year, while the sale of authorisations must be covered by the quota for the year of the sale. As it can be seen in Figure 8, issued authorisations are already considered in relation to bulk POM. It is noted that the Quota-relevant POM estimations do not include amounts of HFCs placed on the market under the exemptions of Article 15(2) of the F-gas Regulation. The exemptions for HFCs supplied to bulk export, to the production of pharmaceutical metered dose inhalers (MDIs) and to feedstock use are quantitatively the most relevant.

Additionally, **Figure 9** shows how the EU-wide overachievement breaks down into quota compliance at company level: in 2015 and 2016, the sum of unused quotas was much larger than the quota exceedances observed for some companies. In 2017, 2018 and 2019, the margin was much closer, especially as non-compliant RACHP equipment importers are also considered. It should be underlined that data on the 2019 quota exceedance for both bulkHFCs and equipment importers are preliminary and have not yet undergone in-depth compliance scrutiny by the European Commission.

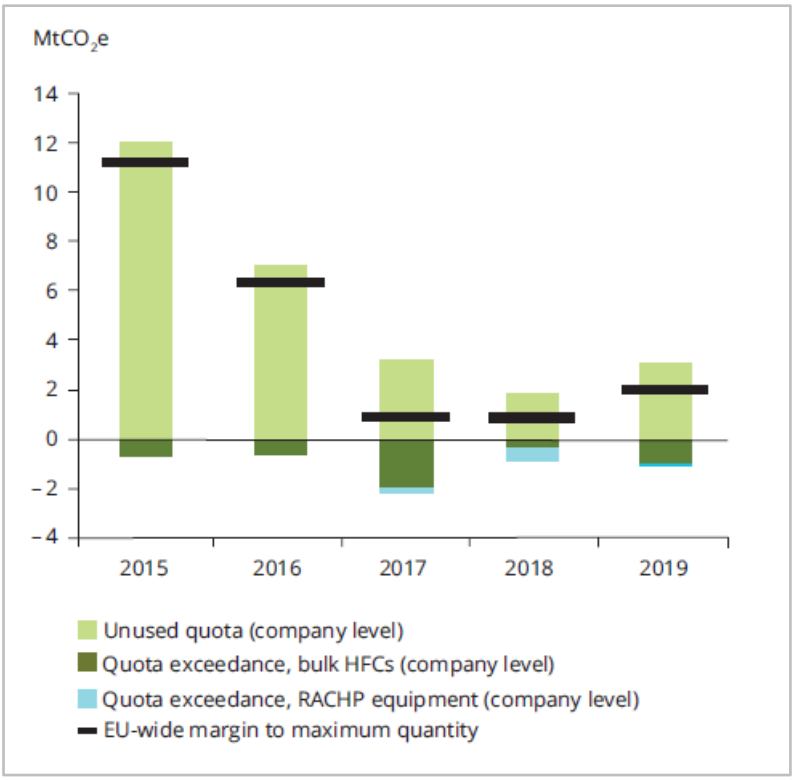


Figure 9:Balance between placing on the market of HFCs and related quotas at EU level[3].

9. In contrast to authorisations, quotas are time-stamped for a specific year and unused quotas cannot be carried over to the following year.

Given that HFCs contained in imported RACHP equipment have been included in the EU HFC phase-down since 2017, equipment importers, as mentioned above, have needed to hold authorisations to use quotas issued by HFC producers or bulk importers that were allocated quotas by the European Commission. **Figure 10** compares the authorisations issued since 2015 with authorisations used since 2017.

