Support contract for an Evaluation and Impact assessment for amending Regulation (EU) No 517/2014 on fluorinated greenhouse gases

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Abbreviations

AC	Air Conditioning
AnaFgas model	Model named „Analysis of t fluorinated greenhouse gases in the EU'
AR	Assessment Report of the IPCC
AREA	European association of refrigeration, air conditioning and heat pump contractors
BAT	Best available techniques
BAU	Business-as-usual
BDR	Business Data Repository
BL scenario	Baseline scenario
BMU	German Federal Ministry of Environment, Nature Conservation and Nuclear Safety (Bundesministerium für Umwelt, Naturschutz und nukleare Sicherheit)
BRG	Better Regulation Guidelines
CDEA	Central Database of Emissions to Air
CDM	Clean Development Mechanism
CF scenario	Counterfactual scenario
CFC	Chlorofluorocarbon
CORAP	Community rolling action plan
CRF	Common Reporting Format
DE	Disposal emissions
DG CLIMA	Directorate-General for Climate Action
EEA	European Environment Agency
EIA	Environmental Investigation Agency
EPEE	European Partnership for Energy & the Environment (industry association)
EPR schemes	Extended producer responsibility schemes
ETC/ACM	European Topic Centre on Air Pollution and Climate Change Mitigation
ETC/CME	European Topic Centre on Climate Change Mitigation and Energy
EU	European Union
EU ETS	EU Emissions Trading System
F-gases	Fluorinated gases
FDIS	Final Draft International Standard
FDM	Food, Drink and Milk industry
FEA	Aerosol industry association
GDP	Gross domestic product
GHG	Greenhouse gas
GIZ	Deutsche Gesellschaft für Internationale Zusammenarbeit
GVA	Gross value added
GWP	Global Warming Potential
HCFC	Hydrochlorofluorocarbon
HCFO	Hydrochlorofluoroolefine
HFC	Hydrofluorocarbon
HFE	Hydrofluoroether

HFO	Hydrofluoroolefine
IA	Impact Assessment
IPCC	Intergovernmental Panel on Climate Change
ISG	Interservice Group
JI	Joint Implementation
LE	Lifetime emissions
MAC	Mobile air conditioning
MDI	Metered-dose inhaler
ME	Manufacturing emissions
MEPS	Minimum energy performance standards
MMR	Monitoring Mechanism Regulation
MOP	Meeting of the Parties
MP	Montreal Protocol on Substances that Deplete the Ozone Layer
MRV	Measuring, Reporting and Verifying
NACE	Statistical classification of economic activities in the European Community
NGO	Non-Governmental Organisation
NIR	National Inventory Report
ODS	Ozone-Depleting Substance
OPC	Open public consultation
PFAS	Per- and polyfluorinated fluoroalkyl substances
PFC	Perfluorocarbon
POM	Placing on the market
QA	Quality Assessment
RAC	Refrigeration and Air Conditioning Sectors
RACHP	Refrigeration, Air Conditioning and Heat Pump Sectors
SME	Small and Medium-sized Enterprise
SVHC	Substance of very high concern
TFA	Trifluoroacetic acid
TFEU	Treaty on the Functioning of the European Union
TFF	Trifluoroacetylfluoride
UBA	Federal German Environment Agency (Umweltbundesamt)
UNEP	United Nations Environment Programme
UNFCCC	United Nations Framework Convention on Climate Change
UNIDO	United Nations Industrial Development Organisation
VA	Value Added
VRF	Variable refrigerant flow
WAM scenario	Scenario with additional measures (Schwarz et al. 2011)
WFD	Waste Framework Directive
WM scenario	Scenario with measures (Schwarz et al. 2011)
XPS foam	Extruded polystyrene foam

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Abstract

This report presents the findings of 'Task 2: Evaluate current EU F-gas policy' under the Support contract for an Evaluation and Impact Assessment for amending Regulation (EC) No 517/2014 on fluorinated greenhouse gases (hereinafter: 'Regulation'). The study involved a detailed review and analysis of available literature and datasets. The study also gathered evidence and views from EU Member States, industry, NGOs and other stakeholders on the functioning of the Regulation through an open public consultation, targeted stakeholder interviews and workshop. This report summarises the evidence base and presents the consultants' conclusions as input to the Commission's Staff Working Document. The analysis is structured under the five evaluation themes of effectiveness, efficiency, relevance, coherence and EU added value, and the eleven more detailed evaluation questions (and multiple sub-questions) under these themes. Conclusions are drawn about the overall performance of the Regulation, what progress has been made towards its objectives and whether they are still relevant for the current needs of the EU. Issues and challenges associated with implementation of the Regulation have also been captured to present a comprehensive set of lessons learned to inform the impact assessment task under the same support study contract.

Confidentiality disclaimer

All data related to Article 19 of the Regulation assessed for this report has not been assessed related to the confidentiality criteria applied by the European Environment Agency (EEA) to determine eligibility for the EEA's public reports. However, as the present report provides data primarily in form of graphics rather than in data tables, confidentiality may possibly be considered less critical. Where this data has been used it has been sourced as follows: (data source: [EEA 2020 confidential dataset]).

Executive summary

Introduction to the evaluation

This report presents the findings of 'Task 2: Evaluate current EU F-gas policy' under the Support contract for an Evaluation and Impact Assessment for amending Regulation (EC) No 517/2014 on fluorinated greenhouse gases.

The Regulation (EU) No 517/2014 (hereinafter: 'the Regulation') sets out several measures to reduce use and emissions of fluorinated greenhouse gases ('F-gases'). The fluorinated gases are hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), sulphur hexafluoride (SF_6) as well as other fluorinated compounds. All of them contribute to climate change as they exhibit high global warming potentials (GWP) once emitted to the atmosphere. The measures set out in the F-gas Regulation include limits for the placing on the market of HFCs, placing on the market bans for products and equipment containing or relying on F-gases as well as containment and recovery measures, certification, reporting and verification. The Kigali Amendment to the Montreal Protocol on Ozone Depleting Substances that came into effect in 2019 controls production and consumption of HFCs on international level and sets an additional framework globally.

The evaluation of the Regulation appraises its functioning to help assess whether the instrument is fit for purpose. In line with the Commission Better Regulation Guidelines and Toolbox, the evaluation assesses the effectiveness, efficiency, coherence, relevance and EU added value of the Regulation in contributing to the reduction of F-gas emissions and demand in the EU. This evaluation also fulfils Article 21(2) of the Regulation which requires the EU Commission to publish a comprehensive report on the effects of this piece of legislation no later than 31 December 2022. The results of the evaluation feed into the parallel impact assessment task (Task 3 under the same study contract) 'Develop options and recommendations for the review of the regulation and assess their impacts'. The evaluation and impact assessment have been undertaken 'back-to-back', with central tasks such as the consultation of stakeholders running in parallel.

Methodology

To support the delivery of the evaluation, the methodology has closely followed the guidance on undertaking Evaluations and Fitness Checks outlined in the Better Regulation Toolbox and has assessed the Regulation against five key evaluation criteria:

1. **Effectiveness:** how successful EU action has been in achieving or progressing towards the original objectives of the intervention.
2. **Efficiency:** how proportionate the benefits of the Regulation have been to the costs.
3. **Relevance:** whether the original objectives of the intervention are still representative of the current needs of society.
4. **Coherence:** identify any internal gaps, overlaps, inconsistencies or complementarities within the F-gas policy framework but also externally with other EU/international policies.
5. **EU added value:** where the implementation of the Regulation at EU level has exceeded the value, which could have been achieved at Member State level.

This report has covered all elements of the Regulation and supporting implementing Regulations and covers the period from 2015 to 2020 (or year for which latest data is available).

The process of evidence gathering involved literature research, stakeholder consultation and modelling. With respect to stakeholder engagement: an open public consultation (OPC) was held from September to December 2020 and provided the possibility for anyone to provide input to the study; targeted interviews have been performed to gather in-depth insights from key stakeholders, and a workshop was held on 6 May 2021.

Key findings under each evaluation criterion

Effectiveness

Overall findings: The Regulation has been mostly effective in meeting its original objectives and the individual measures were found to work together to meet the objectives. The effectiveness of the Regulation as a whole would have been impacted if one or more of the measures had not been included. That said, forward modelling indicates that the original climate goals set for 2030 may not be fully reached. In addition, there are a few challenges such the continued use of some high global warming potential (GWP) F-gases in some sectors where this could be avoided, the occurrence of illegal trade and the multiplication of bulk importers.

The overall objective of the Regulation was to provide a cost-efficient contribution to reach the EU's previous climate targets, i.e. to reach at least a 60% emission reduction by 2030, based on 2005. To facilitate this, the Regulation targeted four objectives. The degree to which these four objectives were met is summarised below.

Objective 1: Discourage the use of F-gases with high GWP in the EU and encourage the use of alternative substances or technologies when they result in lower GHG emissions without compromising safety, functionality and energy efficiency

Use and replacement of HFCs

The supply of hydrofluorocarbons (HFCs) has declined by 37% in tonnes and 47% in terms of CO_2 eq from 2015 until 2019. In contrast, the supply of unsaturated HFCs and HCFCs (synthetic alternatives to HFCs with very low climate impact) has grown to about 18 000 tonnes in 2019, reflecting the role of these substances as HFC substitutes. A significant share of the decline in HFC supply was due to a lower use of a few key high GWP HFCs and HFC mixtures (R134a, R404A and R410A). While the amounts of HFCs contained in imported products and equipment have remained rather constant since 2016, the GWP of these HFCs dropped by 33 % until 2019. As regards the gases exempted from the phase-down, the HFCs amounts in CO_2 eq for the use of metered dose inhalers (MDIs) increased by about 45% in that period.

There has been a shift to F-gas alternatives with lower GWP as well as natural alternatives, as demonstrated by the annual decline in CO_2 eq as of 2016. For the users, natural refrigerants such as CO_2, propane and ammonia have the advantage that they are not restricted in any way under the Regulation. However, there has also been a shift to lower GWP HFCs and mixtures containing HFCs and unsaturated HFCs (e.g. from R410A to R32 in split air conditioning systems; from R404A partly to R448A/R449A in commercial refrigeration). Transition is also going on in all other HFC using sectors. The HFC phase-down has also influenced the reclamation of F-gases in the EU, resulting in a low, but steady increase of these activities.

The most important measures for meeting this objective are the HFC phase-down as well as placing on the market (POM) and use prohibitions that have worked together to discourage the use of F-gases with high GWP.

By design, the HFC phase-down restricts supply which implies price increases for HFCs. Prices of high GWP HFCs increased significantly in mid-2017 and early 2018 until reaching a peak of 6 to 13 times higher than the original price in 2015. These observed price increases for the different HFCs roughly reflected their GWP and were passed on from the upper to the lower levels of the refrigerant supply chain. Prices of high GWP HFCs today (4th quarter 2020) continue to be 0.5-4 times (gas distributor purchase prices in 2020, depending on the HFC) higher than the world market and therefore continue to be an incentive for innovation. In contrast, prices for alternatives that are not covered by the phase-down have remained rather stable and natural alternatives have not seen any price increases which has made climate-friendly technologies more competitive.

The POM and use prohibitions were implemented successfully and have been observed to be effective. According to Article 19 F-gas reporting data, supply and/or equipment imports for respective applications have declined reflecting the implementation of these measures. This is partly related to the fact that the prohibitions have been easily understood by industry and end-users. For fire protection and technical aerosols, prohibition dates already passed. For moveable and split air conditioning systems as well as foam products, the implementation is found to be on track while the prohibition dates are still in the future. On the other hand, there has been technological process in certain areas that are not covered by prohibitions, resulting in suitable alternatives being available but not yet widely used. Also, some emissive types of uses were not considered during the review of the previous Regulation, e.g. uses of HFCs for cooling skin in beauty clinics and in inhalation anaesthetics.

While demand and thus emissions of F-gases are declining, forward modelling indicates that the 2030 goals set for the Regulation may not be fully reached by the current Regulation.

While the extensive shift to climate-friendly technologies clearly demonstrates the effectiveness of the phase-down with accompanying prohibitions, there are also a number of challenges. First there are unjustified barriers to the use of climate-friendly alternatives that relate to safety codes that have not be updated in line with technological progress. Second, an insufficient number of service personnel qualified to install equipment with climate-friendly alternatives may have reduced the uptake of such technologies. Third, there is evidence of imports of HFCs outside the quota system although it is not feasible to provide an accurate estimate of the extent of these illegal activities. A number of actions to prevent the latter activities are ongoing, including by industry itself, but there is also scope for changes to the Regulation to better facilitate enforcement and border controls.

Fourth, some company owners with several affiliates (including actors setting up and registering multiple undertakings), benefit disproportionately from the reserve[1] by getting multiple quota shares. As a consequence, the number of bulk importers increased by a factor of more than twenty between 2012 and 2019. The Commission adopted an Implementing Regulation[2] in 2019 that clarified the quota allocation rules in accordance with the F-gas Regulation which resulted in a decrease in the number of applications for quota from the new entrant reserve for 2020 and 2021. Still, there appears to be a large number of quota holders with no apparent link to the F-gas business. This results in very low quota shares from the reserve to new companies actually trading in gases. Also, it makes it more challenging to prevent illegal imports.

While substances replacing HFCs generally have a negligible GWP, and thus contribute to climate change mitigation, for a few of the replacement substances there may be some undesirable environmental effects that require further monitoring. This relates mainly to the generation of environmentally persistent and accumulative trifluoroacetic acid (TFA) as a breakdown product of unsaturated HFCs in the atmosphere and its subsequent accumulation in the aqueous environment. Furthermore, high-GWP degradation products have lately been identified in the atmosphere as well. These alternative substances, listed in Annex II of the Regulation, are currently not covered by measures that aim at preventing their emissions.

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[1] The HFC phase-down allocates a reserve of HFC quota to new market entrants without previous HFC import or production activity.

[2] Commission Implementing Regulation (EU) 2019/661 of 25 April 2019 ensuring the smooth functioning of the electronic registry for quotas for placing hydrofluorocarbons on the market.

Use and replacement of PFCs and SF_6

Although, perfluorocarbons (PFCs) and sulphur hexafluoride (SF_6), which are used in electrical equipment, semiconductors, photovoltaics and other electronics manufacture, accounted for only 1 % of the EU F-gas supply (in tonnes) in 2019, they represented 18 % in terms of CO_2 eq. However, despite their very high GWP (ranging from 7,000 to 23,000) their use is only restricted for specific applications. Especially in the case of SF_6, alternatives have been developed and intensively researched or even placed on the market over the past years, but the Regulation is not promoting the deployment of those new alternatives. Consequently, for these gases the Regulation was less effective.

Other aspects

The Regulation does not prevent Member States from maintaining or introducing more stringent measures at national level. Some Member States have already implemented additional measures such as tax schemes (e.g. Denmark, Spain), additional requirements for F-gas related customs controls (e.g. Estonia) or leakage checks (e.g. Portugal, Sweden), additional national reporting requirements (e.g. Czech Republic, Estonia, Poland) or measures to support the market uptake of low GWP alternatives (e.g. Finland, Germany, Sweden), while others intend to do so (e.g. Bulgaria, France).

Reporting and verification have been key indicators of the Regulation's success. Data reported under the Regulation were mostly found to provide a reliable basis for monitoring how the EU industries reacted to the intervention.

Independent verification is crucial for effective compliance checks. However, given the strong increase in undertakings applying for new entrants' quota, the amount of quota allocated per company from the reserve in 2019 dropped below the threshold of 10,000 tonnes of CO_2 eq fixed in the Regulation for mandatory verification for HFC producers and importers. This resulted in a gap where 8 % of amounts reported to be placed on the market are not subject to mandatory verification and thus to verify if they had imported higher amounts than reported other less effective actions had to be taken, e.g. inspections. Furthermore, the mandatory verification obligation is not very prescriptive, thus the quality of reports provided by undertakings varies. There is evidence from the stakeholder consultation that the reporting and verification requirements have caused additional administrative costs for businesses. This is further outlined in the 'Efficiency' section.

All Member States have introduced penalties for infringements of the Regulation. However, penalties vary from one Member State to the other and in some cases their level may not be proportionate to the economic gains of illegal activities. This implies that the same violation for importing illegally into the EU single market is penalised differently depending on in which Member State the goods enter. Moreover, the different judicial approaches and legal mechanisms related to the penalties are making it difficult to ensure that penalties in all Member States serve the purpose of being dissuasive. Although some Member States have established equipment registers, data from these systems are not (yet) commonly used for the UNFCCC reporting. However, strengthening the EU wide data on F-gas emissions is necessary to identify potential emissions sources and their significance.

Objective 2: Prevent leakage from equipment and proper end of life treatment of F-gases in applications

Prevention of F-gas leakages from equipment is key to achieving significant emission reductions. The Regulation has continued to address prevention of leakage from equipment and the provision of proper end-of-life treatment. Data available from surveys in a number of Member States have shown the importance of regular leakage checks and associated servicing activities, especially in the commercial refrigeration sector, as leakage rates have declined (further) in recent years. Enforcement and compliance with containment and leakage checks was raised as an area which required further attention to ensure effectiveness.

Current emission prevention requirements only concern F-gases listed in Annex I of the Regulation, while no such requirements apply to other fluorinated gases listed in Annex II, such as NF_3, unsaturated H(C)FCs, fluorinated ethers and alcohols and other perfluorinated compounds. Furthermore, the current prevention provisions only apply to the use of bulk gases, but not to their manufacturing, storage and transport, where leakages can also occur. Thus, for the prevention of emissions related to these gases the Regulation was less effective.

<u>Objective 3:</u> Facilitate convergence towards a potential future agreement to phase down HFCs under the Montreal Protocol

The Regulation has been very successful in meeting this objective. Prior to the implementation of the Regulation there was no international agreement in place to tackle HFC emissions globally. The EU Member States were vocal supporters and advocates of the proposed Kigali Amendment. The Regulation enabled a joint EU negotiation position and the tabling of an amendment proposal that provided crucial impetus for the negotiations. It clearly demonstrated to other Parties that ambitious action on HFCs is possible.

<u>Objective 4:</u> Enhance sustainable growth, stimulate innovation and develop green technologies by improving market opportunities for alternative technologies and gases with low GWP

The HFC phase-down has been a strong trigger for innovation aided by some prohibitions addressing single substances or specific applications. Dozens of new blends, especially mixtures consisting of HFCs and unsaturated HFCs, have entered the EU market since 2015. In addition, the number of undertakings working with natural refrigerants has increased from 400 to 650 in the period 2013 to 2016 and, for example, in the commercial refrigeration sector over 80 % of undertakings increased their levels of investment in R&D between 2011 and 2016 (Shecco, 2016). It is expected that innovation and development of green technologies will continue to grow as a result of the tightening quota system and the prohibitions that will come into effect in the coming years.

Efficiency

Overall findings: The Regulation has resulted in significant emission savings at very low abatement costs linked to technological change. At the same time higher HFC prices, due to the phase-down, implied higher gas cost to end-users that were still using HFCs. These costs were on the other hand offset by equivalent benefits to undertakings in the HFC supply chain.

The Regulation has delivered significant environmental ***benefits*** since its entry into force: it achieved savings in F-gas emissions of 44 million tonnes of CO_2 eq cumulatively until 2019 (GWPs from 4[th] Assessment Report). As for the impacts on energy consumption, stakeholders stated that higher energy efficiency was achieved with F-gas alternatives, especially in new installations, for example in transcritical CO_2 supermarket systems (energy savings of at least 10-14% annually in LIFE C4R project). Generally, new products on the market employing F-gas alternatives are achieving at least the same energy efficiency as comparable products based on F-gas technology.

The cost of technological change leading to emission savings was determined as 0.46 billion € per year. Cost of technological change describes the additional investment and operating cost of end-users for low(er) GWP technologies in comparison to established HFC high-GWP HFC technologies under the assumption of gas prices not altered by the HFC phase-down. Based on these costs, ***average emission reduction costs*** (calculated as the ratio of the annualised technological cost relative to the lifetime-averaged emissions savings) were on average about 6 € per tonne of CO_2 eq. Emission reduction cost observed for the first years of the phase-down are thus below the average of 16 € per tonne of CO_2 eq calculated for the 2030 time-horizon in the 2012 impact assessment for the Regulation (envisioning more costly technologies to be applied for that time horizon). However, the cost of action seems to vary significantly across sectors: In the areas of refrigeration and stationary air conditioning, several sectors had negative technology change costs while others had positive cost. For mobile air conditioning and other HFC application sectors, only positive technology change costs were found. The cost-effectiveness of the Regulation is underlined by the OPC feedback, where respondents did not signal that for any of the individual measures that the costs outweighed the benefits.

The majority of the total compliance costs of F-gas using industries in the EU in the evaluation period was due to increased gas prices as a result of the phase-down. Due to restrictions on their HFC supply under the HFC phase-down, gas producers and gas importers increased the price of high GWP gases which gave a price signal to downstream actors in the HFC supply chain, and subsequently to equipment operators. Where not restricted by long-term contracts, both gas distributors and, further downstream, service undertakings applied surcharges on their respective purchasing prices when selling to their respective customers. Thus, end-user equipment operators paid higher prices for the gas, unless they switch to climate-friendly alternatives. The total costs linked to price increases were determined as 1.71 billion € per year. These expenses were however distributed over a large number of end-users in the EU, either buying new or topping up with HFCs to compensate for leaks in running equipment (operating e.g. approximately 150,000 large supermarket refrigeration systems, 10 million small commercial refrigeration units, 100 million air conditioning systems in buildings and 200 million air conditioning units in vehicles).