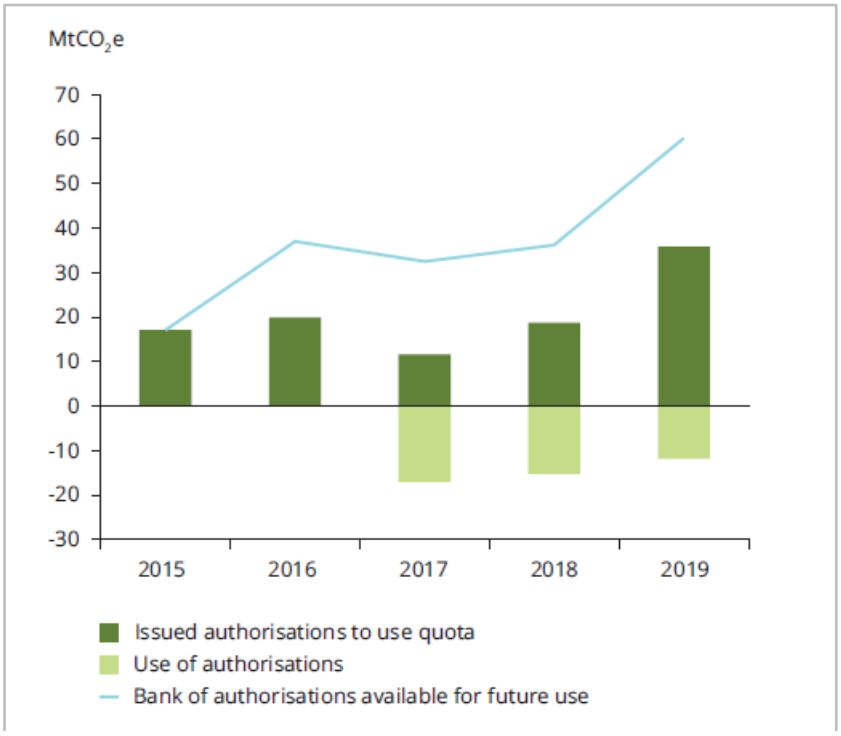


Figure 10: Bank of authorisations for HFCs in RACHP equipment imports[3].

The difference between authorisations issued and authorisations used results in a bank of authorisations stockpiled by equipment importers. By the end of 2019, this bank of stockpiled authorisations amounted to five times the amount of authorisations used in 2019. This is because the amount of authorisations issued in 2019 was about twice the amount in 2018. At the same time, the use of authorisations, which is equivalent to the lawful import of HFCs in RACHP equipment, declined by 22%.

Consequently, the reserve of authorisations built up by the end of 2019 is equivalent to 61% of the 2020 maximum quota allocation and can be used to cover equipment imports in 2020 and future years under the EU HFC phase-down, because acquired authorisations are not earmarked for a particular year. At the same time, this accumulated reserve of authorisations reduces the overall strain on quotas issued for the following years, as RACHP equipment imports in those years will, at least partially, not need to be covered by quotas issued for those years.

2 The implementation of LIFE 3R project into EU's F-gas marketplace

2.1 Demo countries

LIFE 3R project will initially be developed in 3 EU countries, representing the 5% of the population of the EU-28countries: i) **Slovakia (SK)** of 5,45Mhab, ii) **Czech Republic (CZ)** of

10,64Mhab and iii) **Hungary (HU)** of 9,77Mhab. Via the implementation of 3R ECOSYSTEM, these countries are expected to improve their living standards in line of goal of EU by protecting the environment and encouraging job creation among others. They are the new business models designed in the project that are supposed to have very significant implications for labour market outcomes and various other aspects of the working lives of European citizens.

Furthermore, DENV and DACE are strongly connected with a network of installers and distributors in all demo countries (**Figure 11**) thanks to their Business partner's programmes like Climalife (leading UK distributor of Low GWP refrigerants), Linde Group (Refrigerants supplier) and Mitsubishi Heavy Industries Air –Conditionig Europe LTD. This DAIKIN's very high market share in these countries will contribute to the maximisation of the expected impact. It is worth mentioning that up to 72 new full-time job positions are estimated to be created during the demonstration phase for the operation and maintenance of the envisioned demo in the 3 countries: 3 new direct jobs (DENV) and 69 indirect direct jobs due to the increased recovery F-gases activity.