As technology change has just been starting for new equipment in many sectors and there are still high shares of operated equipment relying on established HFC technologies, the HFC price-related compliance cost are still very high in these areas. As users move away from high GWP HFC equipment, this share of cost to end-users decreases, but those continuing to use HFCs remain subject to the future development of HFC prices. Since the quota is allocated for free, the HFC price related compliance costs to the end-users are equally offset by profits in the HFC supply chain and are thus not considered as net cost of the Regulation but rather as a distributional effect.

The majority of F-gas users' total costs (ca. 94%) relates to the refrigeration and air conditioning (RAC) sectors. In relation to total expenditures for the investment in, and operation of, RAC equipment, the calculated compliance cost amounts to about 1% of the total expenditures related to the investment in, and operation of, related equipment.

A regional analysis on cost distribution shows that the southern EU region, representing about 35 % of the EU27+UK population was exposed to compliance cost slightly above proportion at about 37.5 %.

There are also a number of measures in the Regulation that result in some ***administrative burden*** for a range of actors. Gathering evidence from stakeholders, it is estimated that the annual average burden for all stakeholders per annum is around m€19.2.

The evaluation also explores the potential economic effects for industry as a whole. Statistical trend analysis does not suggest that the Regulation has had a significant effect on production, gross value added (GVA) and employment in related sectors, and in addition, any effect (although small) is more likely to have been positive (i.e. led to an improvement in affected sectors) than negative. Furthermore, the Regulation has increased R&D and investment by industry and the wide range of new alternatives is representative of the high levels of innovation driven by the Regulation.

With respect to trade, the Regulation did also not significantly affect the production of F-gases in the EU and EU exports. However, it did have an impact on the imports of F-gases into the EU: Reacting to the switch in demand from HFCs to, partly, natural refrigerants, imports of HFCs and unsaturated HFCs, measured in tonnes of gas, were about 7% lower than they would have been without the revision. Given the higher cost for unsaturated HFCs, however, the value of HFCs and unsaturated HFCs imports was about 16% higher. This analysis suggesting limited (if any) economic impacts was corroborated by respondents to the OPC, the majority of whom suggested the Regulation has had a neutral effect on EU competitiveness.

Relevance

Overall findings: The high-level objectives of the Regulation continue to reflect and respond to the fundamental need of the EU to reduce demand and emission of F-gases. However, developments over the period of implementation, specifically the European Green Deal and a changed international policy environment (Paris Agreement, Kigali Amendment), pose a challenge to the Regulation in its current form, and require more emission reductions. There are also some gaps in the substances and activities covered.

The EU Climate objectives have evolved since the time of the last impact assessment (2012) and demands significantly more action in all sectors to reduce emissions. The Paris Agreement from 2015 urges countries to make the necessary contributions so that global warming can be limited to below 2 (and possibly 1.5) degrees, which requires much swifter and wide-ranging changes globally. The EU recently agreed on an EU Climate Law by, which it is committing to reaching carbon neutrality by 2050 and at least a 55% emission reduction by 2030 compared to 1990. Conversely, the Regulation was designed to meet the climate goals set forward in the 2011 Roadmap[3], which were less ambitious. As regards F-gas emissions, despite large emission reductions especially in the refrigeration sector, they still contribute to 2.5% to the EU's total GHG emissions in 2018 and continued supply and use of F-gases will continue to result in a 'bank' of potential emissions for the future.

The Regulation is the main policy tool through which the EU's compliance with international commitments related to the Montreal Protocol are safeguarded. Except for 2014, HFC consumption has exhibited a downward trend because of the Regulation. The Kigali Amendment was introduced 2 years after the adoption of the Regulation. To continue to safeguard compliance in the future, further changes will need to be made (discussed in more detail under coherence below).

In terms of the scope of the Regulation, a review of the coverage of substances, activities and sectors found that the Regulation continues to capture the most important F-gases, however some gaps with regard to the substances covered have been identified. These include e.g. sevoflurane, enflurane, sulfuryl fluoride, FK-5-1-12 (fluorinated ketone) and other fluorinated gases. Moreover, certain applications are not covered by the reporting requirements, so little information is available, e.g. on the use of SF_6 in particle accelerators, the application of certain PFCs (predominantly $C_{10}F_{18}$) in personal products and medical applications. Also, data collected for reclamation of F-gases was found to be incomplete as only those undertakings which are also importers of F-gases currently need to report. Finally, current requirements cover only F-gas related activities; due to the increasing use of F-gas alternatives and safety issues such as flammability, additional requirements for service technicians working with climate-friendly alternatives is becoming increasingly important.

As regards the flexibility of the Regulation, it was found that it has been flexible to respond to some external challenges, but not others. The emergence and a shift to the use of both natural refrigerants and alternatives with a lower GWP in several sectors has been induced and facilitated by the Regulation and its flexibility. In contrast, the Regulation itself does not have sufficient flexibility to allow for alignment with the Kigali Amendment or any unforeseen issue related to the quota system, such as the lack of gas supply or similar.

Coherence

Overall findings: The Regulation interacts with several regulatory instruments, both in the form of other EU policy and also international agreements. In general, the Regulation was found to show a good level of consistency and coherence with other interventions that have similar objectives, although there are areas that have led to some incoherence and should be addressed, in particular with regard to the Kigali Amendment and custom controls.

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[3] https://eur-lex.europa.eu/legal-content/EN/ALL/?uri=celex%3A52011DC0112

The implementation of the HFC phase-down is crucial for the EU to comply with its obligations under the Kigali Amendment to the Montreal Protocol. Although principally aligned, there are areas which need to be adjusted to ensure full compliance. These areas are the continuation of the EU HFC phase-down after 2030, the introduction of an HFC production phase-down, as well as exemptions and thresholds for placing on the market and reporting thresholds that are not foreseen by the Montreal Protocol. The Montreal Protocol's requirement to have export and import licences for HFCs is fulfilled by requiring registration in EU F-gas Portal and Licensing System before undertaking such activities. However, border controls using this licensing system can be made more effective if full advantage of the upcoming 'EU Single Window environment for Customs'[4] is taken.

Custom controls and surveillance activities are relevant to the success of the Regulation. Uncertainty about the role of customs in enforcing the Regulation has shown that instructions for customs and market surveillance authorities were not sufficiently clear. This, together with a lack of awareness and information available has meant customs authorities have been unable to play an effective role in enforcing the Regulation.

There are also synergies regarding energy efficiency due to complementary measures with the Energy Labelling Regulation (EU) No 2017/1369, the Ecodesign Directive 2009/125/EC, Energy Performance of Buildings Directive 2010/31/EU, and Directive (EU) 2018/2001 on the promotion of the use of energy from renewable sources. Coherence is particularly promoted through Article 11(2) of the Regulation, which allows an exemption from the placing on the market bans set out in Annex III if the equipment with HFCs would achieve lower overall GHG emissions during its life cycle than the same equipment without HFCs.

Restrictions on chemicals on the EU market under the REACH Regulation may possibly pose a challenge to coherence with the F-gas Regulation: Under REACH, scrutiny processes are on-going which could possibly end up restricting the use for example of unsaturated HFC-1234yf which is one of the important substitutes for high-GWP HFCs being phased down under the FGR.

As for internal coherence, the Regulation has generally been found to be consistent and coherent internally and across its implementing acts. There are, however, some areas which require further amendments, including clarification of certain existing definitions and the inclusion of additional definition for e.g. certain categories of equipment, consistency of thresholds for the import of pre-charged equipment, and other issues and clarifications related to individual provisions.

EU added value

The Regulation has a clear added value by implementing co-ordinated action at EU level to ensure compliance with the Montreal Protocol and the EU climate goals. This is corroborated by stakeholders, especially by the responses of the competent authorities from Member States. The Regulation has increased ambition relative to what would have been likely achieved as the sum of individual actions at national levels. Taking co-ordinated action at EU level has increased the effectiveness of the policy to reduce F-gas demand and emissions. Ensuring compliance with the Kigali Amendment at Member State level in an EU without borders would be very difficult if not impossible to ensure. Alongside additional environmental improvements, a key benefit is the creation of a more efficient and less burdensome regulatory environment for the EU F-gas industry, helping to minimise costs and to create a level-playing field. For example, it would be much more costly to conduct 27 implementation levels and implementing the required import and export licensing systems and restrictions at Member State level would hardly have been reconcilable with the rules of the EU Internal Market.

[4] https://ec.europa.eu/taxation_customs/eu-single-window-environment-customs_en

1 Introduction, purpose and scope

1.1 Introduction

This report presents the findings of ‘Task 2: Evaluate current EU F-gas policy’ under the Support contract for an Evaluation and Impact Assessment for amending Regulation (EC) No 517/2014 on fluorinated greenhouse gases (hereinafter: ‘Regulation’). The project has been commissioned under specific contract number: Ref. Ares(2019)7625784 – 11/12/2019. The specific contract entered into force in April 2020 and runs until April 2022 (24 months).

The aim of the service contract is, inter alia, to support the EU Commission in the evaluation of the Regulation through:

- Gathering, compiling and assessing evidence;
- Drafting analytical support document(s) including reports and/or presentations.

This report presents the results of the assessment against the evaluation questions, based on the literature review, analysis of relevant datasets and of stakeholder feedback provided through the open public consultation (OPC), targeted interviews and the stakeholder workshop. This is the supportive study to the official evaluation of the Regulation being conducted by the EU Commission. It provides the necessary analytical background to the Staff Working Document which will be published by the EU Commission.

The study has been undertaken by Öko-Recherche, Ricardo and Öko-Institut. The report is structured as follows:

- **Section 1** explains the purpose and scope of the evaluation;
- **Section 2** provides background to Regulation and its objectives. It also sets out the intervention logic and baseline for the evaluation;
- **Section 3** gives information on the current state of implementation;
- **Section 4** describes the methodology for the evaluation and the process followed;
- **Section 5** provides answers to the evaluation questions based on the evidence gathered;
- **Section 6** sets out conclusions.

1.2 Purpose

The evaluation of the F-gas appraises its functioning to help assess whether the instrument is fit for purpose. In line with the Commission Better Regulation Guidelines and Toolbox, the evaluation assesses the effectiveness, efficiency, coherence, relevance and EU added value of the Regulation in contributing to the reduction of F-gas emissions and demand in the EU.

This evaluation also fulfils Article 21 (2) of the Regulation which requires the EU Commission to publish a comprehensive report on the effects of this piece of legislation no later than 31 December 2022. Due to the EU Green Deal this deadline was moved forward by one year (December 2021). This review report needs to include the following aspects:

- A forecast of the continued demand for hydrofluorocarbons up to and beyond 2030.
- An assessment of the need for further action by the Union and its Member States in light of existing and new international commitments regarding the reduction of fluorinated greenhouse gas emissions.

- An overview of European and international standards, national safety legislation and building codes in Member States in relation to the transition to alternative refrigerants.
- A review of the availability of technically feasible and cost-effective alternatives to products and equipment containing fluorinated greenhouse gases for products and equipment not listed in Annex III, taking into account energy efficiency.

The evaluation will also take into account developments in EU climate policy frameworks like the EU Green Deal and international obligations under the Kigali Amendment to the Montreal Protocol and the Paris Climate Agreement which have occurred over the period of implementation for the F-gas Regulation.

The results of the evaluation feed into the parallel impact assessment task (Task 3 under the same study contract) '*Develop options and recommendations for the review of the regulation and assess their impacts'*. The evaluation and impact assessment have been undertaken 'back-to-back', with central tasks running in parallel. While the evaluation of the Regulation aims to identify issues where measures and provisions might be amended in order to enhance in particular the F-gas Regulation's effectiveness, efficiency and coherence, the impact assessment provides potential policy options to amend the Regulation and an assessment of their likely economic, environmental and social impacts.

1.3 Scope

The evaluation covered all parts of the Regulation. It covered the period from adoption of the updated Regulation in 2014. The scope of the evaluation is presented in Table .

Table 1: Scope of the evaluation

Scope element	Focus
Legislative coverage	• Full text of Regulation (EU) No 517/2014, including all annexes • Implementing decisions accompanying the main Regulation: ▪ Commission Implementing Regulation (EU) 2019/661 of 25 April 2019 ensuring the smooth functioning of the electronic registry for quotas for placing hydrofluorocarbons on the market ▪ Commission Implementing Regulation (EU) 2019/522 of 27 March 2019 amending Implementing Regulation (EU) No 1191/2014 as regards the reporting of data on production and on imports and exports of polyols containing hydrofluorocarbons pursuant to Article 19 of Regulation (EU) No 517/2014 ▪ Commission Implementing Decision (EU) 2018/2023 of 17 December 2018 on amending Implementing Decision (EU) 2017/1984 determining, pursuant to Regulation (EU) No 517/2014 of the European Parliament and of the Council on fluorinated greenhouse gases, reference values as regards reference values for the period from 30 March 2019 to 31 December 2020 for producers or importers established within the United Kingdom, which have lawfully placed on the market hydrofluorocarbons from 1 January 2015, as reported under that Regulation (notified under document C(2018) 8801) ▪ Commission Implementing Regulation (EU) 2018/1992 of 14 December 2018 amending Implementing Regulation (EU) No 1191/2014 as regards the reporting of data referred to in Article 19 of Regulation (EU) No 517/2014 in respect of hydrofluorocarbons placed on the market in the United Kingdom and in the Union of 27 Member States ▪ Commission Implementing Decision (EU) 2017/1984 of 24 October 2017 determining, pursuant to Regulation (EU) No 517/2014 of the European Parliament and of the Council on fluorinated greenhouse gases, reference values for the period 1 January 2018 to 31 December 2020 for each producer or importer which has lawfully placed on the market hydrofluorocarbons from 1 January 2015 as reported under that Regulation (notified under document C(2017) 7080)

Scope element	Focus
	▪ Commission Implementing Regulation (EU) 2017/1375 of 25 July 2017 amending Implementing Regulation (EU) No 1191/2014 determining the format and means for submitting the report referred to in Article 19 of Regulation (EU) No 517/2014 of the European Parliament and of the Council on fluorinated greenhouse gases ▪ Commission Implementing Regulation (EU) 2016/879 of 2 June 2016 establishing, pursuant to Regulation (EU) No 517/2014 of the European Parliament and of the Council, detailed arrangements relating to the declaration of conformity when placing refrigeration, air conditioning and heat pump equipment charged with hydrofluorocarbons on the market and its verification by an independent auditor ▪ Commission Implementing Regulation (EU) 2015/2068 of 17 November 2015 establishing, pursuant to Regulation (EU) No 517/2014 of the European Parliament and of the Council, the format of labels for products and equipment containing fluorinated greenhouse gases ▪ Commission Implementing Regulation (EU) 2015/2067 of 17 November 2015 establishing, pursuant to Regulation (EU) No 517/2014 of the European Parliament and of the Council, minimum requirements and the conditions for mutual recognition for the certification of natural persons as regards stationary refrigeration, air conditioning and heat pump equipment, and refrigeration units of refrigerated trucks and trailers, containing fluorinated greenhouse gases and for the certification of undertakings as regards stationary refrigeration, air conditioning ▪ Commission Implementing Regulation (EU) 2015/2066 of 17 November 2015 establishing, pursuant to Regulation (EU) No 517/2014 of the European Parliament and of the Council, minimum requirements and the conditions for mutual recognition for the certification of natural persons carrying out installation, servicing, maintenance, repair or decommissioning of electrical switchgear containing fluorinated greenhouse gases or recovery of fluorinated greenhouse gases from stationary electrical switchgear ▪ Commission Implementing Regulation (EU) 2015/2065 of 17 November 2015 establishing, pursuant to Regulation (EU) No 517/2014 of the European Parliament and of the Council, the format for notification of the training and certification programmes of the Member States ▪ Commission Implementing Regulation (EU) No 1191/2014 of 30 October 2014 determining the format and means for submitting the report referred to in Article 19 of Regulation (EU) No 517/2014 of the European Parliament and of the Council on fluorinated greenhouse gases ▪ Commission Implementing Decision 2014/774/EU of 31 October 2014 on determining, pursuant to Regulation (EU) No 517/2014 of the European Parliament and of the Council on fluorinated greenhouse gases, reference values for the period 1 January 2015 to 31 December 2017 for each producer or importer who has reported placing on the market hydrofluorocarbons under Regulation (EC) No 842/2006 of the European Parliament and of the Council (notified under document).
Geographical coverage	• EU 28 (EU27+UK)
Sectoral coverage	• Stationary RACHP • Transport refrigeration • Fire protection • Semiconductor, photovoltaics and other electronic manufacture • Switchgear and related electrical equipment • Aerosols • Foams • Other
Temporal coverage	• Evaluation period is from Regulation's entry into force (1 January 2015) until present (2020 or year for which latest data is available)

Scope element	Focus
	• Note some actions taken during this period will have enduring impacts outside of this period (e.g. continuing to reduce emissions of F-gases post-2020). The analysis will take into account all impacts associated with actions taken in response to the Regulation over the period from 2015 to 2020

2 Background to the intervention

2.1 Overview of the Regulation and its objectives

2.1.1 F-gases and policy background

Fluorinated greenhouse gases ('F-gases') are man-made substances used in numerous industrial applications and include hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), sulphur hexafluoride (SF_6), nitrogen trifluoride (NF_3) as well as other fluorinated substances. Due to their high global warming potentials (GWP), F-gases contribute significantly to climate change.

Production and consumption of F-gases, specifically HFCs, have increased considerably because they are widely used as substitutes for ozone depleting substances (ODS), which are being phased-out globally under the Montreal Protocol. F-gas emissions are mainly released from refrigeration, air conditioning and heat pump (RACHP) equipment, foams, aerosols, solvents, and fire protection equipment. Other emissions sources include halocarbon production, certain industrial processes in semiconductor and non-ferrous metal industry as well as the use in switchgear for transmission of electricity.

F-gas emissions have long been addressed by international conventions such as the United Nations Framework Convention on Climate Change (UNFCCC) and its Kyoto Protocol. As a party of the Kyoto Protocol, the EU has to report on the status of the reduction commitments made under the UNFCCC and in relation to EU legislation on greenhouse gas (GHG) emission reductions. Regulation (EU) No 525/2013 stipulates the overarching mechanism for monitoring and reporting greenhouse gas emissions ('Monitoring Mechanism Regulation', MMR)[5]. In more detail, Commission Implementing Regulation (EU) No 749/2014 sets the requirements for national reporting under Regulation (EU) No 525/2013[6].

Recognising the threat of F-gases, specifically HFCs, to global climate change, the international community decided in 2016 in Kigali (Rwanda) on an Amendment to the Montreal Protocol. The so-called Kigali Amendment entered into force on 1 January 2019 and implements a global HFC phase-down by cutting down the HFC production and consumption by more than 80 % over the next 30 years. There are different baseline years and HFC reduction schedules for Article 5 and non-Article 5 countries, with developed countries starting first and developing countries taking on reduction commitments in the medium-term, in addition to the Ozone phase-out also regulated under the Montreal Protocol. The phase-down of HFCs requires the development and uptake of suitable alternative refrigerants with lower global warming potential, which can substitute for HFCs. Beyond the specific reduction schedules, the amendment introduced import/export licensing and reporting requirements for HFCs. By extending the scope of controlled substances to HFCs, the Montreal Protocol took an important step towards the long-term goals set by the Paris Climate Agreement.

The EU was the first region in the world where a complete F-gas legislation had been established. The first F-gas Regulation (EC) No 842/2006 of the European Parliament and of the Council of 17 May 2006 on certain fluorinated greenhouse gases' was supplemented with nine Commission implementing regulations. The 2006 Regulation contained provisions related to certification of technicians and undertakings dealing with F-gases, reporting on F-gases, leakage checking and recovery requirements for F-gas containing equipment, placing on the market bans for few products and equipment containing or relying on F-gases as well as prohibitions of the use of certain F-gases in specific applications. HFCs are addressed not only by the F-gas Regulation, but also by Directive 2006/40/EC ('MAC Directive'), which bans the use of HFCs with a GWP > 150 in new passenger cars since 2017. The MAC Directive leads to the replacement of HFC-134a as refrigerant in passenger car AC systems, an important source of demand, by low GWP solutions.

[5] Regulation (EU) No 525/2013 accessible under https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:32013R0525
[6] Regulation (EU) No 749/2014 accessible under http://eur-lex.europa.eu/legal-content/EN/TXT/?uri=uriserv:OJ.L_.2014.203.01.0023.01.ENG

In 2015, Regulation (EC) No 842/2006 was replaced by the current Regulation. The level of ambition of the revised Regulation was significantly extended, inter alia, to include an HFC phase-down schedule and HFC quota allocation system, additional certification and reporting requirements and an additional set of placing on the market and use bans. Since the Regulation was adopted pursuant to Article 192 (1) Treaty on the Functioning of the European Union (TFEU), it does not prevent EU Member States from maintaining or introducing more stringent measures that are comparable with the TFEU provided the Member State notifies the EU Commission of any such measures.

A series of technical reports were published by the EU Commission as required by Article 21 of the Regulation. These include a report on barriers posed by codes, standards and other legislation for F-gas alternatives in RACHP and foam sectors in 2016 (Commission, 2016) and in 2017 an assessment of the 2022 requirement to avoid high-GWP HFCs in some commercial refrigeration systems (European Commission, 2017) and an assessment of the quota allocation method (European Commission, 2017). In 2020, the EU Commission published reports on the availability of refrigerants for new split AC systems that can replace F-gases or result in a lower climate impact (European Commission, 2020), the availability of alternatives to F-gases in switchgear and related equipment (European Commission, 2020) and on the availability of HFCs on the Union market (European Commission, 2020). The findings of these reports will serve as a technical input to the review.

2.1.2 Objectives of the Regulation and problems it is intended to solve

2.1.2.1 *Issues identified by the 2012 Impact Assessment*

In 2012, the Impact Assessment for the review of Regulation (EC) No 842/2006 on certain fluorinated greenhouse gases was published. It highlighted key issues with the first F-gas Regulation and challenges that still needed to be addressed, which were also pointed out in the EU Commission's report in 2011 (European Commission, 2011).

As shown in

Table, Regulation (EC) No 842/2006 was deemed insufficient, with the Impact Assessment mentioning that it barely discouraged the use of F-gases that are very potent greenhouse gases. It was acknowledged by the Impact Assessment that the MAC Directive does restrict use of F-gases, however, it was highlighted that its focus is narrow, i.e. passenger cars only. Furthermore, the 2012 Impact Assessment highlighted the availability of many F-gas alternatives in nearly all fields of application.

Other issues were raised such as shortcomings in training and certification and containment provisions. In some sectors over 50 % of personnel and undertakings had not been certified by 4 July 2011. Unsatisfactory compliance by undertakings with the schedules for leakage checks and the obligation to install leakage detection systems was identified low compliance on containment measures. The stakeholder consultation at that time found that 84 % of respondents had the view that the status quo of implementing the existing regulation was not sufficient.

Table 2: Main issues with Regulation (EC) No 842/2006 identified in the 2012 Impact Assessment

Main issues identified by the 2012 IA of Regulation (EC) No 842/2006 (European Commission, 2012)	Brief description
The Regulation was insufficient	• The Impact Assessment remarked that even full application of the F-gas Regulation (EC) No 842/2006 would at best achieve a stabilisation of emissions. • This would be insufficient to reach the EU's climate goals that requires a reduction in the F-gas sector of 60% by 2030, compared to 2005.
Lack of regulation of alternatives to ozone depleting substances	• The phasing out of ozone depleting substances (ODS) under the Montreal Protocol means an increased use of ODS alternatives. • Use of F-gases as Ozone replacements has increased, and there has been a global shift towards the production and use of F-gases. • However, the choice of alternatives to Ozone is not regulated.
The Regulation mainly focused on reducing emissions the during the lifetime and at the end of life of F-gas containing equipment	• Regulation (EC) No 842/2006 did not sufficiently focus on reducing emissions by preventing F-gas use in the first place. • This is because it mostly included: o Provisions on containment and recovery of F-gases from end-of-life equipment (Article 3 & 4); training and certification requirements for personnel handling F-gases (Article 5); reporting in order to monitor the sales of F-gases (Article 6); and labelling of equipment containing F-gases (Article 7); o Bans only existed for narrowly defined niche application areas where superior alternatives were already commonplace (Article 8 & 9) (with the exception of passenger car AC systems which were covered by the MAC Directive).
Increasing use of F-gas containing equipment and products	• Use of F-gases in refrigeration and air conditioning, foams, aerosols and electrical equipment, but especially RAC, was expected to grow, leading to more emissions.
Long lifespans of F-gas equipment	• Certain F-gas equipment (e.g. RAC equipment) has long lifespans (10-20 years for smaller equipment, 20-30 years for larger systems). • This must be taken into consideration, as leakage may occur throughout the equipment lifespan in addition to at end-of life treatment.
Climate effects were not reflected in F-gas pricing	• In order for there to be a transition in investments in alternative technologies, industry requires a clear price signal which factors in the climate impact of F-gases. • The Impact Assessment highlighted there is no clear regulatory price signal. • The lack of signal means there is a lower market penetration of alternative products than would be optimal from a societal perspective.

2.1.2.2 *Needs and objectives of the Regulation*

Leading on from the issues identified in the 2012 Impact Assessment, both general and specific policy objectives for the revised Regulation were identified.

Table provides an overview of these objectives. The 2012 Impact Assessment, alongside a broader body of work, led to the establishment of Regulation (EU) No 517/2014 of the European Parliament and of the Council of 16 April 2014 on fluorinated greenhouse gases, which repealed the Regulation (EC) No 842/2006 and entered into force on 1 January 2015.

Table 3: Summary of the Regulation's objectives identified in the 2012 Impact Assessment

General objective
Keep climate change below 2º C of pre-industrial levels by reducing GHG emissions in the EU by 80 to 95% in 2050 compared to 1990. This target corresponds to the necessary reduction levels identified by the Intergovernmental Panel on Climate Change (IPCC) for developed countries and was endorsed both by the Council and the European Council as the EU 2050 emission reduction target.
Specific objectives
Contribute to the achievement of the EU 2050 reduction target by reducing CO_2 eq from F-gases in the EU by: • Discouraging the use of F-gases with high GWP in the EU where suitable alternatives exist. • Encouraging the use of alternative substances or technologies when they result in lower GHG emissions without compromising safety, functionality and energy efficiency, and achieving higher market shares for these technologies. • Preventing leakage from equipment and proper end-of-life treatment of F-gases in applications. • Facilitating convergence towards a potential future agreement to phase down HFCs under the Montreal Protocol. • Enhancing sustainable growth, stimulate innovation and develop green technologies by improving market opportunities for alternative technologies and gases with low GWP. • Creating efficient and proportionate mechanisms for reaching the environmental objectives while limiting any undesirable effects on SMEs and employment, the administrative burden for undertakings and authorities, the abatement costs per tonne of CO_2 eq and preserving the competition in the internal market (to the extent possible).
Operational objectives
• Consistent with the specific and general objective, the operational objective is to reduce F-gas emissions in the EU by 60% in 2030 compared to 2005. • A second operational objective is to do so in a cost-effective manner by taking consistent, and cost-efficient measures (up to a maximum of 50 € per tonne of CO_2 eq), at reasonable costs to industry and with minimum administrative effort. • Upgrading of the existing legislation through clarifications as well improving the enforceability of legislation should contribute to achieving better implementation and application of the legislation and contribute to achieving the objectives above.
Consistency
The objectives of this initiative are consistent with and reinforce the other policies and objectives*

**These include the 2050 EU Low Carbon Roadmap, EU 2020 priority sustainable growth: building a more competitive low carbon, EU Better Regulation the 'think small first' principle, EU efforts of eco-design and energy efficiency, and the negotiations for an international agreement under the Montreal Protocol to phase down HFCs.*

2.1.3 Overview of the Regulation

The current Regulation builds on Regulation (EC) No 842/2006, while the latter was strengthened in three ways:

- The total amount of the HFCs to be placed on the EU market was limited in 3-year steps ending up at 21 % in 2030 compared to 2015 ('HFC phase-down');
- Additional prohibitions on types of new equipment containing or relying on F-gases, in cases where less harmful alternatives were available;

- Additional leak checks, servicing, and recovery obligations for F-gas equipment to further prevent emissions from existing equipment[7].

As for the specific articles of Regulation (EC) No 842/2006, articles that were amended or evolved in the *revised* Regulation include containment (Articles 3 to 10 (of the 2014 Regulation)), placing on the market and control of use (Articles 11 to 14 (of the 2014 Regulation)), reduction of the quantity of HFCs placed on the market (Articles 15 to 18 (of the 2014 Regulation)), and reporting (Articles 19 and 20 (of the 2014 Regulation)).

2.1.3.1 *Coverage*

The Regulation covers different actors, F-gases and activities. These are affected by different provisions, as shown in the tables below.

Table 4: Overview of main actors affected by the Regulation and provisions impacting them

Actors	Requirements
Producers and importers of F-gases	• Primarily affected by the HFC phase-down and provisions related to the quota mechanism, but also by placing on the market and use restrictions, including requirements on registration and annual reporting, as well as labelling of F-gas containers, • Evidence needs to be provided that trifluoromethane (HFC-23) generated as a by-product during the manufacture of feedstock has been destroyed or recovered for further use (Article 7(2)).
Exporters of F-gases	• Compliance with annual reporting requirements for virgin, recycled, reclaimed or destroyed F-gases exported from the EU and hold a license for export (be registered).
Manufacturers and importers of pre-charged products and equipment	• Primarily affected by provisions on labelling, requirements for registration and reporting, obtaining quota authorisations and documenting compliance (‘declaration of conformity’) for the import and EU manufacture of pre-charged products equipment as well as placing on the market restrictions for new equipment.
Operators of equipment	• Must ensure compliance with requirements on containment (i.e. leakage checks and repair, end-of-life) and engagement of certified service technicians for the installation, servicing, maintenance, repair and decommissioning of the equipment and the recovery of F-gases and the keeping of records. • Need to adjust to placing on the market and use restrictions and to lower quantity of F-gas available,
Service technicians/undertakings	• Affected by provisions on the containment (i.e. leakage checks and repair) and record keeping and must be certified pursuant to a certification programme that includes training and an evaluation process in order to carry out installation, servicing, maintenance or repair of the equipment containing or relying on F-gases as well as recovery.
Member States competent authorities	• Responsible for the implementation, compliance with and enforcement of the Regulation on national level. • Competent authorities, including customs authorities, should ensure that they have access to the HFC Registry to obtain the necessary information required for compliance checks. • They are also required to provide certification programmes and ensure the availability of sufficient training and evaluation processes in line with the set minimum requirements, encourage the development of producer responsibility schemes and establish national reporting systems for the collection of F-gas emission data.
Feedstock users	• Must comply with the reporting requirements. • Feedstock use is not part of the HFC phase-down but losses need to be minimised (Article 7(1).
Destruction facilities	• Need to comply with reporting requirements.
Training providers and certification bodies	• Must offer training programmes that consider the minimum requirements set out for the certification and attestation programmes and evaluation processes, while ensuring that the content trained includes information on applicable regulations and technical standards, emission prevention, F-gas recovery, safe handling of equipment and alternative technologies. • Must follow the defined certification processes in line with the set minimum requirements, including examinations

[7] https://ec.europa.eu/clima/policies/f-gas/legislation_en

As for F-gases themselves, the Regulation currently covers 19 hydrofluorocarbons (HFCs), seven perfluorocarbons (PFCs) and sulphur hexafluoride (SF_6) in Annex I, Section 1 to 3. These are shown in the table below. These gases are subject to the following provisions: phase-down (HFCs only, unless F-gas is part of a blend also containing HFCs), placing on the market and use prohibitions, containment, labelling, reporting and certification requirements.

Table 5: Overview of F-gases included in Annex I of the Regulation

Reference	Gas group	Gas	GWP_{100} (AR4)
Annex I Section 1	**HFCs**	**HFC-23**	14 800
		HFC-32	675
		HFC-41	92
		HFC-125	3 500
		HFC-134	1 100
		HFC-134a	1 430
		HFC-143a	4 470
		HFC-152	53
		HFC-152a	124
		HFC-161	12
		HFC-227ea	3 220
		HFC-236cb	1 340
		HFC-236ea	1 370
		HFC-236fa	9 810
		HFC-245ca	693
		HFC-245fa	1 030
		HFC-365mfc	794
		HFC-43-10mee	1 640
Annex I Section 2	**PFCs**	**PFC-14 (CF4)**	7 390
		PFC-116 (C2F6)	12 200
		PFC-218 (C3F8)	8 830
		PFC-3-1-10 (C4F10)	8 860
		PFC-4-1-12 (C5F12)	9 160
		PFC-5-1-14 (C6F14)	9 300
		PFC-c-318 (c-C4F8)	10 300
Annex I Section 3	**SF_6**	**SF_6**	22 800

In addition, the Regulation covers 'other fluorinated greenhouse gases', which are only subject to reporting obligations according to Article 19 of the Regulation (unless they are part of blends with F-gases from Annex I). The listed gases include five unsaturated hydrofluorocarbons (HFCs)/hydrochlorofluorocarbons (HCFCs), 33 hydrofluoroethers (HFEs) and fluorinated alcohols and four other perfluorinated compounds. The full list of other gases covered can be found in Annex II (Section 1 to 3).

2.1.3.2 *Key provisions*

This section provides a brief overview of the key provisions in the Regulation. This list is not exhaustive and serves as a summary only.

HFC phase-down and quotas (Articles 15 and 16)

A core element of the Regulation is the HFC phase-down that aims at considerably reducing the placing on the market of HFCs in the EU. It implies a progressive reduction of HFCs by two-thirds, starting in 2015 and running through 2030 (Article 15 in conjunction with Annex V). To implement the HFC phase-down, quotas are allocated annually to producers and importers of bulk gases, which allow them to place limited HFC quantities on the market (Article 16).

Quotas were first allocated annually for the period 2015 to 2017 based on:

- Calculated reference values for those producers and importers who reported data for the period 2009 to 2012 under Article 6 of Regulation (EC) No 842/2006;
- Annual quota declarations from new entrants (entities without a reference value) by using the formula set out in Annex VI (basically pro-rata).

From 2018, quota is based on:

- Reference values re-calculated every three years as of 31 October 2017 that are based on lawful placing on the market since 2015 as reported under Article 19.
- Annual quota declarations from HFC importers and producers (open to both new entrants and entities with a reference value).

HFCs destined for the following uses are exempted from the phase-down: imports for destruction, feed-stock use, exports, military use, semiconductor industry and – from 1 January 2018 – pharmaceutical metered dose inhalers (MDIs) (Article 15 (2)). However, placing on the market of HFCs for these uses is subject to labelling (stating the exempted use) and reporting requirements.

The annual average of the total quantity placed on the market during the period from 2009 to 2012 serves as baseline (183.1 Mt CO_2 eq / 100 %) for the HFC phase-down start in 2015. The table below shows the percentages to calculate the maximum quantity of HFCs to be placed on the market in the respective years.

Table 6: HFC phase-down schedule (Article 15 in conjunction with Annex V of the Regulation)

Year	Percentage of baseline (average POM in the period 2009 to 2012)
2015	100%
2016 to 2017	93%
2018 to 2020	63%
2021 to 2023	45%
2024 to 2026	31%
2027 to 2029	24%
2030	21%

The initial maximum quota quantity was reduced to 170.3 Mt CO_2 eq in 2016 and 2017 (= 93 % of the 2015 baseline quantity). The EU market faced the second and steepest reduction step in 2018, and following a recalculation of the maximum quantity, which allowed for the subtraction of exempted gases according to Annex V, an HFC quota totalling 101.2 Mt CO_2 eq was allocated. This was about 40 % less than for 2017. It should be noted that due to the complex calculation rules set out in Annex V of the Regulation, the Annex V reduction schedule set out in percentages in Table 6 does not directly translate into reductions of admissible HFC quantities of the same percentages: In the calculation of maximum quantities, fisrt the percentage reductions are applied, and subsequently absolute amounts of reported quota exemptions are subtracted. As the result of that calculation approach, the 21% given in Annex V for 2030, for example, translate into a maximum quantity for 2030 at approximately 11% of the maximum quantity for 2015.

The maximum quantities were recalculated for 2019 and 2020 to consider newer data on exemptions, with HFC quota totalling 100.3 Mt CO_2 eq and 99.5 Mt CO_2 eq respectively.

Registration (Article 17)

Registration in the F-gas Portal & HFC Licensing System is compulsory, inter alia, for importers, producers, in order to receive a HFC quota (Article 17). It is also mandatory for exporters of F-gases and importers of equipment containing HFCs and all entities supplying or receiving exempted gases such as those HFCs imported for destruction, for use as feedstock, directly exported in bulk, as well as for use in military equipment, in semiconductor manufacture or metered dose inhalers (MDIs). Member States are requested to cooperate and exchange information with the EU Commission when it is necessary for the assessment of the completeness and accuracy of information provided by the undertakings. Once a company is registered, the EU Commission issues a paper for print out confirming that the company´s registration[8]. A valid registration is a trade licence as required for HFCs under the Montreal Protocol, while the licence is a necessary but not sufficient condition to import and export, i.e. other requirements such as proper labelling, submission of required documents (e.g. declaration of conformity, evidence of destruction of HFC-23 by-production) and availability of sufficient quota or quota authorisations need to be met. Member State competent authorities, in including customs authorities can access the HFC Registry to check if the undertakings are registered.

Placing on the market (Articles 11 to 13)

Article 11 in conjunction with Annex III of the Regulation include prohibitions for placing on the market of products and equipment containing or relying on F-gases, while Article 13 includes restrictions for the use of F-gases. Most of the Annex III prohibitions have already come into effect, however, there are still some prohibitions that will become effective in the coming years. These prohibitions are shown in Annex 7.

Article 12 stipulates that products and equipment containing, or whose functioning relies upon F-gases shall not be placed on the market unless they are labelled. This applies to refrigeration equipment, air-conditioning equipment, heat pumps, fire protection equipment, electrical switchgear, aerosol dispenser that contain fluorinated greenhouse gases, with the exception of metered dose inhalers for the delivery of pharmaceutical ingredients, all F-gas containers, F-gas based solvents and organic Rankine cycles.

There are also certain exemptions under Article 11 (3), and if a product is subject to that exemption, it has to be labelled accordingly. It must also include a reference that those products or equipment may only be used for the purpose for which an exemption under that Article was granted.

Containment (Articles 3 to 7)

Article 3 prohibits any intentional release of F-gases, that is not technically necessary. Furthermore, operators of F-gas equipment must be taking all technically and economically feasible precautions to avoid emissions and must respect certain leak check requirements, including that when a leak is detected it must be repaired without undue delay.

Leak checks must be carried out by personnel certified according to Article 10 (European Commission, 2015): Many containment measures were already included in Regulation (EC) No 842/2006. The current Regulation slightly extended the coverage and established F-gas charge thresholds related to leakage check frequencies were defined in terms of tonnes of CO_2 eq instead of measuring the gas charge size in kilos in order to better reflect the climate impact or GWP, respectively, of the different types of F-gases (Article 4).

The products or equipment that contain F-gases in quantities of 5 tonnes of CO_2 eq or more (not contained in foams) that are subject to leak check requirements are:

- stationary refrigeration, air conditioning and heat pump equipment

[8] Commission Implementing Regulation (EU) 2019/661 of 25 April 2019 ensuring the smooth functioning of the electronic registry for quotas for placing hydrofluorocarbons on the market, https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32019R0661&from=EN.

- stationary fire protection equipment
- electrical switchgear
- refrigeration units of refrigerated trucks and trailers (new)
- organic Rankine cycles (new).

The frequency of these leak checks is outlined in the table below.

Article 6 of the Regulation requires that operators of equipment are subject to leak checks to maintain records for each piece of equipment. In addition to Regulation (EC) No 842/2006, the Regulation includes the requirement for reporting of the measures taken to recover and dispose of the F-gases decommissioned equipment. These records must be kept for at least five years and be made available, upon request, to the Member State competent authority or the EU Commission in order to check compliance.

Table 7: Comparison of the leak check schedules required in the previous and current F-gas Regulation

Regulation (EC) No 842/2006 (Article 3)	Regulation (EU) No 517/2014 (Article 4)	Availability of a leakage detection system (LDS)	Frequency of leak checks
Equipment containing F-gases of 3 kg or more, but less than 30 kg	Equipment containing F-gases of 5 tonnes of CO_2 eq or more, but less than 50 tonnes of CO_2 eq	No	12 months
		Yes	24 months
Equipment containing F-gases of 30 kg or more, but less than 300 kg	Equipment containing F-gases of 50 tonnes of CO_2 eq or more, but less than 500 tonnes of CO_2 eq	No	6 months
		Yes	12 months
Equipment containing F-gases of 300 kg or more	Equipment containing F-gases of 500 tonnes of CO_2 eq or more	No	3 months
		Yes	6 months

Recovery (Article 8)

Article 8 stipulates that operators of stationary equipment or refrigeration units of refrigerated trucks and trailers that contain F-gases not contained in foams shall ensure that the recovery of those gases is carried out by natural persons that hold the relevant certificates provided for by Article 10, so that those gases are recycled, reclaimed or destroyed.

Certification and training (Article 10)

Regulation (EC) No 842/2006 and its Implementing Regulations set out measures for training and certification which have been expanded under the Regulation. Article 10 of the Regulation requires the Member States to establish or adapt certification programmes and training for natural persons who:

- Install, service, maintain, repair, or decommission equipment that is subject to leak checks (Article 4(2)(a) to (f)),
- Carry out leak checks (Article 4(2)(a) to (e)),
- Recover F-gases (Article 8(1)).

Certification and training should ensure that the certified personnel are kept up to date with applicable regulations and standards, emission prevention, recovery of F-gases, safe handling of equipment, information on relevant technologies to replace or reduce F-gas use, including safe handling.