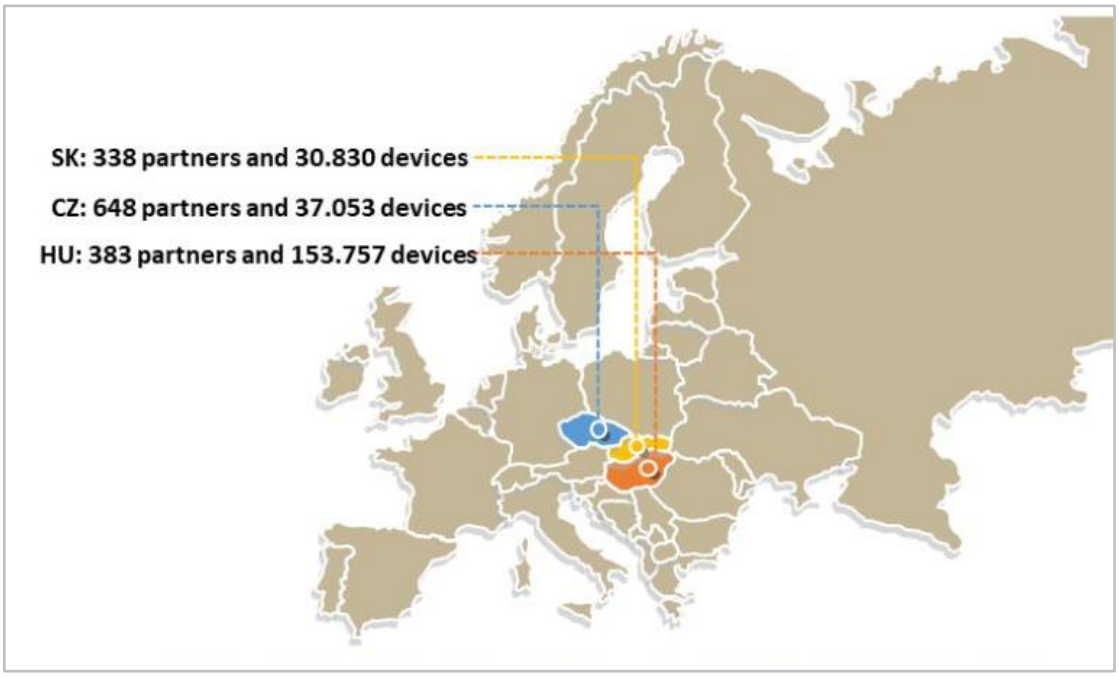


Figure 11: Demo sites and infrastructure for LIFE 3R.

2.2 Other EU countries with well-established DAIKIN network

After the trials in Hungary, Slovakia and Czech Republic, the 3R ECOSYSTEM will be rolled out in several countries in parallel in EU and outside EU. Nevertheless, the scaling of the project in all European Member States Markets is considered to be the ultimate goal. According to the relevant estimations, the replication plan above will result in the creation of 10 full time jobs (DENV) after demonstration and 562 indirect jobs, after the project when the demo is in a final version. All EU countries where DAIKIN group has a strong dealer network as well as the company's corresponding business names are summarized in **Table 1**:

Table 1: Daikin's dealer network in the EU.

	EU member country	Daikin'sbusiness name
1.	Belgium	DAB
2.	Central Europe	DACE
3.	Italy	DACI
4.	Spain	DACS
5.	France	DAF
6.	Germany	DAG
7.	Greece	DAGR
8.	Netherlands	DANL
9.	Norway	DANO
10.	Portugal	DAPT
11.	Sweden	DASW
12.	United Kingdom	DAUK