Implementing Regulation (EU) No 2015/2067 introduced additional minimum requirements for the testing of certified personnel. These minimum requirements include a basic knowledge of the EU and international climate change policy, including the United Nations Framework Convention on Climate

Change (UNFCCC), and information on relevant technologies to replace or to reduce the use of fluorinated greenhouse gases and their safe handling.

Reporting (Article 19)

Under Article 19 of the Regulation, each producer, importer and exporter that produced, imported or exported one metric tonne or 100 tonnes of CO_2 eq or more of fluorinated greenhouse gases and gases listed in Annex II during the preceding calendar year shall report to the EU Commission the data specified in Annex VII on each of those substances for that calendar year.

Annex VII includes multiple data requirements (e.g. total quantity of each substance produced in the Union, quantities of each substance that have been recycled, reclaimed and destroyed, the technology used for destruction of substances). F-gases contained in imported products or equipment also have to be reported on. Annex 7 provides an overview of these.

2.1.4 Intervention logic

The intervention logic frames the evaluation questions the study seeks to answer and defines the scope and depth of the analysis. The evaluation explores each of the steps in the intervention logic and, in particular, the movement from one step to the next, e.g. how effectively and efficiently actions have been translated into results. It focuses on the causality of the Regulation in delivering expected results and impacts. The intervention logic is presented in Annex 2. It is also broken down into individual pathways linking objectives, actions, outputs, and their impacts.

The intervention logic starts from the **needs** that the Regulation is intended to address and its **objectives,** consisting of its general objective (to 'make a significant contribution to reducing GHG emissions in the EU by 80 to 95% in 2050 compared to 1990'), alongside specific and operational objectives. **Inputs** are then outlined from the EU Commission, Member State competent authorities and industry. These then undertake a range of **activities** – both the adoption of the Regulation and the actions on the EU Commission, Member States competent authorities and industry that follow from implementation. Following through the **activities** should lead to a number of **outputs**. Under the Regulation, a number of outputs are linked to the proper functioning of the quota system (annual quota allocation by the EU Commission, recording in the HFC Registry, (re-)calculation of reference values. Several outputs relate to other key Articles: a reduction in the use of high GWP gases and uptake of alternatives, actions to recover, recycle and reclaim F-gases, labels on F-gas products, and training of service technicians. There are also a number of outputs related to other elements of the Regulation, e.g. relating to producer responsibility schemes, reporting, monitoring of emissions, database of verified annual reports, licences for imports/exports.

If implementation of the Regulation is effective, this should lead to several **expected outcomes**:

- Further reduction of F-gas emissions and reduction of leakage
- Less consumption of F-gases, in particular reduction in the use of high GWP F-gases, increased development and use of alternatives to F-gases
- Improved transparency and greater awareness in the field of F-gas use and emissions through good stewardship of F-gas actors (producers/users/technical personnel, etc.)
- Monitoring of policy progress and success; and enforcement actions in EU Member States and detection of illegal activities detected and/or avoided.

In turn, these outcomes should result in the following positive **impacts**:

- Contribution to achieving the EU's climate mitigation targets.
- Contribution to green growth and increased industrial and technological innovation in the EU through the development of alternatives to F-gases.

- Contribution to efforts of reducing F-gases at global level and increasing level of the EU's political credibility.

A number of **external factors** are relevant in relation to the intervention logic, i.e. factors outside of the influence of the intervention, which may still influence the delivery of the stated objectives. For the Regulation, external factors include: other regulatory frameworks (both internationally; at EU level and at national government level outside the EU); wider changes in the global F-gas market, both on the demand and supply side, including the way in which equipment and substances are traded (e.g. growing online market); R&D on climate-friendly technologies; broader stakeholder interests and wider public concerns (including political pressure linked to climate change).

Overlaid onto the intervention logic are the five criteria which form the basis for any evaluation undertaken in line with the Better Regulation Guidelines:

- **Effectiveness:** Are the impacts (outputs and effects) envisaged by the objectives achieved? This effectively considers whether the objectives themselves have been achieved in practice.
- **Efficiency:** How do the outputs compare to the inputs? Have they been achieved in an efficient manner?
- **Relevance:** Are the objectives of the Regulation still relevant for the needs in society and problems to address?
- **Coherence:** Is the Regulation internally coherent? Does it complement or conflict with other existing policies and strategies as well as new ones?
- **EU added value:** How do outcomes (outputs and effects) compare with what would have been achieved in the absence of the Regulation?

The intervention logic has been used to develop the individual evaluation questions under each of the evaluation criteria.

2.2 Counterfactual scenario

The counterfactual is a hypothetical scenario of the F-gas demand and emissions in the EU27+UK that would have occurred if the Regulation had not been adopted.

2.2.1 Legal framework in absence of the Regulation

Prior to the implementation of the Regulation, F-gases were mainly covered by measures set out by Regulation (EC) No 842/2006 and Directive 2006/40/EC. Regulation (EC) No 842/2006 introduced certain prohibitions on the placing on the market of (new) products and equipment using F-gases (

Table). It also banned the use of SF_6 in magnesium die-casting in quantities over 850 kg per year from 1 January 2008.

Table 8: Prohibitions on placing on the market set out in Annex II of Regulation (EC) No 842/2006

Fluorinated greenhouse gases	Products and equipment	Date of prohibition
Fluorinated greenhouse gases	Non-refillable containers	4 July 2007
Hydrofluorocarbons and per-fluorocarbons	Non-confined direct-evaporation systems containing refrigerants	4 July 2007
Perfluorocarbons	Fire protection systems and fire extinguishers	4 July 2007
Fluorinated greenhouse gases	Windows for domestic use	4 July 2007
Fluorinated greenhouse gases	Other windows	4 July 2008
Fluorinated greenhouse gases	Footwear	4 July 2006
Fluorinated greenhouse gases	Tyres	4 July 2007
Fluorinated greenhouse gases	One component foams, except when required to meet national safety standards	4 July 2008
Hydrofluorocarbons	Novelty aerosols	4 July 2009

The MAC Directive 2006/40/EC prohibited the use of F-gases with a GWP of over 150 in new mobile air conditioning systems from 1 January 2017. This applies to all passenger cars and light commercial vehicles up to 1.305 tonnes.

Regulation (EC) No 842/2006 set out certain containment and recovery measures in Article 3 and 4. Together with provisions on training and certification (Article 5) and labelling (Article 7), these measures are assumed to have led to reductions in emission rates, both over the lifetime and the end-of-life of equipment, especially for the sectors of refrigeration and stationary air conditioning. For one, it is assumed that service personnel are better qualified to reduce emissions during servicing and has a higher awareness of negative environmental consequences of F-gas emissions. Also, improvements in tightness of new equipment due to technological developments are supposed to occur, led by an increased incentive to reduce leakage rates.

While not always targeting F-gases specifically, certain EU Directives and Regulations aim to reduce the energy use of equipment and/or increase energy efficiency (see section 5.4.1 on Coherence for more detail). This should lead to reduced leakage rates in new equipment, even in the absence of the current F-gas Regulation, which is reflected in reduced lifetime emission rates in the counterfactual scenario.

In absence of the Regulation, no further prohibitions on the use of F-gases and, very importantly, no placing on the market restrictions for products and equipment containing F-gas would exist. Consequently, the average GWP of F-gases on the EU market would remain at a very high level and there would be little incentive to invest into research and development of low-GWP alternatives.

2.2.2 Expected evolution of key variables

Apart from policy variables, demand and emissions of F-gases are also influenced by other aspects, mainly population growth, as well as economic and technical developments and lifestyle changes (e.g. increased use of comfort cooling and heating). Both modelled scenarios (counterfactual and baseline) assume a positive correlation between population size and demand for F-gases. However, for some subsectors, the demand is assumed to reach a point of saturation that is defined by a maximum number of units per person. For example, for personal cars, the model assumes that the density of cars, and thus mobile air conditioning units, will not exceed 75 % of the population of a given country.

In the model used to project demand and emissions of F-gases (see Annex 1), population growth is only used as a proxy for changes in stock when no data on equipment is available. This applies to all future projections but not to backward-looking developments where such data is available. Thus, for the counterfactual scenario, changes in population growth are not directly used as input data. The same applies to economic developments which are represented by changes in the gross domestic product (GDP) of EU Member States.

Finally, changes in technology are assumed for some sectors that lead to a reduction in charge size and consequently, F-gas demand and emissions.

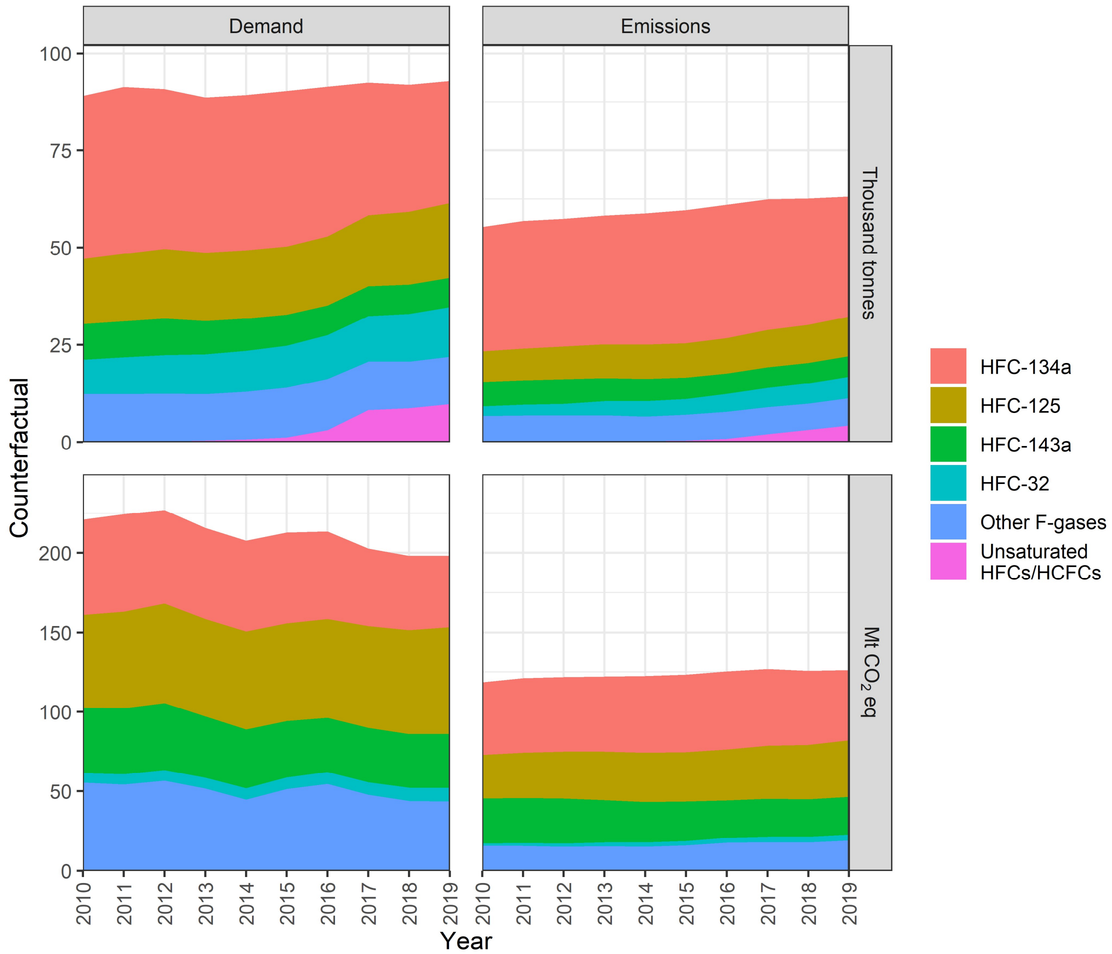
2.2.3 Counterfactual points for comparison

In absence of the Regulation, in the years between 2010 and 2019, the overall demand of F-gases would have increased slightly in metric tonnes but would have decreased slightly in CO_2 eq (Figure 1 and Table). F-gas emissions, on the other hand, would have increased for both metrics. This is because there is a general lag-time between changes in demand and resulting changes in emissions. While new equipment is progressively charged with lower-GWP gases, most of the existing stock still emits high-GWP gases, especially at end-of-life.

In metric tonnes, HFC-134a has the largest share of demand and emissions. Especially since 2017, this share is assumed to decrease, due to the replacement of HFC-134a with the unsaturated HFC-1234yf in car air conditioning systems due to the MAC Directive. Other quantitively notable F-gases are HFC-125, HFC-143a and HFC-32. They are part of the very high-GWP mixtures R404A, mostly used in refrigeration applications, and R410A, mostly used in air conditioning applications. Without regulatory restrictions, their shares will remain constantly high under the counterfactual. Due to their very high GWPs, HFC-125 and HFC-143a have very large shares of demand and emissions when expressed in CO_2 eq.

The group ‘other F-gases’ consists of HFCs (mostly HFC-152a, HFC-365mfc and HFC-245fa), PFCs (mostly small quantities of CF_4 and C_6F_{14}), NF_3 and SF_6. SF_6 is by far the greatest contributor to this group when expressed in CO_2 eq.

Figure 1: Modelled demand and emissions of F-gases by gas/gas group in the counterfactual scenario between 2010 and 2019 for the EU



Source: AnaFgas modelling

Table 9: Yearly sums of the modelled demand and emissions of F-gases in the counterfactual scenario between 2010 and 2019 for the EU

Counterfactual scenario	F-gas demand		F-gas emissions	
Year	kt	Mt CO_2 eq	kt	Mt CO_2 eq
2010	89	221	55	119
2011	91	224	57	121
2012	91	227	57	122
2013	89	216	58	122
2014	89	208	59	123
2015	90	213	60	123
2016	91	214	61	125
2017	92	203	62	127
2018	92	198	63	126
2019	93	198	63	126
Sum (2014 to 2019)	**548**	**1 233**	**368**	**750**

Source: AnaFgas modelling

2.2.4 Comparison with previous modelling

The counterfactual roughly compares to the 'with measures' (WM) scenario from the preparatory study for a review of Regulation (EC) No 842/2006 by Schwarz et al. (2011) but the counterfactual was updated based on more current available data on, for example, developments in technology, population growth and gross domestic product (GDP) (as the counterfactual is backward-looking and the WM scenario was making assumptions towards the future). Also, the WM scenario did not include Croatia, while the counterfactual encompasses the EU27+UK.

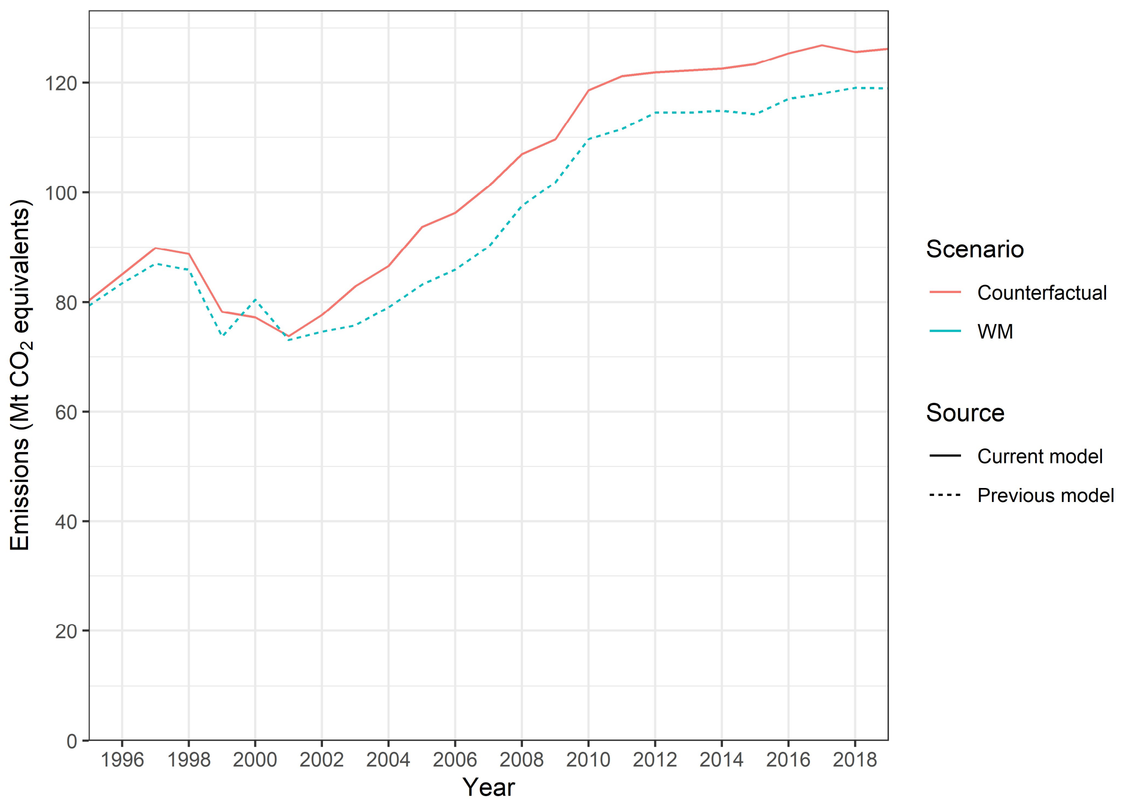
Comparing the emissions from both scenarios, the counterfactual is consistently higher than the WM scenario except for the year 2000 (Table and Figure 2). There are some explanations for these discrepancies. For one, the compared metrics are not identical (EU27 vs. EU27+UK), leading to lower emissions for the WM scenario, although this effect should be relatively small. More importantly, the updates in the counterfactual include adjusted emission rates. Also, sales and stock data, as well as data on F-gas use and population development were updated in the counterfactual scenario.

Table 10: Difference in F-gas emissions between the previous WM scenario (EU27, excl. Croatia) and the AnaFgas counterfactual scenario (EU27+UK)

F-gas emissions (Mt CO_2 eq)	2010	2015	2019
WM scenario (old model)	110	114	119
Counterfactual scenario (current model)	119	124	127
Difference (%)	8%	9%	6%

Source: Schwarz et al. (2011) and AnaFgas modelling

Figure 2: Comparison of current (EU27+UK) and previous (EU27, excl. Croatia) F-gas emission modelling results until 2019



Source: Schwarz et al. (2011) and AnaFgas modelling

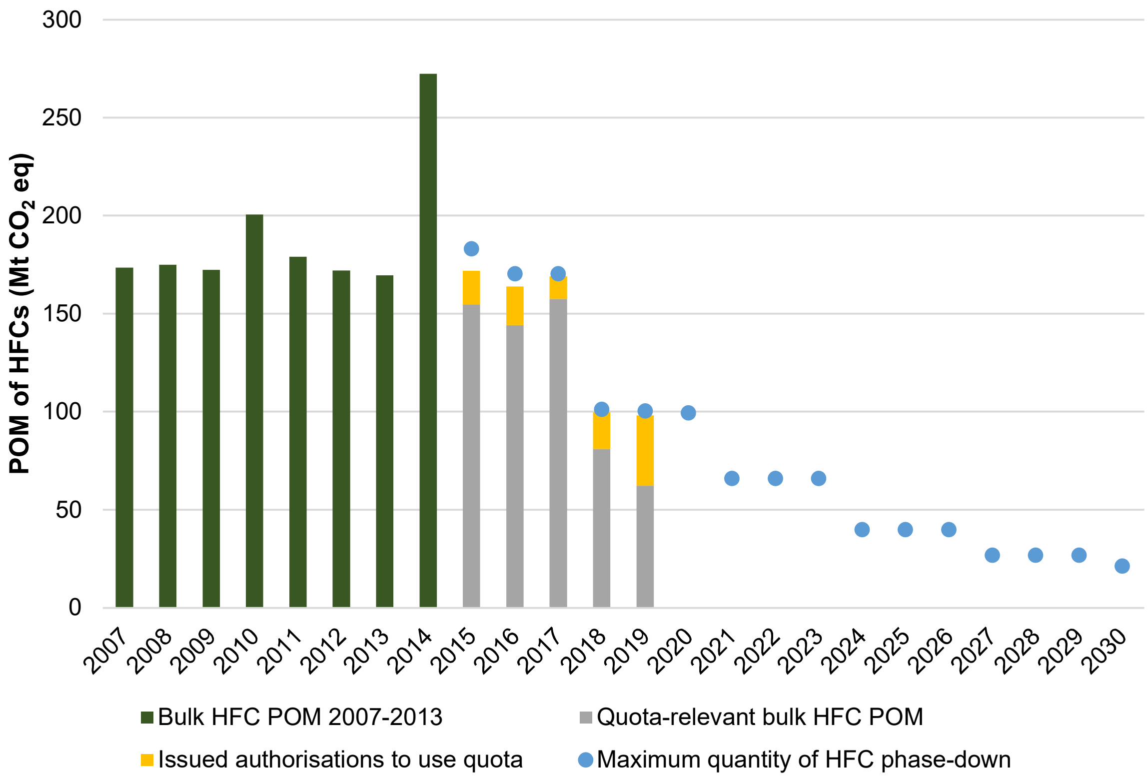
3 Implementation state of play

3.1 Use and emissions

The basis for this assessment is the annually reported production, import, export and destruction of F-gases in the EU that is published every year (EEA, 2020). This reporting is based on Article 19 of the Regulation.

As can be seen in the figure below, the placing on the market of F-gases in the EU, expressed in CO_2 eq, declined in 2018 when compared to the quantities in 2017. The reason for this is mainly the HFC phase-down, which presents the core measure of the Regulation. In 2018, placing on the market (POM) of HFCs was restricted to 63 % of the 2015 quantities (100 %), based on the average quantities placed on the market in the period 2009 to 2012. In 2019, as in all previous years, the POM of HFCs did not exceed the allowed limit of 100.3 Mt CO_2 eq and the quota-relevant bulk HFC POM decreased compared to 2018, while the issued authorisations to use quota increased.

Figure 3: Placing on the market (POM) of HFCs in the EU



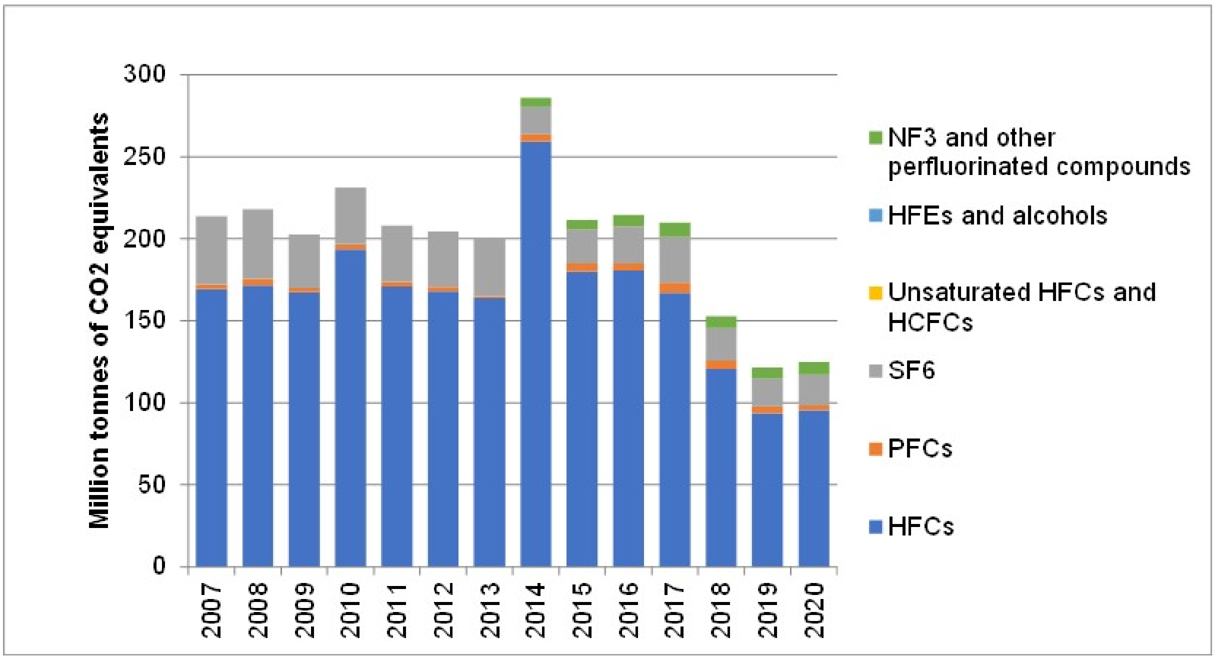
Source: [(EEA, 2020)]

HFCs are the most important group of F-gases, both in terms of quantity (Figure 4) and intended use (Figure 5), being the main gas group for refrigeration, air conditioning and heat pump (RACHP) applications. The HFC phase-down strongly influences the placing on the market of HFCs (Figure 3), but does not cover other F-gases, such as SF_6, NF_3 and PFCs (unless part of HFC blends). These gases, however, on average, made up 23 % of the EU supply of F-gases in 2019, with an average share of 17 % in the period 2014 to 2019 (Figure 4, expressed in Mt CO_2 eq).

While the supply of SF_6 was lower in the period of 2014 to 2019 (average of 20.6 Mt CO_2 eq) compared with the period of 2007 to 2013 (36.3 Mt CO_2 eq), the PFC supply was higher (5.0 and 2.8 Mt CO_2 eq for periods 2014-19 and 2007-13 respectively).

The reporting of NF_3, PFPMIE, HFEs, as well as unsaturated HFCs and HCFCs, has only been required since 2014. While for NF_3 and HFEs there is no clear trend visible (on average 6.8 and 0.1 Mt CO_2 eq, respectively), an increasing supply of unsaturated HFCs and HCFCs was reported since 2017. Due to the low GWP of unsaturated fluorocarbons, however, this amounts to less than 0.1 Mt CO_2 eq per year.

Figure 4: EU supply of F-gases



Note: From 2007 to 2013, only HFCs, PFCs and SF_6 had to be reported on and imports in products and equipment were not included.
Source: [EEA 2021 F-gases reporting data]

The following Table 11 gives an overview of relevant sectors and F-gases in the EU27+UK.

Table 11: Relevant sectors in which F-gases are used

Sector	Relevant F-gas groups	Most relevant F- gases	Subject to prohibitions and/or HFC phase-down
Refrigeration, air-conditioning and heating (RACHP)	HFCs	HFC-134a, HFC-125, HFC-32, HFC-143a, HFC-23	HFC phase-down and prohibitions (except military equipment)
	Unsaturated HFCs	HFC-1234yf	No (Annex II substance)
	PFPEs, mainly for heat transfer fluids		No
Foam	HFCs	HFC-152a, HFC-365mfc, HFC-245fa, HFC-227ea, HFC-134a	HFC p4.hase-down and prohibitions (except military equipment)
	Unsaturated HFCs	HFC-1234ze(E)	No (Annex II substance)
	Unsaturated HCFCs	HCFC-1233zd(E)	No (Annex II substance)
Fire protection	HFCs	HFC-227ea	HFC phase-down and prohibitions (except military equipment)
Aerosols	HFCs	HFC-134a	Phase-down and prohibitions (except military equipment)
	Unsaturated HFCs	HFC-1234ze(E)	No (Annex II substance)
Metered dose inhalers (MDIs)	HFCs	HFC-134a, HFC-227ea	No
Electrical equipment including switchgear	SF_6	SF_6	No
Magnesium industry – Die-casting – Recycling of die-casting alloys – Sand casting – R&D	SF_6	SF_6	Prohibitions for Mg die casting and recycling of Mg die-casting alloys (Article 13)
Semiconductor and electronics manufacture, especially plasma etching	PFCs, NF_3, SF_6, HFCs, PFPEs	HFC-23, PFC-14 (CF_4), PFC-116 (C_2F_6), PFC-218 (C_3F_8), NF_3, SF_6	No
Feedstock for production	PFCs	TFE (Tetrafluoroethylene; C_2F_4, unsaturated PFC), PFC-1216 (unsaturated PFC)	No
Inhalation anaesthetics	Fluorinated ethers	Desflurane, Sevoflurane and Isoflurane	No
Solvents	HFCs	HFC-34-10mee	HFC phase-down
	PFCs, unsaturated HCFCs, HFEs	PFC-5-1-14 (C_6F_{14}), HCFC-1233zd, HFE-7100 (HFE-449sl)	No
Military applications	HFCs, PFCs, SF_6, possibly also unsaturated HFCs, HCFCs, HFEs	HFCs, PFCs, SF_6	No
Particle accelerators	SF_6	SF_6	No
Tracer gases	PFCs, SF_6	PFCs, SF_6	No
Personal products	HFCs, PFCs	HFC-152a in sprays, mousses; PFC-9-1-18 ($C_{10}F_{18}$) in anti-wrinkle creams, nail polishing products	Prohibition for technical aerosols relevant for aerosol applications only (sprays)
Lubricants	PFPEs		No

RACHP is clearly the most relevant sector with 63 % of all applications in 2019 (heat transfer fluids play a negligible role), according to the most recent EEA report on F-gases (Figure 5). This holds true especially when expressed in metric tonnes (71 %). HFCs are the most abundantly used gases in this sector, mainly HFC-134a and the blends R404A (52 % HFC-143a, 44 % HFC-125, 4 % HFC-134a), R407C (52 % HFC-134a, 25 % HFC-125, 23 % HFC-32) and R410A (50 % HFC-125, 50 % HFC-32)[9]. The use of HFC-134a is declining but it is still playing the major role in terms of supply in metric tonnes (25 733 tonnes in 2019, 25 % of all F-gases). In terms of CO_2 eq, use of HFC-134a (37 Mt CO_2 eq, 39 %) is almost on par with HFC-125 (34 Mt CO_2 eq, 36 %), with the latter predominantly used only in blends.

Within the RACHP sector, HFC-32 and HFC-1234yf also play a pivotal role and are increasingly being used. HFC-32 is the leading replacement for R410A in stationary air-conditioning applications, due to its lower GWP of 675.[10]

HFC-1234yf is the major refrigerant for mobile air conditioning systems in passenger cars and replaced HFC-134a in all new vehicles since 2017 as a consequence of the MAC Directive. HFC-1234yf is a representative of the newly marketed class of unsaturated HFCs and HCFCs, so-called hydrofluoroolefins (HFOs) and hydrochlorofluoroolefins (HCFOs, sometimes also abbreviated as HFOs), whose main characteristic is their very short atmospheric lifetime that leads to very low GWPs. While HFC-1234yf, thus, helps to mitigate climate change, there is some concern that it could have negative environmental effects because it degrades into the very mobile and highly persistent trifluoroacetic acid (TFA) that may accumulate in drinking water (see for example, (Zhai, 2015), (Scheurer, 2017), (Freeling, F., et al, 2020). Unsaturated HCFCs also introduced chlorinated gases, such as HCFC-1233zd(E), back on the market.

In 2019, 74 % of all PFCs (323 tonnes, 3.2 Mt CO_2 eq) were used for 'semiconductor, photovoltaics and other electronics manufacture', with semiconductor manufacturing accounting for 73 % of the use in this category. To a lesser extent, PFCs were also used for foams incl. pre-blended polyols (11 %, 47 tonnes, 0.4 Mt CO_2 eq) and as solvents (6 %, 26 tonnes, 0.2 Mt CO_2 eq). 8 % of the total supply of PFCs in 2019 (34 tonnes, 0.3 Mt CO_2 eq) were reported under the category 'other or unknown application' and 1 % (5 tonnes, 0.1 Mt CO_2 eq) for 'refrigeration, air-conditioning and heating and other heat transfer fluids'.

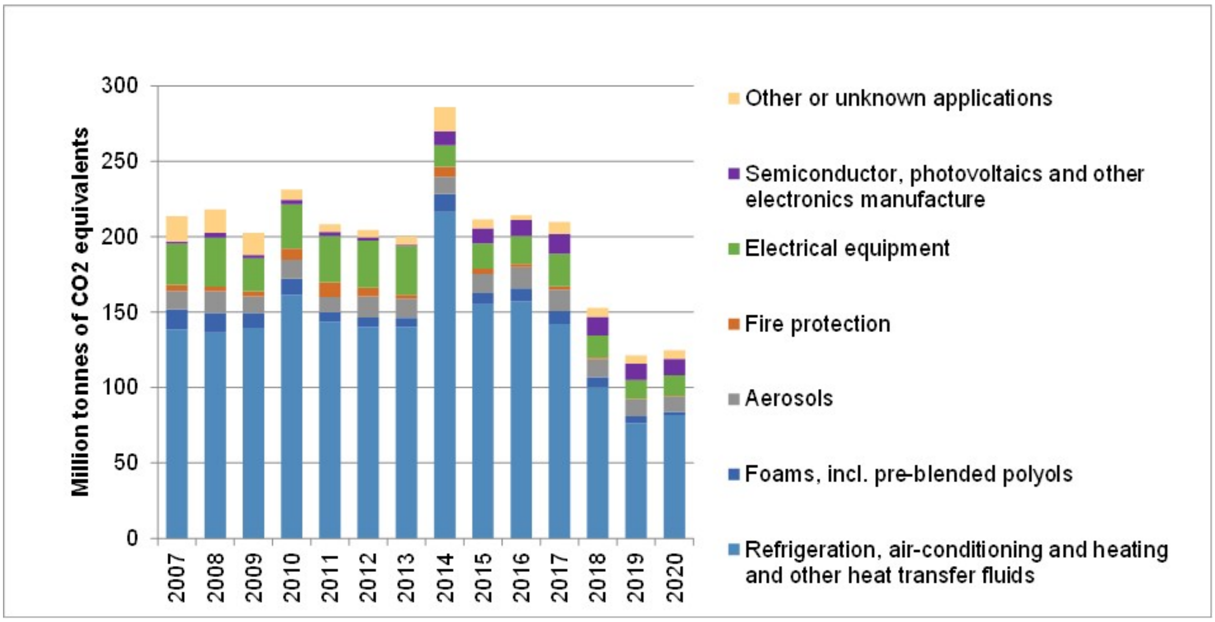
With 73 % of the total supply, SF_6 was mostly used for electrical equipment in 2019 (534 t), followed by 'other or unknown applications' with 23 % (169 tonnes) and semiconductor manufacture with 3 % (24 tonnes).

NF_3 was almost solely used for semiconductor manufacture in 2019 (408 tonnes), with some negligible quantities reported for unknown applications.

[9] The prefix 'R' denotes that the gas or blend of gases is used as a refrigerant (thus, HFC-134a can also be labelled R134a). Throughout this document, however, this prefix will only be used for blends because there is no other denotation available. For single gases, on the other hand, it conveys more information to use the chemical prefix, such as HFC-, that allows to differentiate between groups of gases, such as HFCs, HCFOs and HFOs.

[10] All GWPs in this document are taken from the Annexes to the Regulation that are bases on the 4th IPCC Assessment report (AR4).

Figure 5: Intended uses of the total EU supply of F-gases

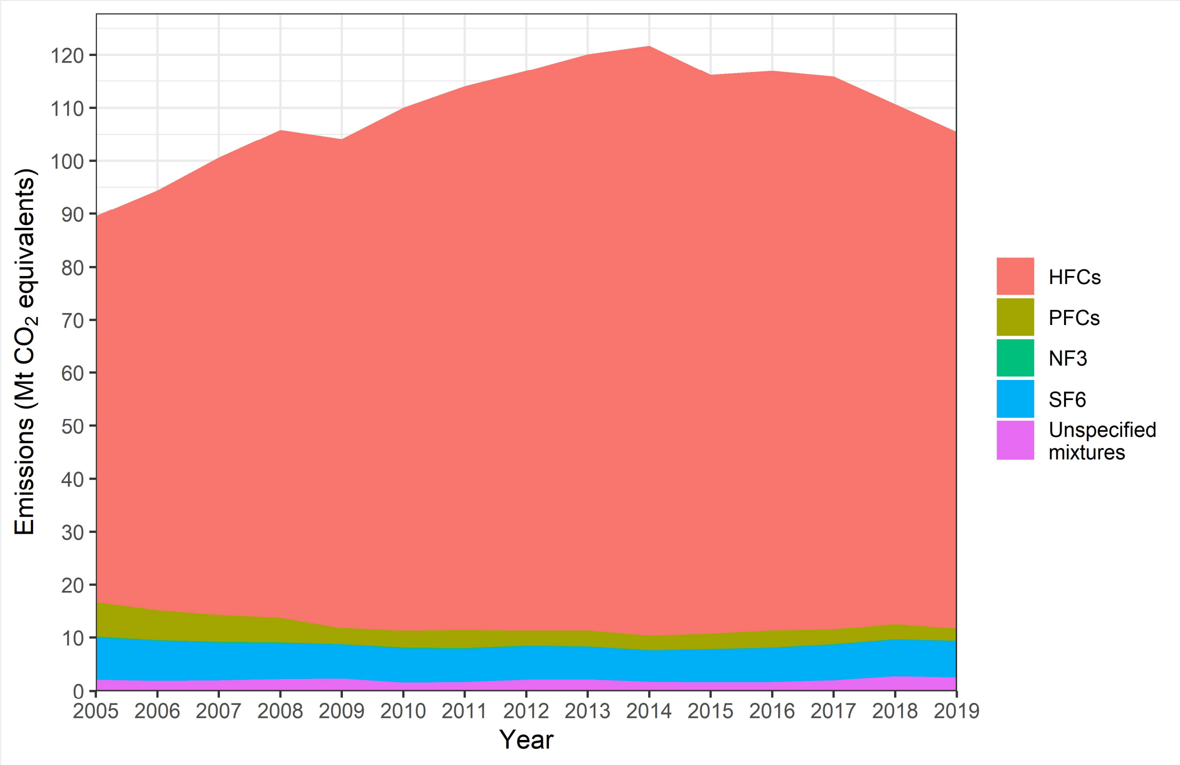


Source: [EEA 2021 F-gases reporting data]

Emissions of all F-gases have also shown a declining trend since 2014 (expressed in CO_2 eq), as presented in Figure 6, based on reported data under UNFCCC (National Inventory Report for EU27+UK). This reduction in emissions is mainly driven by the POM phase-down of HFCs in the EU.

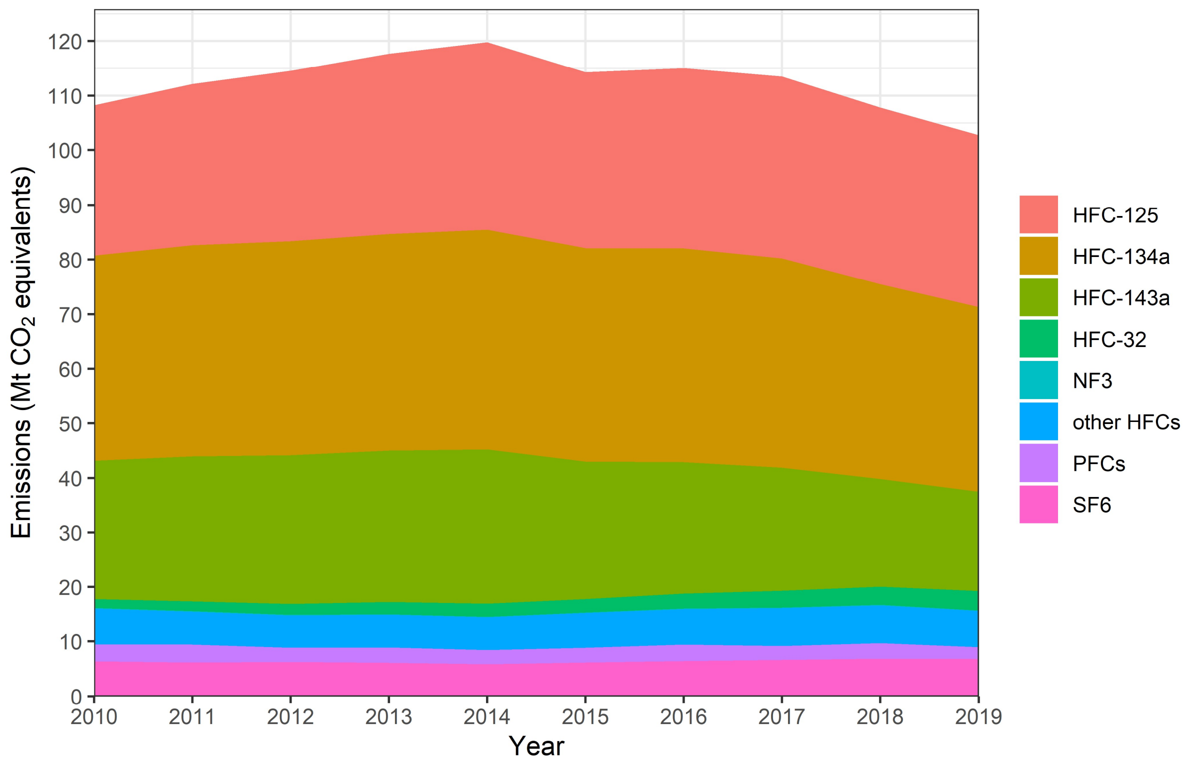
The most relevant HFCs that led to an overall decrease in emissions were HFC-143a and, to a lesser extent, HFC-134a (Figure 7). HFC-143a showed a reduction in emissions from 28 Mt CO_2 eq in 2014 to 18 Mt CO_2 eq in 2019, and HFC-134a from 40 Mt CO_2 eq to 34 Mt CO_2 eq. Main reason for this reduction was the replacement of R404A in refrigeration applications. R404A consists of 52 % HFC-143a, 44 % HFC-125 and 4 % HFC-134a. The fact that HFC-125 did not show a comparable reduction in emissions (the decrease was 3 Mt CO_2 eq from 2014 to 2019) is because many replacement blends for R404A, such as R448A, R449A and R452A contain significant quantities of HFC-125.

Figure 6: F-gas emissions in the EU27+UK by substance group



Source: (European Union, 2021)

Figure 7: F-gas emissions EU27+UK by important HFCs and other F-gas groups



Source: (European Union, 2021)

One of the measures related to prohibitions under the Regulation is Article 12 which outlines labelling requirements for products and equipment that contain, or whose functioning relies on, F-gases. No data exists on the overall compliance with labelling requirements. That said, stakeholders (targeted interviews) generally consider labelling to be effective and important for proper enforcement by the Member State competent authorities.