2.3 LIFE 3R contribution to EU market priorities

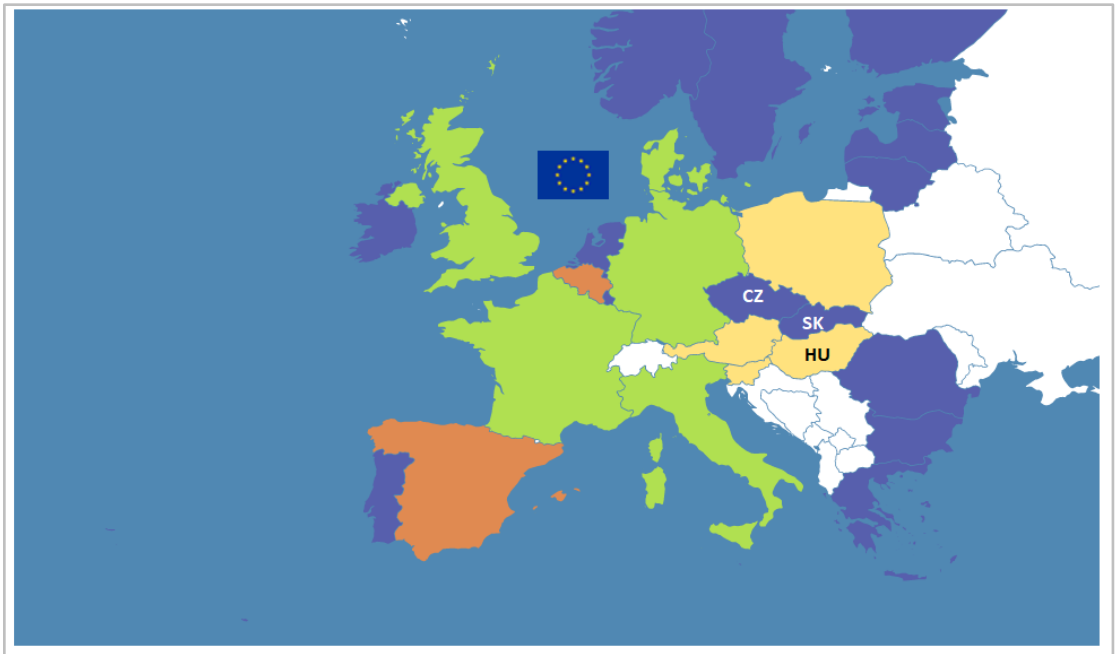
Currently, there is no common methodology or place applied for F-gas stakeholders to get in contact easily and trade refrigerants. Therefore, the development of an **innovative Self-certification scheme** is one of the LIFE 3R project main priorities, enabling both the removal of barriers existing today in HVAC-R sector as well as the efficient and reliable management of recovered F-gas within the EU market. Special emphasis is given on transparency in order to harmonise F-gases amounts, quality and prices.

LIFE 3R project also aims to the control of F-gases and the reduction of greenhouse emissions, via the implementation of an integral and economically viable f-gas **circular economy** scheme, thus providing a new sustainable business model into the European HVAC-R industry.

Otherwise, Daikin strategy involves the establishment of a high-quality refrigerant circulation economy ecosystem (3R ECOSYSTEM) with the parallel elimination of low-quality recycled refrigerant from the market. In the meantime, the proper treatment of F-gases at the end of the lifecycle of Air Conditioning and Refrigeration equipment will be secured, resulting in the:

- recovery of all refrigerants in the installed base;
- re-use through Recycling or Reclamation;
- proper disposal in case that cannot be re-used.

As shown in **Figure 12**, the demo countries have no info available (SK, CZ) or are implementation in progress (HU). LIFE 3R will assist on the progress to the implementation of the F-gas rules within the 3 demo countries that are considered to be representative enough to extract a final version applicable for the whole EU.



Legend of the map

Green: The F-gas rules have been implemented and updated requirements have been adopted
Yellow: Implementation is in progress
Orange: No progress made
Blue: No information available

Figure 12: Implementation of F-gas regulation [10].

10. EPEE-European Partnership for Energy and Environment.

2.4 Assessment LIFE 3R legal barriers in EU

After initial legal assessments in 3 pilot countries and available information from some other EU countries, the legal barriers for LIFE 3R are mostly connected to used refrigerant handling. Otherwise, there is lack of a uniform legal policy, across EU, how to define and handle the refrigerant that is recovered from the unit but it is not processed yet. The biggest issue, in the majority of the countries, is that used refrigerant is declared a hazardous waste. However, this kind of definition reduces significantly the potential of circular economy as well as restricts or even blocks refrigerants trading process not only locally but nationally and internationally, too. This is quite reasonable since hazardous waste handling requires a different, very strict approach. Below, they are summarized the legal highlights/barriers for a few of the EU countries where DAIKIN is well-established:

- **Slovakia** is probably an exception to the rule as recovered refrigerant from the unit is not immediately declared a (hazardous) waste, but represents a valuable resource. It can be re-used, traded and recycled, without legal barrier, on condition that standard records and log books must be properly maintained. Then, this kind of re-usable refrigerant is transported without special licences and may be freely transported to the recycling or collecting points as well as from collecting points to recycler.