According to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories (IPCC, 2006), F-gas emissions are reported for different emission source categories to the UNFCCC. The main use of HFCs is as a substitute for Ozone depleting substances in refrigeration and air conditioning, foam inflation, fire protection, aerosols and solvents, and some other applications. In recent years certain HFC emission reductions in refrigeration and air conditioning were achieved, however F-gas emissions still contributed 2.5 % to the EU's total GHG emissions in 2018. Moreover, HFC emissions from refrigeration and air conditions showed a strong increase of more than 80 million tonnes CO_2 eq in the period 1990 to 2018 due to the introduction and increasing use of HFCs as alternatives to ozone depleting substances in that sector. The use of HFCs as fire extinguishing agents has decreased in the past years due to restrictions at EU level through the Regulation and national regulations (this trend was confirmed by industry trade association through the workshop).

PFCs are used to a small extent as substitutes of ozone depleting substances, but mainly in semiconductor manufacturing. SF_6 and NF_3 are not ODS substitutes but used in the electrical and electronics industry (i.e. for manufacture of integrated circuits or semiconductors, TFT flat panel displays, photovoltaics), while SF_6 is also used in the manufacture and operation of electrical equipment (Oko-Researche, 2020).

3.2 F-gas supply

3.2.1 Imports and exports

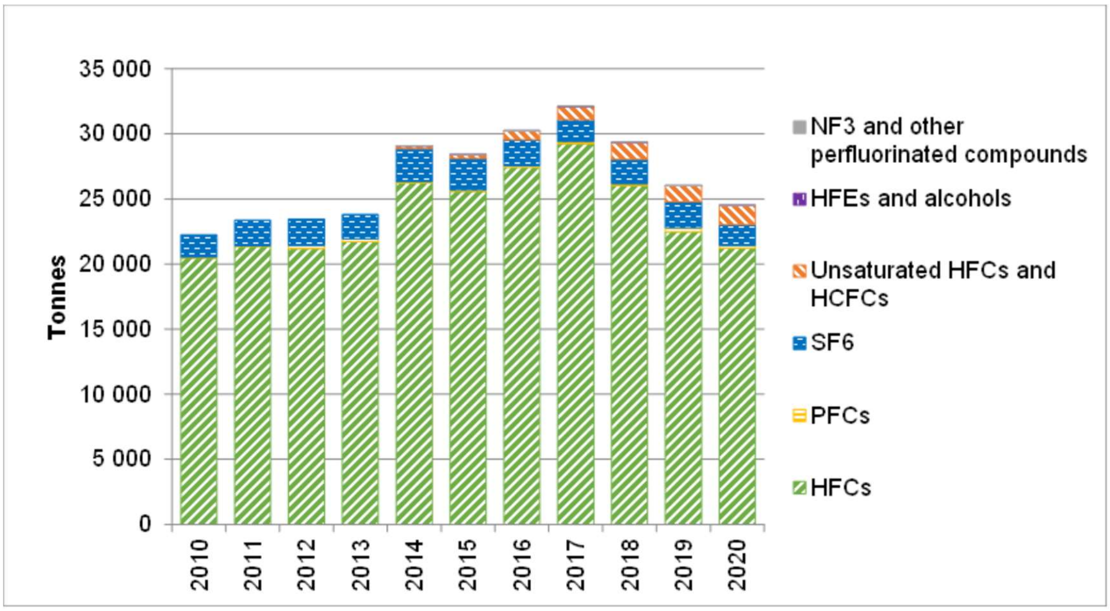
Imports of F-gases into the EU continue to show high levels. Although total imports have declined since 2018 both in tonnes and in CO_2 eq, imports in 2019 were broadly comparable to 2015 levels (2% increase in tonnes). Compared with 2007 amounts, total imports increased by 42 % to 2019, however, it should be noted that Annex II F-gases and HFCs, PFCs and SF_6 in products and equipment were not subject to reporting for the years 2007-2013. When looking at CO_2 eq, the total imports show a different trend, and actually decreased by 33 % and 8 % to 2019, respectively, compared to 2015 and 2007. This reflects a switch to lower GWP gases.

Total imports of F-gases are dominated by HFCs, which accounted for 74 % in tonnes and 82 % in CO_2 eq of the total in 2019. Unsaturated HFCs/HCFCs made up 24 % of imports in tonnes and only about 0.1 % in CO_2 eq. PFCs and SF_6 both accounted for less than 1 % of the total in tonnes and for 3 % and 8 %, respectively, in CO_2 eq. While the share of HFCs in total F-gas imports show a decreasing trend both in tonnes and CO_2 eq, the share of unsaturated HFCs/HCFCs has significantly increased since 2015, by 499 % in tonnes. Due to its much lower GWP compared to HFCs, the increase has been lower when measured in CO_2 eq. The share of PFCs and SF_6 in total imports has been relatively stable since 2015, both in tonnes and in CO_2 eq.

Equipment imports made up 12 % of the total imported amount or 10 % of the GWP in 2019. Imported equipment was predominantly charged with HFCs, which accounted for 92 % in tonnes (or 98 % in CO_2 eq), the reminder being almost completely unsaturated HFC-1234yf. For bulk imports, the share of HFCs is somewhat smaller, with 71 % in tonnes and 80 % in CO_2 eq in 2019.

Bulk exports of F-gases from the EU show a decreasing trend in the last years, reducing by about 10 % annually since 2017. Measured in CO_2 eq, the decline is less steep, with a 1 % reduction in 2019 compared with 2018, following a 4 % decrease the year before. 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/HCFCs, 2019 exports are about 20 % higher than in 2017. Exports of F-gases contained in products and equipment are not subject to obligatory reporting.

Figure 8: EU27+UK exports of F-gases (tonnes)



Source: [EEA 2021 F-gases reporting data]

3.2.2 Production

The 2020 EEA report shows that in the period 2007 to 2019 the production quantity decreased by 64 % (metric tonnes), while expressed in CO_2 eq, production dropped by 42 %. The average GWP of F-gas production increased though which reflects that proportionally larger quantities of high-GWP gases were manufactured (average GWP was 3,012 in 2007 and 4,820 in 2019). This illustrates that EU industry is focussing on few gases for special applications such as SF_6 (GWP 22800), PFCs (GWP in the range of ca. 7000 – 12000) as well as certain HFCs (e.g. HFC-227ea; GWP 3220). Production quantity in 2007 excludes Annex II gases because these were not subject to reporting for the years 2007-2013.

HFCs dominate the production of F-gases and accounted for 87 % of the total in 2019 (or 45 % in CO_2 eq). Approximately 5 % (expressed in GWPs) of EU HFC production is going to exempted use as MDIs, covering about 25% of the EU demand in medical-grade HFCs for MDI production. About 15 % (expressed as GWPs) of EU HFC production is HFC-365mfc of which about 75 % were exported. HFC-365mfc is a specialty HFC used mostly for foam blowing. While SF_6 accounts for roughly 10 % of F-gas production, it constitutes about half of the production expressed in CO_2 eq. Large quantities of SF_6 are exported, both in bulk and equipment (mainly electrical switchgear).

3.3 F-gas end-of-life

3.3.1 Destruction and feedstock use

Destruction and feedstock use of F-gases is reported almost exclusively for HFCs. The amounts destroyed have significantly increased since 2007 (by about 2 900 in tonnes in 2019), however the amounts reported in the period 2016 to 2018 were about 50 % below 2015 levels. In 2019, destruction more than doubled in tonnes compared to 2018, mostly due to more complete reporting on the by-production of HFC-23 and subsequent destruction. Feedstock use has been almost constant since 2015, at levels of approximately 3-4 Mt CO_2e/a, with a small increase in 2018.

3.3.2 F-gas reclamation (Article 8)

Reclaimed HFCs are not subject to the limits of the HFC phase-down, and even gases with high GWP can still be used to service larger refrigeration equipment until 2030. Reclaimed gases can ensure the availability of HFCs such as R404A (for which alternatives are expensive or not yet readily available) on the market going forward, especially as the phase-down becomes tighter. According to the annual reported data, the level of reclaimed gases is still low although the amounts of reclaimed HFCs have more than tripled since 2015 and made up 2.5 % of the EU supply of virgin HFCs in 2019 (or 4 % measured in CO_2 eq). Still, given the amounts ‘banked’ in equipment that reaches its end of life, there appears to be more untapped potential for increasing reclamation activities in the EU in the coming years. As mentioned in the EEA 2020 report, while 97 % of reclaimed amounts are HFCs, SF_6 contributes to 20 % of the GWP of reclaimed gas. The majority of F-gases on the EU market are hence still virgin gases.

At the end-of-life (EOL) of equipment, the contained F-gases can be recycled, reclaimed or destroyed. While recycled gases undergo only a basic cleaning process, reclaimed gases are treated in such a way as to reach virgin qualities. Recycled and reclaimed (non-virgin) HFCs are exempted from the phase-down. Consequently, the increasing use of non-virgin HFCs allows for an equivalently increasing use of virgin HFCs.

At present, there is limited information on the extent of the use of non-virgin HFCs in the EU. A reporting obligation for recycled or reclaimed F-gases exists for producers, importers and exporters and the reported data shows an increase in 2019 in recycling and reclamation especially for HFC-143, which is a major component of the blend R404A (**Fehler! Verweisquelle konnte nicht gefunden werden.**). Other important HFCs also show a clear increase compared to previous years. However, these figures do not include data from undertakings that recycle or reclaim gases without being also an importer or producer. Through stakeholder engagement, a national association from Poland (Prozon) indicated that in Poland in 2019 about 30% of recovered refrigerant was reclaimed, which increased to 44% in 2020. These levels are thought to rank highest within the EU. As Prozon explained, reclamation activities are strongly linked to the availability of facilities within the country, as cross-border shipments are difficult to organize. High shares of reclamation are thus expected in France, Belgium, Czech Republic, Germany, the Netherlands and UK.

Table 12: Reported reclaimed quantities as percentage of total supply for important HFCs

		Reclamation (% of supply)		
Gas	**GWP**	**2010**	**2015**	**2019**
HFC-23	14 800	-	0.1 %	6.4 %
HFC-143a	4 470	0.5 %	1.7 %	26.4 %
HFC-125	3 500	0.4 %	1.1 %	5.1 %
HFC-227ea	3 220	-	1.2 %	0.8 %
HFC-134a	1 430	0.3 %	0.5 %	1.6 %
HFC-32	675	0.6 %	0.9 %	1.5 %

Source: (EEA, 2020)

3.4 Measures preventing leakage of emissions

3.4.1 Leak checking and leakage rates (Articles 3-5)

There are no quantitative data on the actual number of ***leak checks*** performed within the different sectors. However, evidence that the requirements were implemented is provided indirectly since documented leak rates (refill rates) reduced (see the following sections). Furthermore, compliance is thought to be rather high today by Member States authorities and industry.

Nevertheless, cases on non-compliance with leakage checks are sometimes discovered: One prominent example of a breach of leak checks has been reported in Cooling Post, where the supermarket chain Lidl was fined €9,200 in the Czech Republic as a result of being unable to provide leak check records during air conditioning and refrigeration checks at 21 of their stores carried out by Czech Environmental Inspectorate (CEI) agents between July and October 2019. The director of the regional inspectorate of the CEI stated that ‘*a total of 80 applications for leak tests were carried out in violation of the European regulation, according to which the operator must, among other things, ensure a leak test* *for prescribed cooling applications at least once every 6 or 12 months. He is then obliged to keep records of inspections for at least five years'* (Cooling Post, 2020).

The following table provides an overview of national databases from several Member States and the ***leakage rates*** determined from these datasets. It has not been possible to gather information for this evaluation on leakage rates from all Member States which have electronic databases. In Hungary, only undertakings are provided with a certificate after the enterprise registered in the Climate Gas Database[11]. For Slovakia, there is the national reporting system 'Leaklog' run by the Slovak Association for Cooling and Air-conditioning Technology (SZ CHKT) and which is also used for the national reporting to the UNFCCC (Tomlein et al, 2019).

Overall, the data from the national databases show that leakage rates are higher in commercial refrigeration applications as compared to stationary air conditioning and heat pumps. In terms of refrigerants, higher leak rates are observed for R404A while R134a shows lower rates which is likely due to the lower working pressure of the latter.

Some detailed information on the commercial refrigeration sector is available from the 'Chilling Facts' reports published by the EIA. The reports are based on surveys among retail chains throughout Europe. The following table shows a comparison of the reported leakage rates by retailer in 2014 and 2015. It needs to be underlined that those retailers provided their data on a voluntary basis. Leakage rates are expressed as a percentage of system charge lost over a year (EIA, 2017). The report found that under the Regulation 'leakage continues to be a problem for some retailers, although the data presented has not been updated since 2015 and so it is unclear how seriously the problem persists.

[11] https://nemzetiklimavedelmihatosag.kormany.hu/ (Act LX of 2007)

Table 13: Overview of leakage rates based on records in national equipment databases

	Poland	Slovakia	Hungary	Germany
Recording in national data-base	Mandatory	Mandatory	Mandatory	Voluntary (VDKF)
Data coverage	320,000 units of RACHP equipment (containing 5 tonnes of CO_2 eq or more F-gases) and about 6,000 fire protection units (end 2020)	RACHP only: 1,200 equipment operators and over 250 service undertakings (2019)	More than 91,000 equipment units: > 81,000 stationary RACHP units, > 9,600 refrigeration units of trucks and trailers, > 300 fire protection systems, > 300 electri-cal switchgear units	RACHP only: 1,000 service undertakings, 45,000 operators, 200,000 cooling circuits and a total charge of 2,520 tonnes (May 2019)
Format of in-formation on leakage	By refrigerants and ap-plications; for 2020	By refrigerants and ap-plications; sample based on 2017 for total charge of ca. 200 tonnes	By applications and re-frigerants; for 2019	By refrigerants or appli-cations; average values for the period 2014-2018
Total leakage average	3 %	4.2%	2.1%	2-3 %
Refrigeration	3.71 %	Commercial refrigera-tion: R134a: 3.5 % R404A: 11.5 % R407C: 8.6 % R410A: 5.7 %. Average: 7.1 %	Stationary RACHP: 2.1 %	Commercial refrigera-tion: 3.83 %
		Industrial refrigeration: R134a: 3.5 % R404A: 11.5 % R407C: 1.2 % R410A: 7 % Average: 3.6 %		Industrial refrigeration: 2.07 %
Stationary air conditioning	1.7 %	R134a: 0.4 % R407C: 3.1 % R410A: 3.3 %. Average: 2.5 %		Split AC: 1.53 % Centralised AC: 1.32 % VRF: 1.75 %
Heat pumps	1.74 %	R134: 3.1% R410A: 4.7%		2.92 %
Leakage by re-frigerants				R404A 3.31 % R507A 3.46 % R134a 1.31 % R410A 1.33 %

Table 14: Evolution of leakage rates for different retailers

Retailer	2014	2015
Dia	24.17 %	20.01 %
Kaufland	10 %	10 %
Metro	11.1 %	9.8 %
Migros	6.6 %	6 %
Waitrose	6.35 %	6.98 %

The literature also presents specific data points in some cases. For example, a paper presented by F. Mastrapasqua at 19th European RAC conference[12] in 2021 noted that: *'While in the rest of Europe the*

[12] https://www.centrogalileo.it/wp-content/uploads/2021/04/New_Programme_19th_European_Conference-1.pdf (paper un-published)

greenhouse gas emissions from HFCs have been decreasing in the last few years, in Italy they are increasing exponentially due to the consumption of very high global warming potential HFCs mainly in connection to the maintenance of the old supermarket systems and hypermarkets which still use highly climate-impacting refrigerants and which lose 12-15% of their total charge each year into the environment due to the operating losses (over 2,500 tons per year).'

Some data for specific cases was also provided through stakeholder engagement. For example, one industry stakeholder from the electronics sector reported leakage rates of 1.25%, well below industry average. Feedback from stakeholders (workshop) also elaborated on some of the actions they had taken. For example, a switchgear industry representative noted they had taken great efforts to prevent and reduce leakage of SF_6 emissions, including:

- repeated leakage tests on non-sealed SF_6 switchgear (extra high voltage and high voltage)
- installed leakage-detection systems on each SF_6 switchgear (extra high voltage, high voltage and medium voltage)
- partially installed gas-density monitoring systems.

3.4.2 Record keeping (Article 7)

As already established under the previous Regulation (EC) No 842/2006, record keeping is an obligation of equipment operators if their equipment is subject to leak checks. These records are to be stored by the operators and servicing undertakings need to keep copies for at least five years. However, the format of these logbooks is not specified in the Regulation and might be based on paper documents, electronic files (e.g. Excel tables) or databases.

There is no comprehensive information on the actual use of different formats. Data from Germany, where a national database does not exist, suggest that electronic tools for record keeping have been gaining acceptance during the last years: The branch association VDKF performs regular surveys among their members and found that the share of respondents preferring electronic tools increased to 77 % in 2019, while 23 % still make use of analogue tools for the record keeping).

In certain Member States, electronic equipment databases have been introduced and their use is required by national legislation. Data on units, refrigerant charges, refill quantities etc. are collected in electronic databases and serve as a basis for enforcement and further national measures. Member States which established such electronic equipment registers include for example Poland, Hungary, Slovakia, Czech Republic, and Italy, based on information from competent authorities.

3.4.3 Certification (Article 10)

A survey of Member State authorities (European Commission, 2016) carried out for a 2016 EU Commission report found that there were already 160,000 trained and certified F-gas technicians working on RACHP, covering a total of 40,000 undertakings. This equated to 40 F-gas technicians and 10 undertakings per 100,000 population on average with variations across Member States.

An updated estimate of the numbers of F-gas certified personnel for the stationary RACHP sector has been made based on a survey (AREA, 2021) and information provided by stakeholders. Some data came from official sources (national authorities, certification bodies) whilst others are estimates. It is estimated around 360,000 personnel have been trained across 120,000-130,000 undertakings (EU + UK). The majority of personnel certificates for RACHP related to Category I (88 %), while Category II (7.5 %), Category III (1.2 %) and Category IV (3.6 %) were of minor importance.

No complete data set is available, but there is also evidence of training in other sectors for individual Member States:

- **Bulgaria:** Since 2015, 886 technicians were given training attestations for recovery of F-gases from air-conditioning equipment in motor vehicles.

- **Estonia:** For firefighting and MAC, the total number of certifications were 55 and 1284 respectively since 2015. There have been no certifications for SF_6, though certifications from other Member States are recognised.
- **Finland:** In addition to the requirements of the Regulation, servicing of all mobile equipment is covered by the national certification requirements. The Finnish Safety and Chemicals Agency (Tukes) has issued approximately 5,500 personal certificates since 2015, of which: 3,500 are for air conditioning in motor vehicles.
- **Sweden:** Since 2015, the number of certifications has been 2,657 for mobile AC, 150 for electrical switchgear and 16 for fire extinguishers.

Further evidence of training activities was provided by stakeholders (Workshop feedback, OPC) who elaborated on some of the actions they had taken. For example, a switchgear industry representative noted they had taken great efforts to prevent and reduce SF_6 leakage, including handling of SF_6 is exclusively done by certified staff according to the Regulation, and another noted that the system of training, certification and registration has definitely supported the efforts to reduce the use of SF_6.

Table 15: Net numbers of F-gas certified personnel in stationary RACHP sector (according to Regulation 2015/2067) in the EU based on a survey by AREA and complementary information from MS authorities

Country	Personnel certificates	Company certificates	Source of information
Austria	3,281	1,148	ÖKKV 2020
Belgium	5,200	2,000	AREA
Bulgaria	2,947	1,019	MS authority
Croatia	1,418	1,745	AREA
Czech Republic	6,000	900	AREA/MS authority
Denmark	4,021	1,748	AREA
Estonia	465	N/A	AREA
Finland	7,552	3,397	AREA
France	N/A	35,289	AREA/ADEME 2020
Germany	44,000	3,500	AREA/VDKF
Greece	10,900	100	AREA
Hungary	5,837	5,160	MS authority
Ireland	4,300	1,200	AREA
Italy	73,400 / 75,000	39,000 / 35,000	AREA/MS authority
Netherlands	5,020	2,263	AREA
Poland	23,986	8,346	AREA
Portugal	5,300	1,558	AREA
Slovakia	2,150	1,924	AREA
Spain	127,000	15,987	AREA
Sweden	5,810	1,615	AREA
Total	**338,587 / 340,187**	**123,899 / 127,899**	

3.5 Reporting and verification obligations (Articles 19-20)

According to Article 19 of the Regulation, producers, (bulk) importers and (bulk) exporters, feedstock users and undertakings destroying F-gases as well as importers of products and equipment containing have to submit an annual report on their annual activities by 31 March of the following year. The reporting obligation relates to F-gases of both Annex I and Annex II of the Regulation. The reporting thresholds for producers, bulk importers and bulk exporters are 1 tonne of F-gas or 100 tonnes of CO_2 eq (total of all handled gases per company). For equipment importers the reporting threshold is 500 tonnes of CO_2 eq of F-gases. The number of undertakings reporting under the Regulation approximately doubled from 77 in 2007 to 153 in 2013 (Table 16**Fehler! Verweisquelle konnte nicht gefunden werden.**). After the revision of the Regulation, however, the number of reports increased by approximately a factor of 20 until 2019.

Table 16: Activities reported by undertakings under the Regulation

	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Reports received	77	86	94	110	125	133	153	468	780	1284	1728	2137	3146
of which mention:													
Production of F-gases	6	12	8	7	9	10	9	10	9	9	8	8	9
thereof: HFC production	4	9	6	5	7	8	7	6	6	6	5	5	7
Bulk import of F-gases	55	53	58	70	77	91	112	187	293	379	577	895	1694
thereof: bulk HFC import	48	47	53	66	73	86	107	173	282	366	563	877	1675
Bulk export of F-gases	44	47	64	75	74	81	82	92	99	111	119	115	112
thereof: bulk HFC export	37	39	55	67	64	70	72	81	89	98	104	100	94
Import of products or equipment pre-charged with F-gases	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	228	427	840	1039	1079	1012
thereof: RACHP equipment charged with HFCs	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	220	409	826	1028	1067	1002
Destruction	6	8	7	8	10	11	10	10	15	13	13	16	18
Feedstock use	2	2	2	2	1	1	1	3	3	3	3	5	2
Supply of quota authorisation	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	20	34	94	335	842
thereof: quota authorisation without any EU production, import or export	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	7	6	22	52	357

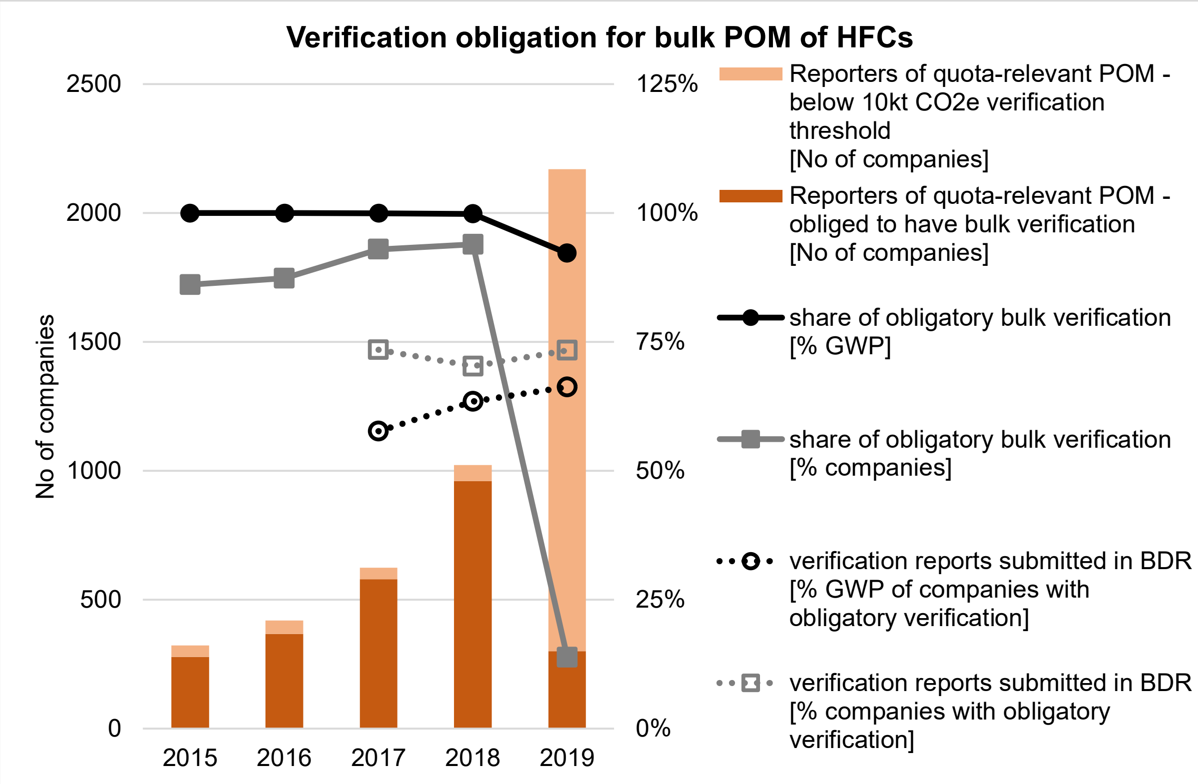
Notes: 'n.a.': not applicable: The reporting obligation for equipment importers applied for reporting on 2014 for the first time. Reporting on quota authorised to other undertakings has been applying since 2015.
The geographical scope of presented data is the EU27+UK except Croatia for 2007-2008 and the EU27+UK for 2009-2019.
Undertakings may report on more than one activity.
RACHP equipment: refrigeration, air conditioning, and heat pumps.

Source: (EEA, 2020)

Verification obligations for reporting data to be submitted according to Article 19 are in place for HFC producers and (bulk) importers where the HFCs placed on the market (POM) exceed the threshold of 10,000 tonnes of CO_2 eq. For importers of HFCs in pre-charged refrigeration, air conditioning and heat pump equipment, the applied threshold for mandatory verification[13] is 100 times lower at 100 tonnes of CO_2 eq.

Figure 9 shows how the 10 kt CO_2eq (= 10,000 t CO_2 eq) threshold for HFC producers and importers of bulk HFCs affects the completeness of verification.

Figure 9: Verification obligation for bulk EU27+UK POM of HFCs



Note: The (voluntary) option to submit bulk verification reports in the BDR was not available for years before 2017.
Source: [EEA 2020 confidential dataset], own calculations

Until 2018, the number of active undertakings with POM below the threshold was relatively constant, between 40-60. The share of undertakings that were subject to obligatory verification increased from 86 % to 94 % in the period 2015 to 2018 and the share of POM covered by obligatory verification was at 99.8 – 99.97 %. In 2019 however, the coverage of POM by verification changed significantly due to the number of new entrants applying for 2019 quota went up strongly[14] and thus the standard quota allocation to new entrants dropped below the level of 10 000 tonnes of CO_2 eq and thus under the reporting threshold. In 2019, the share of undertakings obliged to provide a verification report dropped to 14 % of all undertakings placing HFCs on the market and the share of POM of HFCs covered by obligatory verification dropped to 92 %.

For RACHP equipment importers, the mandatory annual submission of verification reports must be done by 31 March, i.e. the same date as the due date for the Article 19 report. For both the Article 19 report and the verification report, the BDR (EEA) reporting platform operated by the EEA is to be used. Bulk verification reports have to be available annually by 30 June, i.e. three months after the 31 March due date for the Article 19 report. However, bulk verification reports do not need to be actively submitted by

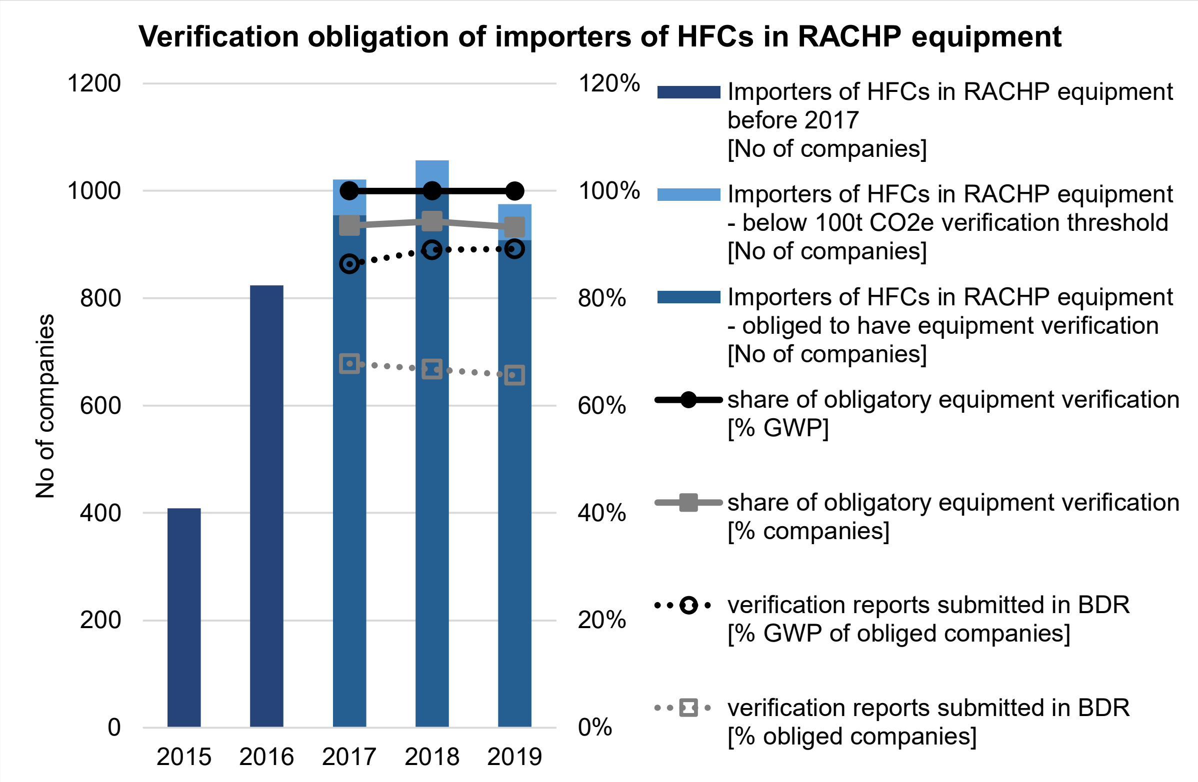
[13] The verification obligation for RACHP equipment importers applies to the declarations of conformity that RACHP equipment importers have to draw up under Article 14 of the Regulation and as specified in Commission Implementing Regulation (EU) 2016/879 the scope of the verification has to include a consistency check with the data reported by the undertakings under Article 19.
[14] For further discussion of the increase in the number of quota applicants see refer to EQ2b

undertakings unless explicitly requested by EU or national authorities. Thus, the use of the BDR reporting facility dedicated to bulk verification is only voluntary unless this is specifically requested.

An option to actively submit a bulk verification report to BDR has been available since 2018 (for 2017 POM) and has been used by almost 75 % of undertakings with obligatory verification (i.e. above the 10 kt CO_2 eq threshold), representing an increasing share of 58 % (2017) to 66 % (2019) of the respective POM above the threshold, measured in CO_2 eq. Note that verification reports where a submission had been explicitly requested by EU and/or Member State authorities in the course of compliance scrutiny are included in those numbers.

Figure 10 presents comparable information for the verification coverage of HFCs in RACHP equipment imports. Note that the amount of HFCs in imported RACHP equipment has been at approximately 10 % to 15 % of total POM, measured in CO_2 eq.

Figure 10: Verification obligation for EU27+UK importers of HFCs in RACHP equipment



Note: The obligation to have HFC imports in RACHP equipment covered by quota authorisation and to have the reporting verified entered into force 2017.
Source: [EEA 2020 confidential dataset], own calculations

Since 2017, imports were below the threshold of 100 tonnes of CO_2 eq for about 5 % of undertakings reporting in the BDR on HFCs in RACHP equipment and thus not subject to the verification obligation (and neither subject to the Article 19 reporting verification). The share of the GWP of HFCs in imported RACHP equipment not subject to obligatory verification was as low as 0.02 – 0.03 % in the years 2017 to 2019.

About one third of obligated equipment importers failed to submit the verification report to the BDR in 2017-2019. The share of the GWP of HFCs in RACHP equipment covered by verification reports submitted to the BDR, however, was higher at 86-89 % as it was mostly equipment importers with relatively low amounts of HFCs who failed to submit the verification report. During the yearly compliance exercise, the EU Commission informed Member States of all undertakings that did not submit their verification reports and requested appropriate action.

3.6 Member State actions

3.6.1 Producer responsibility schemes (Article 9)

According to Article 9 of the Regulation, it is the responsibility of Member States to encourage the establishment of producer responsibility schemes for the recovery of F-gases and their recycling, reclamation or destruction. There is not, however, any mandatory requirement in the Waste Framework Directive and related Directives for Member States to extend responsibility for F-gases to the producer. The producer responsibility schemes established (or not) by MS are set out in the following table.

Table 17: Evidence gathered on existence of producer responsibility schemes in EU Member States

Member State	Description	Information source
Belgium	No scheme in place	Targeted interview with the Member State authority
Bulgaria	No scheme in place	Targeted interview with the Member State authority
Denmark	A voluntary deposit-refund scheme (the so-called KMO scheme) has been running by the contractor's association since 1992 and initially focussed on ozone depleting substances but was expanded to HFCs later. An upfront fee is charged together with the price for the virgin refrigerant by the operator and is used to cover for expenses related to recovery, reclamation and destruction.	Targeted interview Member State authority; Schwarz et al. 2011
Estonia	Planned to set-up an ODS and F-gas handling centre with collection and logistic system, whereby gases will be gathered in a national recycling centre and then will collaborate with another Member State on reclamation and chemical analysis. A potential financial scheme would involve funds from different sources. As a result of this, the national ODS and F-gas handling centre has been equipped with more equipment (basic cleaning) and exchange containers. Cooperation has been established with the Polish foundation PROZON for reclamation and gas analysis meeting ASHRI standard. The Estonian Environmental Research Centre´s ODS and F-gas handling centre is also continuously holding campaigns to raise awareness of its activities. Information is spread to owners of equipment containing controlled substances that it is free to hand over substances to the handling centre, and help is offered in choosing right technology/gas after the substances have been recovered. It has gained interest since 2020 because of the high GWP refrigerant bans and exemptions. The concept of the potential collection and recycling system and its elements/players has been introduced to the Estonian Refrigeration Association, although it requires further action for implementation.	Targeted interview with the Member State authority
Finland	Recovery, recycling, reclamation and destruction of F-gases does take place but there is no official scheme to support it. One company carried out recycling and reclamation of refrigerants (Eco Scandic), one company carries out destruction of refrigerants (Fortum), and there are two undertakings that carry out destruction of refrigerators (Cool Finland Oy and Elwira Oy).	Targeted interview with the Member State authority
France	A take back scheme (introduced in 2007 and extended in 2015) requires that used HFCs must be taken back at no cost although distributors are allowed to place an upfront levy on the sale of virgin or reclaimed HFC refrigerants to recover costs associated with waste management at end-of-life.	(EIA, 2016)
Germany	A legally binding take-back scheme was introduced in 2009. It obliges producers and distributors of F-gases to take back recovered refrigerants. Service undertakings handing in recovered refrigerants are charged a fee for reclamation and destruction.	German Federal Ordinance on Climate Protection; targeted interview industry

Member State	Description	Information source
Italy	No scheme in place	Targeted interview with the Member State authority
Malta	The Malta Competition and Consumer Affairs Authority is currently engaged in internal talks with other Government entities responsible for waste and recycling to evaluate the possibility of the introduction of a producer responsibility scheme.	Targeted interview with the Member State authority
Netherlands	There is a producer responsibility scheme for all large household equipment (including refrigerators): producers and importers who first place household appliances on the market legally obliged to collect and recycle used appliances in accordance with the legally required quality standards[15]. There is also a regulation on producer responsibility for all electronic equipment. Companies that are the first to market electrical and electronic equipment in the Netherlands must individually or jointly set up a logistics system for waste management and also arrange the financing for this, driven by the WEEE Directive[16]. In 2020, 39.1 tonnes and 2.5 tonnes of heat or cold exchanging equipment for domestic and professional use respectively, were reported as collected under producer recovery schemes[17]. That said, engagement with Dutch industry stakeholders has highlighted a number challenges with these schemes. Namely recycling companies do not always prevent emissions as waste legislation is not always well enforced, and this links to problems related to waste codes that may enable this.	Interview with INSUS
Poland	No scheme in place (but noting this was not applicable as there are no F-gas producers in Poland).	Targeted interview with MS authority
Portugal	Introduced a new national regime for waste in 2020, which included an extension of producer responsibility. Under the new decree: • The extended responsibility of the producer is the financial or financial and organisational responsibility of the producer of the product related to the management of the life-cycle phase of the products when they become waste, in accordance with the scheme and specific legislation; • The product's manufacturers should be encouraged to promote changes in its design in order to give rise to less waste in its production and subsequent use, and to allow the re-use and recycling of the products, ensuring that the treatment of the resulting waste takes place, in accordance with the principles of the protection of human health and the environment and the hierarchy of waste. • The application of the preceding paragraph depends on technical feasibility and economic viability, global impacts on the environment, human and social health, and respect for the proper functioning of the internal market; • The responsibility of the producer of the product for the management of waste from their own products, may be taken over on an individual basis, or transferred to an integrated system, in accordance with specific legislation. • Products' manufacturers covered by extended producer responsibility are obliged to report to the NWA (National Waste Authority) through the integrated electronic waste registration system (named SIRER) the necessary information to monitor the implementation of the extended producer liability scheme, in particular the type and quantity of products placed into the market.	Targeted interview with MS authority
Spain	Within the national F-gas taxation established in 2014, a rebate for used gases is possible – part of the tax can be refunded when used gases are delivered to an authorized waste manager for proper treatment.	Targeted interview with MS authority

[15] https://stichtingwitgoed.nl/
[16] https://www.afvalcirculair.nl/onderwerpen/afvalregelgeving/landingspagina/elektr(on)ische/
[17] https://www.nationaalweeeregister.nl/assets/uploads/PDF/2021/Rapportage%202020%20def%2020210628.pdf

Member State	Description	Information source
	For SF_6, a voluntary agreement with industry is in place which sets requirements for SF_6 recovery from end-of-life equipment.	

In addition, for other Member States interviewed (Austria, Czech Republic, Romania and Sweden), no affirmative information was provided through stakeholder engagement hence it is unclear whether producer responsibility schemes have been developed or not.

For those MS with which a targeted interview was not conducted, a targeted literature search could not find any evidence of such schemes (Croatia, Cyprus, Greece, Hungary, Ireland, Latvia, Lithuania, Luxembourg, Slovakia, and Slovenia).

In a minority of cases, private sector action has sought to fill the gaps. Daikin established the LooP scheme (Daikin, n.d.) (stakeholder interview) in 2019 for refrigerant recovery, reclamation and reuse is based on the network of Daikin stores throughout Europe as well as partnerships with installers and reclamation facilities. It focusses on the refrigerant R410A in VRF systems so far. The EU-funded LIFE 3R project contributes to the scheme as it establishes an online platform for the trading of recovered and reclaimed refrigerants.

3.6.2 Penalties (Article 25)

According to Article 25(1) of the Regulation, Member States shall lay down the rules on penalties applicable to infringements of the Regulation and shall take all measures necessary to ensure that those penalties are implemented while ensuring that they are effective, proportionate and dissuasive. The Member States were requested to notify their penalty provisions to the EU Commission by 1 January 2017 at the latest. All Member States notified national measures on penalties for infringements of the Regulation within the set deadline of 1 July 2017, with the exception of Italy and Romania, which received formal notice by the EU Commission in July 2019. Following this formal notice, both countries implemented fines for breaches of the Regulation in late 2019 or early 2020, respectively (Cooling Post, 2019).

Member States have introduced penalties for infringements of the Regulation and as allowed by the Regulation, the levels of penalties set vary between Member States.

No overall data exists on the number of contraventions of different provisions. Through the targeted interviews, Member State competent authorities provided insights on the types of non-compliance under Article 25 (1). Cases of infringements that have been identified were identified across a wide range of the provisions: smuggling at borders, import of HFCs in non-refillable containers, lack of record keeping (Article 6), import without statement on destruction of HFC-23 by-production (Article 7), handling equipment by non-certified personnel (Article 10), import of prohibited products and equipment (Article 11 and Annex III), incorrect labelling (Article 12), cases of quota and quota authorisation exceedances, i.e. import without sufficient quota or quota authorisations (Article 14 and 15), import without registration (Article 17), and incorrect or lack of reporting or verification (Article 19). One Member State competent authority reported that many cases of non-compliance were related to misinterpretation of the requirements of the Regulation, while another stated that for inspectorates, non-complaint actions are often difficult to discover so that they rely on reports from e.g. competing undertakings, indicating infringements.

Furthermore, no data exists on the total numbers of inspections carried out in different Member States. However, stakeholders (interview with Member States) suggested that the extent of inspections varied between Member States and also depended on national enforcement resources.

In addition to the penalties to be imposed by Member States, Article 25 (2) of the Regulation states that undertakings exceeding their quota face a penalty of twice the exceedance amount, applied to the subsequent quota allocation by the EU Commission. Since the Regulation entered into force, the following quantities of quota exceedances have been identified based on Article 19 reporting data.

Table 18: Quota exceedance (in Mt CO_2 eq)

	2015	2016	2017	2018	2019
Company level	0.7	0.6	2.4	1.0	1.0
thereof: production/ bulk import of HFCs	0.7	0.6	2.0	0.3	0.8

Source: (EEA, 2020)

Furthermore, the number of non-compliant undertakings identified in the HFC Registry are presented in the following table.

Table 19: Number of non-compliant undertakings

	2015	2016	2017	2018	2019
HFC producers / bulk importers	31	26	34	28	37
Importers of RAC equipment charged with HFCs	-	-	145	171	104

Source: (DG CLIMA HFC registry, n.d.)

3.6.3 Data reporting systems (Article 20)

Article 20 of the Regulation stipulates that Member States shall establish reporting systems for the relevant sectors referred to in this Regulation, with the objective of acquiring (to the extent possible) emissions data that can be used as valid basis for F-gas emissions reporting to the UNFCCC. The emission reporting currently relies on export estimates for emission factors in most cases rather than actual emissions data based on the equipment stock present in the country. The following table is based on information from National Inventory reports as well as feedback received in the targeted interviews with Member States competent authorities and gives an overview of the different data collection systems in place. Many countries rely on a combination of expert estimates, surveys and statistics.