Refrigerant becomes a waste in the moment it is declared a waste. In this case, it must be properly disposed and records about it kept.

Given the favourable national legal framework, it should be highlighted the importance of succeeding the demo roll out in Slovakia's case. This is reasonable because it is expected to act as an example-country which willmultiply the positive environmental, social and economic impacts as well as give a boost for the further development of LIFE 3R project in other EU countries, firstly in the demo ones and secondly in the rest.

- **Czech Republic** case was initially blocked by the fact, that if refrigerant is not recycled on site of recovery, a licence for hazardous waste handling must be possessed for further processing and trading with non-regenerated refrigerant is limited to companies with licences. New opinion of Ministry of Environment from January 2021, foresees free usage of the LIFE 3R platform for trading with recovered refrigerant. Installation Company is allowed to determine whether a refrigerant is suitable for re-use, and it can offer/sell it to the distributor for recycling or reclaiming. However, such distributor or collector of the refrigerant must possess all licences for hazardous waste handling, even if it is clear that refrigerant will be recycled and re-used. This fact is quite restrictive resulting in the reduction of buyers and trading potential, too. Considering that there are a few companies with licences for trading with hazardous waste, LIFE 3R will be possible to be implemented with a view to developing an innovative trading system and opening possibilities for a wider re-using of refrigerant.

- In **Hungary**, situation with F gasses is not fully clear since some gaps were discovered in the interpretation of the Hungarian legal environment. Yet, there is no legal barrier for implementing 3R platform to the market. Similar to Czech situation, key problem is handling with refrigerant since it is hazardous waste by definition. Based on existing national legislation, it is possible the recovered refrigerant to be handled and transported to a recycling company, but only for own purposes, and in small quantity (it is not defined what it means). DENV and DACE are cooperating with the Hungarian dedicated ministries and agencies in filling the gaps and defining the legal frame which will support circular economy of refrigerants.

- **Spain** as well as other EU countries indicates feasibility issues regarding the 3R ECOSYSTEM implementation. In any case, recovered refrigerant is considered a hazardous waste and complex procedures are required to obtain licences and authorisations for handling such refrigerant. Otherwise, it takes so much time to obtain all mention authorizations that a realistic estimation is between 12 to 24 months. The cost only for the paperwork needed would be around 25.000,00 €. Although this is not all what needs to be done in preparation phase, it represents a serious barrier for refrigerant re-use, recycling or any other similar action crucial to enabling circular economy of refrigerants.

- In **Germany**, Daikin Chemical Europe owns one of two EU distillation facilities for reclamation of refrigerants (another one is in Netherlands, and one more is being built in Poland, also through LIFE funding[(11)]) and so it can be easily confirmed that there

are similar barriers as well as special licences are required to recycle/reclaim used refrigerant. Refrigerants suitable for reclamation which are imported for the purpose of filling in the capacities, they are referred as hazardous waste (complex authorisation procedures are required). Hence, this determination complicates the flow of refrigerant which might be re-used and also acts as an obstacle for processing larger, international quantities (coming to other EU countries) to be reclaimed.

The removal of barriers like these above is expected to enable even international trading/transporting of refrigerant suitable for reclamation. Therefore, Daikin Group via 3R ECOSYSTEM aims to take advantage of existing resources thus opening additional trade potential and business opportunities for Medium-Sized Enterprises (SMEs), under the circular economy requirements applied by EU.

Moreover, regulating in-country refrigerant handling, according to Slovakia's example, would further encourage business with used refrigerants as well as it would support the whole range of stakeholders in the F-gas sector to learn to make use of existing resources, protecting at the same time the environment.

11.https://life-prozon.eu/en/about-the-project/actions

However, the export or import of such refrigerant to/from non-EU countries is a critical factor that should be paid attention to. Any relaxations in the legal system regarding the characterization of refrigerant as hazardous waste or not must be carefully imposed, so as not to pose a potential threat especially for exporting refrigerant to other countries, where control and record keeping is not so accurate and defined as in EU.

3 F-gases recovery and CO_2 emissions reduction potential

3.1 General assumptions

First of all, HVAC-R (heating, ventilation, air conditioning and refrigeration) systems have been classified according to **Table 2**. They have been assumed four (4) basic types of units: Residential, Commercial, Industrial and Super Market.

Table 2: Simple and high-level classification of HVAC-R units.

Category	*Classification*	*High level classification*
SPLIT	Small Residential Units	Residential
SKY AIR	Commercial light unit	Commercial
VRV	Big Commercial unit	Commercial
PACK	Commercial light unit	Commercial
CHILLER MINI	Commercial light unit	Commercial
CHILLER SMALL	Commercial light unit	Commercial
CHILLER MEDIUM	Big Commercial unit	Industrial
CHILLER LARGE	Big Commercial unit	Industrial
CHILLER CENTRIFUGAL	Big Commercial unit	Industrial
AHU	NA	NA
REFR-Stationary<CCU	Commercial light unit	Super Market
REFR-Stationary<CVP	Big Commercial unit	Super Market
REFR-Stationary<ZEAS	Big Commercial unit	Super Market
H H/P	Small Heat Pumps	Residential
H BOILER	NA	NA

After that, the basic information for each unit category (charge, average life of equipment and renovation rate) is depicted in **Table 3**:

Table 3: Basic information for each unit category.

Type of Unit	Charge (Kg/unit)	Average life of Equipment (years)	Renovation Rate (%)
Small Residential Units	*1,5*	*10*	*10*
Commercial light unit	*2,9*	*10*	*15*
Big Commercial unit	*18,8*	*15*	*20*
Small Heat Pumps	*4,0*	*10*	*10*
Industrial units	*300,0*	*10*	*25*
Super Markets			*45*

Finally, all estimations for both F-gases recovery and CO_2 reduction rates are based on the following basic assumptions:

1. Split units are considered with R410a.
2. Sky air is considered with R410a and also with 0,5 kg of extra charge.
3. VRV is considered as a 10HP unit with additional charge of ½ the precharged.
4. Industrial and small heat pumps are rough estimation of the market.
5. F-gases GWP is considered to be equal to this of R410a: 1 ton of F-gas=2.087,5 tonnes of CO_2.

3.2 Calculations

3.2.1 LIFE 3R's demos (SK, CZ, HU)

LIFE 3R's demos will involve a total of 221.640 AC devices, including residential, commercial, industrial and supermarket units. The world AC demand was estimated at 110,97 million units in 2018 by the Japan Refrigeration and Air Conditioning Industry Association, so the demos envisaged in LIFE 3R represent a 0,2% of this world demand, which is very representative at this scale. This means 441.923 Kg of F-gases per year. Considering the average life of each type of equipment, the total estimation of installed F-gases in the three demo countries is 7.640 tonnes, translated into 16 million tonnes of CO_2. Detailed calculations are shown in **Table 4**:

Table 4: Estimation of installed base for both f-gases and CO2 emissions.

Country	*Type of unit*	*Units (pieces/year)*	*Total f-gas* (kg/year)*	*Estimation of installed base** (tons refrigerant)*	*Estimation of installed base (million tons $CO_{2,e}$)*
Slovakia (SK)	*Small Residential Units*	*27.630*	*41.445*	*414*	*0,87*
	Commercial light unit	*2.500*	*7.250*	*73*	*0,15*
	Big Commercial unit	*700*	*13.125*	*197*	*0,41*
	Small Heat Pumps	*2.085*	*8.340*	*83*	*0,17*
	Industrial units	*45*	*13.500*	*135*	*0,28*
	Super Markets		*27.600*	*138*	*0,29*
	Total f-gas	*30.830*	*61.820*	*1.040*	*2,17*
Czech Republic (CZ)	*Small Residential Units*	*27.000*	*40.500*	*405*	*0,85*
	Commercial light unit	*7.529*	*21.834*	*218*	*0,46*
	Big Commercial unit	*2.524*	*47.325*	*710*	*1,48*
	Small Heat Pumps	*2.325*	*9.300*	*93*	*0,19*
	Industrial units	*200*	*60.000*	*600*	*1,25*
	Super Markets		*69.000*	*345*	*0,72*
	Total f-gas	*37.053*	*109.659*	*2.371*	*4,95*
Hungary (HU)	*Small Residential Units*	*144.194*	*216.291*	*2.163*	*4,52*
	Commercial light unit	*4.430*	*12.847*	*128*	*0,27*
	Big Commercial unit	*2.203*	*41.306*	*620*	*1,29*
	Small Heat Pumps	*2.680*	*10.720*	*107*	*0,22*
	Industrial units	*250*	*75.000*	*750*	*1,57*
	Super Markets		*92.000*	*460*	*0,96*
	Total f-gas	*153.757*	*270.444*	*4.228*	*8,83*
	Total f-gas in Trial Countries	***221.640***	***441.923***	***7.639***	***15,95***

* Total = (Units) x (Charge)

** Estimation of installed base (tons refrigerant) = (Total) x (Average of life)

Thus, considering the average renovation rate of each sector, the estimated recovered F-gas during the LIFE 3R project is approximately 1.490 metric tonnes of F-gases, a figure that is equivalent to almost 3,1 million CO_2 tonnes. The breakdown per demo as well as the totals of recovered F-gases and CO_2 emissions savings can be checked in **Table 5**:

Table 5: Breakdown per demo and totals of recovered F-gases and CO2 emissions savings.

	SK: F-gas recovered via 3R		***CZ: F-gas recovered via 3R***		***HU: F-gas recovered via 3R***		**Total recovered via 3R**	
	tons F-gas	*tons CO2,e*	*tons F-gas*	*tons CO2,e*	*tons F-gas*	*tons CO2,e*	*tons F-gas*	*tons CO2,e*
Small Residential Units	*41,4*	*86.516*	*40,5*	*84.544*	*216,3*	*451.507*	*298,2*	*622.568*
Commercial light unit	*10,9*	*22.702*	*32,8*	*68.368*	*19,3*	*40.227*	*62,9*	*131.297*
Big Commercial unit	*39,4*	*82.195*	*142,0*	*296.373*	*123,9*	*258.680*	*305,3*	*637.249*
Small Heat Pumps	*8,3*	*17.410*	*9,3*	*19.414*	*10,7*	*22.378*	*28,4*	*59.202*
Industrial units	*33,8*	*70.453*	*150,0*	*313.125*	*187,5*	*391.406*	*371,3*	*774.984*
Super Markets	*62,1*	*129.634*	*155,3*	*324.084*	*207,0*	*432.113*	*424,4*	*885.831*
Total	*195,9*	*408.910*	*529,8*	*1.105.908*	*764,7*	*1.596.312*	**1.490,4**	**3.111.129**

3.2.2 Daikin's total target at EU wide level

As it has been referred before, DAIKIN group already has a strong dealer network in many EU countries like France, Italy, Spain, Greece, Belgium, Netherland, Germany, Portugal, Sweden, Norway, UK and others (see Table 1). Based on company's data for 2021, the total F-gas installed base in all these countries is a little less than 87.935 tonnes (equivalent to 183,5 million tonnes of CO_2). The relevant recovered base due to LIFE 3R project is calculated at almost 11.485 tonnes of f-gases (including UK), respectively. All the information above is extensively presented in **Table 6**:

Table 6: Installed and renovated base for EU countries with well-established DAIKIN network (2021 estimate).

Daikin's business name	Estimation of installed base (tons refrigerant)	Estimation of installed base (tons $CO_{2,e}$)	Estimation of renovated base (tons refrigerant)
DAB	*1.992,7*	*4.159.670*	*358,2*
DACE*	*14.537,2*	*30.346.395*	*2.500,9*
DACI	*19.697,0*	*41.117.555*	*1.793,6*
DACS	*12.850,2*	*26.824.814*	*1.276,7*
DAF	*13.874,1*	*28.962.197*	*1.768,0*
DAG	*7.437,6*	*15.525.996*	*1.865,4*
DAGR	*4.298,9*	*8.974.035*	*356,8*
DANL	*2.093,3*	*4.369.732*	*245,9*
DANO	*NA*	*NA*	*NA*
DAPT	*2.436,7*	*5.086.533*	*233,5*
DASW	*1.124,3*	*2.346.937*	*124,7*
DAUK	*7.592,4*	*15.849.021*	*961,2*
Total (with UK)	***87.934,4***	***183.562.885***	***11.484,9***
Total(without UK)	***80.342,0***	***167.713.864***	***10.523,7***

*DACE EU countries: Slovakia, Czech Republic, Hungary, Austria, Slovenia, Croatia, Romania, Bulgaria

Regarding renovated base, the total result has been extracted by including residential, commercial, industrial as well as supermarket units. The percentage contribution of each of them to the total recovered amount of F-gas, is depicted in **Figure 13**. It is noted that United Kingdom has been taken into account for the relevant calculations.

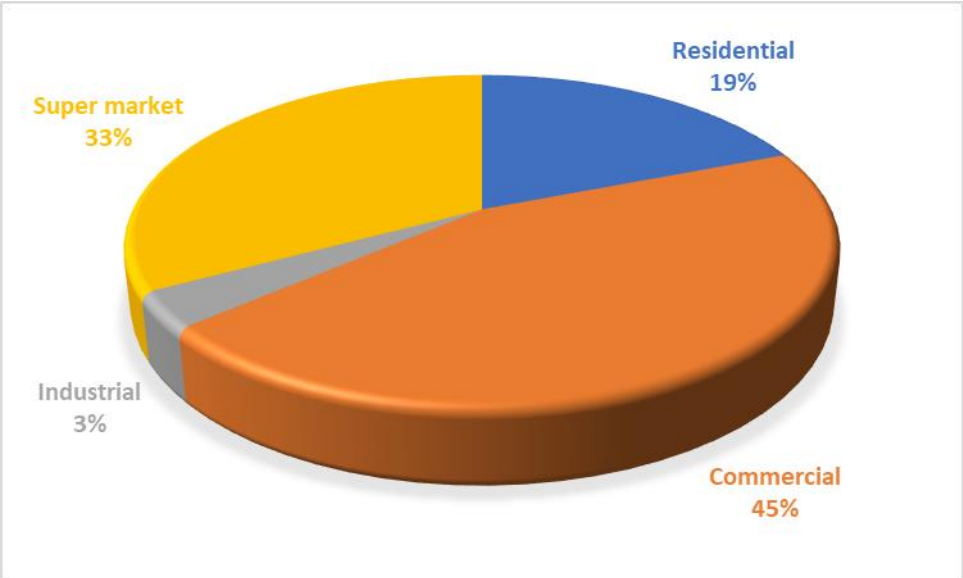


Figure 13: Percentage contribution of residential, commercial, industrial and supermarket units to F-gas renovated base as regards as EU countries with well-established DAIKIN network (2021 estimate).

4 Conclusions

The current F-gas market status in the EU as well as the quantitative and qualitative objectives (levels of refrigerant recovery/reduction of carbon dioxide emissions, new job positions, etc.) of the application of the 3R project in 3 demo-countries (SK, CZ, HU) on the one hand and subsequently on the other hand, in the majority of other EU member countries, is the subject of interest in this deliverable.A basic estimation is that the final version of 3R project is capable of limiting theannual bulk imports in the range of 20% by mass when being scaled to all European Member States Markets. Preventing greenhouse gas emissions as well as mitigating dependence in bulk gases by non-European countries (mainly from China, United States and Japan) are some other positive aspects, too.

Overall, it is expected that all the information included in the report, will play a guiding role in the implementation of the next deliverables belonging to C4 category of LIFE 3R. These are:

- Exploitation strategy.
- Transferability and IPR analysis.
- Updated Business plan.
- Replication and transferability plan.