Table 20: Examples of data collection systems

Member State	Short description of available data collection system
Estonia	The main national electronic data collection system (FOKA registry) for ODS and F-gas equipment (electronic logbook) has been implemented since 2012. The system includes stationary refrigeration, air conditioning and heat pumps, firefighting systems, SF_6 switchgear and solvent equipment. The electronic data collection information system has been continuously updated to meet the requirements from new regulation and restrictions. It is also used for risk analysis for enforcement purposes as well as an information source to conduct the GHG inventory. The undertakings supplying F-gases keep their own records according to Article 6. They are regularly inspected by the authorities. For other sectors, information from industry is used.
Finland	There is an electronic data collection system that collects data on F-gas quantities used (in bulk and product and equipment), but not on emissions. F-gas emissions are currently calculated for UNFCCC reporting based activity data collected via questionnaires and from statistical data sources. There is cooperation with other Nordic countries on UNFCCC reporting on F-gases, e.g. comparison and harmonisation of emission factors.
France	Uses data collected by ADEME and referring to service amounts reported by undertakings (not based on equipment units) for UNFCCC reporting
Germany	A bottom-up model covering all relevant F-gas uses has been established and continuously improved since the mid-1990s. Data from various industry stakeholders, industry statistics as well as data based on the national Environmental Statistics Act (F-gas quantities for different uses by

Member State	Short description of available data collection system
	branches) are compiled annually and serve as basis for emission estimates submitted to the UNFCCC. Emission factors are based on literature as well as expert estimates.
Italy	A national data collection scheme has been established to collect all information related to the provision of Article 6 of the Regulation and to record sales of F-gases and non-hermetically sealed equipment charged with F-gases in accordance to Article 11 (4), (5). However, emissions data from the data collection scheme is only used for validation of indicated estimations
Malta	A data collection scheme has been implemented with respect to the use of F-gases. The system is manually driven and the data collection system works by having distributors of F-gases in bulk and technicians who are to buy these products collect data as per Article 6. These are then listed by the individuals on templates issued by the authority and kept as records. The authority periodically asks for these records so that data is collected.
Poland	Poland has established a Central Database of Emissions to Air (CDEA) that is an electronically operated centralized system for reporting on GHG emissions to air, including Ozone and F-gas emissions. Data from that system are reported to UNFCCC and are collected from various sources, taking into account data available in the electronic Central Register of Equipment Operators (CREO) and Database for Business Reports (DBR). From the CREO, actual emissions (i.e. leakages) from stationary RACHP equipment, stationary fire protection systems containing 5 tonnes of CO_2 eq of F-gases or more and from electrical switchgear equipment containing 6 kg of SF_6 or more are available. From the DBR, the F-gas quantities lost because of leakage, i.e. actual emissions (leakages) from F-gas cylinders as well as during activities undertaken by servicing undertakings are available.
Portugal	Portugal has established a platform for equipment subject to leak checks (5 tonnes of CO_2 eq and more), operators have to report some type of data which includes the type of equipment and its fluid, the quantity of F-gases that are installed, the quantity added to replace the leakage and recovered/reclaimed/recycled quantities. It is an electronic data collection system used by undertakings which are obliged to report under the existing framework, for undertakings. From this system an annual internal report is produced, but not published so far. The data is mainly collected for the GHG inventory (UNFCCC, COM requirements) has not been used to perform detailed screening of the data due to lack of resources, but final objective would be to conduct extensive analysis.
Spain	Uses data from its HFCs tax system to estimate service quantities and hence derive F-gas emissions due to leakages. It should be noted though that refill of leakages might does not fully reflect operation emissions since emissions from equipment not serviced at all are not included. Emissions occurring during the handling of F-gas containers (refrigerant management) are also typically not included.

4 Methodology

4.1 Overview

To support the delivery of the evaluation, the methodology has closely followed the guidance on undertaking Evaluations and Fitness Checks outlined in the Better Regulation Toolbox. The evaluation consists of an assessment based on the five key criteria: efficiency, effectiveness, EU added value, coherence and relevance. The study was undertaken between April 2020 and June 2021.

4.2 Evaluation questions

Eleven evaluation questions were developed to guide the analytical work focused on the criteria (1) relevance, (2) effectiveness, (3) efficiency, (4) coherence and (5) EU added value of the Regulation. These, alongside a mapping to the Intervention Logic, are presented in Table 21.

4.3 Answering the evaluation questions / evaluation matrix

The evaluation matrix is presented in Annex 3. This is based on the broad objectives and description of the evaluation criteria set out in the combined evaluation roadmap/inception Impact Assessment (European Commission, 2020) (note this did not define a detailed set of evaluation questions. The evaluation matrix in Annex 3 sets out the following aspects for each evaluation question, which were used to structure the study approach:

- **Sub-questions:** Sub-questions have been developed for each of the eleven evaluation questions assessed. These draw out aspects of each question based on our interpretation and understanding of the evaluation questions.
- **Assessment criteria:** these describe the operational questions we would seek to answer for each sub-question. They will also be used to support the development of questions to be asked to stakeholders as part of the interviews and surveys.
- **Indicators:** This column highlights potential indicators that can be used to monitor/measure the respective impacts. These indicators will provide a metric which can be used to measure the different components of the intervention logic.
- **Data analysis approach:** This describes in detail the overall approach and the methods and tools to be used by which we expect to answer the question.
- **Data sources and data collection methods:** This describes the key sources we expect to use to answer the question as well as the way in which the data may be gathered e.g. via consultation of selected stakeholders.

4.4 Data sources

4.4.1 Desk research

Extensive literature review has been conducted to inform the assessment based on the evaluation criteria. It involved an in-depth review of a range of sources, including: references in the terms of reference for this support study; from current work being undertaken by project partners; from reports and other evidence signposted as well as official documents published by the EU Commission, reports from previous pan-European and national level studies, scientific articles, position papers, meeting proceedings and legal texts. In total over one hundred literature sources have been reviewed in detail, providing evidence related to all of the evaluation criteria. These are listed in Annex 4.

Table 21: Evaluation questions and link to intervention logic

Criteria	Evaluation questions and related sub-questions	Link to intervention logic
1) Effectiveness	**1. To what extent have the objectives of the Regulation been met? To what extent can the observed effects be attributed to the Regulation and its individual elements?** a. To what extent have the ‘HFC Phase down’ and ‘Placing on market and control of use’ requirements discouraged the use of F-gases and encouraged use of alternatives? i. What has been the combined effect? ii. What has been the contribution of the ‘Placing on market and control of use’ requirements (Article 11-13)? iii. To what extent have the ‘HFC phase down’ requirements (Articles 14 to 18) discouraged the use of F-gases and encouraged use of alternatives? b. How effective has the Regulation been in preventing leakages of F-gases (Articles 3 to 8 and 10)? c. How effective have the reporting and verification obligations (Articles 19 to 20) and the F-gas Consultation Forum (Article 23) been in supporting the achievement of the objectives of the Regulation? d. To what extent have Member State actions contributed to the achievement of the objectives (covering Articles 9 and 25)? e. How effective has the Regulation been to enhance sustainable growth, stimulate innovation and develop green technologies by improving market opportunities for alternative technologies and gases with low or zero GWP? f. To what degree has the Regulation facilitated convergence towards a potential future international agreement?	Analysis of effectiveness seeks to determine how successful EU action has been in achieving or progressing towards the original objectives of the intervention. ***Intervention logic:*** compares the ‘Effects’ of the F-gas Regulation (including ‘Outputs’, ‘Results’ and ‘Impacts’) to its ‘Objectives’
	2. What factors have contributed to or hindered the achievement of the objectives of the Regulation? What have been the unintended/unexpected effects? a. What external factors have contributed to the success or not of the Regulation? b. Have there been any unintended/unexpected effects of the intervention, including on trade of F-gases?	
2) Efficiency	**3. What have been the benefits of the Regulation?** a. What environmental benefits has the Regulation delivered? b. What economic benefits has the Regulation delivered? c. What social benefits (health and safety) has the Regulation delivered?	Analysis of efficiency compares how proportionate the benefits of the F-gas Regulation have been to the costs. Intervention Logic: compares ‘Inputs’ to ‘Outputs’, ‘Results’ and ‘Impacts’
	4. What have been the costs of the Regulation? a. What has been the change in operative and other costs to businesses of undertakings? How are these costs split by sector and EU Member State? b. Which administrative costs have been incurred by undertakings?	

	c. What have the environmental costs of the Regulation been? d. Have there been any other (indirect) economic costs? e. What have the social costs of the Regulation been?	
	5. To what extent have the costs been proportionate to the benefits?	
	6. Are there any unnecessarily complicated or burdensome aspects and areas of excessive costs? What are the reasons and magnitude of any identified inefficiencies?	
3) Relevance	**7. To what extent do the objectives of the Regulation continue to reflect and respond to the needs of the EU?** a. Does the problem persist? b. Does the Regulation cover all relevant F-gases, sectors and sub-sectors that use F-gases, as well as all actors in the F-gas supply and use chain? c. Does the Regulation continue to sufficiently contribute to EU climate change goals (also with view to the ambition raising as part of the EU Green Deal)? d. Does the Regulation sufficiently safeguard compliance with international commitments related to the Montreal Protocol (Kigali Amendment)?	Analysis of relevance seeks to ascertain whether the original objectives of the intervention are still representative of the current needs of society. ***Intervention logic:*** links 'Objectives' back to original 'Needs'
	8. Has the Regulation been flexible enough to respond to new or emerging issues, such as technological or scientific advances or other changes?	
4) Coherence	**9. To what extent is the Regulation externally consistent and coherent i.e. with other interventions which have similar objectives?**	Analysis of coherence seeks to identify any internal gaps, overlaps, inconsistencies or complementarities within the F-gas policy framework but also externally with other EU/international policies ***Intervention logic:*** Links 'Objectives', 'Inputs', 'Activities' and 'outputs' to 'External factors', in particular other policies; as well as to some of the ´operational objectives' (e.g. efficient mechanism)
	10. To what extent is the Regulation internally consistent and coherent, in particular across its implementing acts? How well do the different provisions of Regulation operate together to achieve its objectives?	
5) EU added value	**11. To what degree has the Regulation enabled successful and cost-effective EU action regarding the reduction of F-gases beyond what would have been possible at national level?**	Analysis of EU added value aims to identify where the implementation of the Regulation at EU level has exceeded the value which could have been achieved at Member State level. ***Intervention logic:*** Considers whether 'Results' and 'Impacts' could have been achieved without the 'Inputs', 'Activities' and 'Outcomes' specific to the F-gas Regulation

4.4.2 Modelling

4.4.2.1 *Baseline and counterfactual scenario*

In order to quantify the effect of the Regulation, a bottom-up stock model was used to calculate yearly demand and emissions of F-gases in metric tonnes and CO_2 equivalents for all relevant sectors and sub-sectors. The model is based on the AnaFgas (abbreviation for 'Analysis of Fluorinated greenhouse gases in the EU') model described in (Schwarz et al, 2011). In the following, AnaFgas refers to the updated model used for this evaluation. A detailed description of the model can be found in the Annex to this document.

Demand is defined as quantities of gas required for first filling of new equipment and re-filling of existing equipment in a given year. The AnaFgas model assumes yearly re-fillings of emitted quantities, which is not necessarily the case over the lifetime of equipment, and thus the modelled yearly demand can deviate in the short term.

Emissions are defined as quantities being released from existing equipment (lifetime emissions) and emissions at end-of-life (disposal emissions), as well as manufacturing, by-product and fugitive emissions from the production of halocarbons, semiconductors and aluminium. The AnaFgas model assumes specific emission factors for the different sectors and sub-sectors, as well as scenarios. A full list can be found in the Annex.

Two scenarios were calculated for the period from 2010 to 2019:

BASELINE SCENARIO

- Yearly demand and emissions of F-gases in the EU under the current regulatory framework.
- All measures of the Regulation, its predecessor Regulation (EC) No 842/2006 and Directive 2006/40/EC relating to emissions from air conditioning systems in motor vehicles ('MAC Directive') apply.
- Update and continuation of the AnaFgas model from the preparatory study for a review of Regulation (EC) No 842/2006 (Schwarz et al, 2011).
- Sources include the reporting of F-gases in the EU (EEA 2020), National Inventory Reports (NIR) from the UNFCCC reporting (UNFCCC), and further assessments that have been conducted by the project partners in recent years and expert consultations.

COUNTERFACTUAL SCENARIO

- Yearly demand and emissions of F-gases in the EU in the absence of the current Regulation.
- Only measures of the former F-gas Regulation (EC) No 842/2006 and Directive 2006/40/EC relating to emissions from air conditioning systems in motor vehicles ('MAC Directive') apply.
- Based on the baseline scenario but continued use of F-gases assumed for all sectors.

A comparison of both scenarios allows for the quantification of the effect of the Regulation.

4.4.3 Field research

A variety of stakeholder consultation methods were used to gather additional evidence and fill in data gaps from the desk research. The main consultation activities were the following:

- Feedback received on the Evaluation roadmap
- Open public consultation (OPC)
- Targeted stakeholder interviews
- Stakeholder workshop

A summary of the stakeholder consultation activities and findings is presented in the Consultation Synopsis report developed in line with the Better Regulation Guidelines and included as Annex 5 to this report.

4.4.3.1 *Open public consultation (OPC)*

An online open public consultation (OPC) is a requirement of the Better Regulation Guidelines. The EU Commission – supported by Ricardo, Öko-Recherche and Öko-Institut – launched an OPC on possible changes to the Regulation. The OPC focussed on the performance of the Regulation to date with respect to its relevance, effectiveness, efficiency, EU added value and internal and external coherence. In addition, the OPC aimed at gathering views from stakeholders on envisaged future policy options and their likely environmental, economic and social impacts, while also including questions capturing the context of the European Green Deal and recent technological progress, considering these as drivers for further ambition. It offered an opportunity for any interested individual from any type of stakeholder group to give their opinion on the main evaluation questions.

The OPC questionnaire was published via the EU Survey platform on the EU Commission website[18]. The OPC was open to anyone via the online system and it was accessible in all EU languages. The OPC was launched on 15 September 2020 and closed 29 December 2020 (midnight Brussels time). The questionnaire was structured with questions spread across the following four sections: 'About you – Respondent profile', 'Part 1 – Awareness of F-gases', 'Part 2 – General views on the F-gas Regulation', and 'Part 3 – Specialised views on policy options'.

A total of 241 responses and 44 attachments were provided. Once the OPC finished, the data was downloaded from the EU Commission's consultation platform: 'Have your say'[19]. The results of the OPC are included in the Stakeholder Consultation Synopsis Report included as Annex 5 to this report. A detailed OPC analysis has been submitted to the EU Commission.

4.4.3.2 *Targeted stakeholder interviews*

As a part of the targeted consultation, 34 semi-structured interviews were undertaken. The targeted interviews covered a broad range of stakeholders including: 16 Member State competent authorities, two customs authorities, one NGO, 16 EU business associations and organisations and individual undertakings. In addition, two Member State competent authorities and two customs authorities provided written response to the interview questions.

The interviews were based on proformas which included questions on the performance of the Regulation, while covering all five evaluation criteria underpinning the fitness check (effectiveness, efficiency, coherence, relevance, EU-added value) which were tweaked depending on the expertise of the stakeholders, and general and concrete implementation and enforcement issues. In addition, questions covered impacts related to envisaged policy options for the amendment of the Regulation as well as data on present and future administrative and implementation and enforcement costs.

Stakeholders were given the opportunity to check and complement the interview notes and submit additional information after the interview.

4.4.3.3 *Stakeholder workshop*

A full-day online workshop was held to receive feedback from stakeholders on the findings of the evaluation, potential policy options and initial findings of the impact assessment. The workshop took place as a virtual event on 6 May 2021 and was attended by 355 participants. The participants were primarily industry stakeholders representing relevant business organisations and associations. Other participants included NGOs and representatives from public authorities.

[18] https://ec.europa.eu/info/law/better-regulation/have-your-say/initiatives/12479-Review-of-EU-rules-on-fluorinated-greenhouse-gases/public-consultation

[19] https://ec.europa.eu/info/law/better-regulation/have-your-say

The workshop provided the project team the opportunity to present the preliminary results of the evaluation, focussing separately on the findings for the effectiveness, efficiency, relevance, coherence and EU added value for the Regulation. The project team then provided an overview of the policy options analysed in the study supporting the impact assessment, including how the policies were identified and their envisaged objectives. The remainder of the workshop focussed on the modelling approach and presentation of the different scenarios before a presentation of the preliminary findings regarding the assessment of impacts.

The workshop concluded with an explanation of the data needs still required by the project team in order to complete both the evaluation and impact assessment. Participants were provided two and a half weeks to provide additional feedback (to 24th May) with 69 participants subsequently providing further feedback.

The agenda and notes of the workshop will be presented as Annexes to the stakeholder consultation synopsis report. The feedback received at the events will be fully reflected in the draft final evaluation report.

4.5 Limitations

There were a number of limitations and data gaps encountered during the evaluation study. A detailed account of these, including the mitigation actions taken by the project team and their overall impacts to the study have been included in more detailed overview of limitations is provided in Annex 1. A summary of the key limitations are presented in this section.

Sources of evidence considered are given for each evaluation question and key data gaps and limitations are flagged. Despite these limitations, the triangulation of different data sources has helped to elaborate the conclusions drawn from the evidence base. In some cases, even after triangulation, these challenges have still placed a limit on the certainty of conclusions drawn from the analysis (i.e. regarding administrative costs). However, this has not fundamentally challenged the deduction of broader recommendations to support the parallel IA.

4.5.1 Limitations to the model

A clear distinction between the impacts of the different measures of the Regulation on the demand for HFCs is not always possible. Prohibitions have specific dates that directly result in transitioning processes, such as replacing high-GWP HFCs with low-GWP alternatives. These transitions are expected to align relatively closely with the prohibition dates, but first market developments are expected to occur prior to prohibition dates. The same applies to the effects of the HFC phase-down. Specific dates for the reduction of placing on the market quantities are set by the Regulation and transitioning processes should align with these dates. However, as is the case for prohibitions, market developments in anticipation of phase-down steps are to be expected.

When looking at the years between 2014 and 2019, any changes in market developments of HFCs will be influenced by the HFC phase-down steps (freeze in 2015, reduction to 93 % in 2016 and reduction to 63 % in 2018), as well as certain prohibitions.

For R404A (52 % HFC-143a, 44 % HFC-125, 4 % HFC-134a; GWP 3,922), for example, the demand is expected to decrease strongly until 2019 and this is reflected in the reported data (see section **Fehler! Verweisquelle konnte nicht gefunden werden.**). The model calculates a reduction of around 53 % from 2014 to 2019 (HFC-143a can be used as a proxy for R404A because it is not used as a single gas and not part of any other mixture included in the model).

The main reason for this reduction is certainly the increase in HFC price as a consequence of the phase-down in 2016 and 2018 but also the ban on the use of more than around 10 kg[20] of R404A for servicing

[20] Art. 13 prohibits the servicing of refrigeration equipment with a charge size of 40 tonnes of CO_2 eq or more with F-gases with a GWP >2,500, which roughly equates to 10 kg of gas for R404A with a GWP of 3,922.

of existing equipment from 1 January 2020 according to Article 13 of the Regulation (with the exception of military equipment and very low temperature applications), as well as the prohibitions of HFCs with a GWP over 2,500 in stationary refrigeration equipment (with the exception of very low temperature applications) and commercially used and hermetically sealed refrigerators and freezers from 1 January 2020. It is, however, not possible to clearly differentiate between these effects from the model output, i.e. how much of the 53 % reduction was due to the phase-down alone.

This applies to other sectors as well. Generally, specific effects of measures can only be extracted from the model when no confounding effects of other measures are present. Since all market participants are usually aware of phase-down and prohibitions, for HFCs, changes in demand will likely be the additive result of both measures. For other F-gases, on the other hand, direct effects of prohibitions can be extracted from the model results.

4.5.2 Other limitations

In addition to modelling limitations, there were a number of other gaps and challenges which the evaluation faced. These included:

- Reporting data used to examine the effectiveness of POM restrictions only covers imports (not EU produced equipment) and does not provide a precise sector split.
- Reporting data for POM restrictions only goes to 2019, so one cannot judge the impact of prohibitions which fall after this date.
- No comprehensive data is available on labelling compliance
- No comprehensive data are available on recycled and reclaimed F-gas quantities as only undertakings which are also importers of F-gases currently need to report, but not facilities performing recycling and reclamation only.
- Reporting data for recovery and reclamation only exists for importers, producers and exporters, hence the data is not complete.
- Compliance with the leak checking requirements under Article 4 and Article 5 of the Regulation is difficult to assess first-hand as there are no comprehensive studies in this area. Assessments of the existing national databases are often not publicly available (e.g. Poland) or even confidential (e.g. Italy) and/or limited to sample datasets (e.g. Slovakia).
- No consistent data tracking leakage rates pre and post implementation for the entire EU are available. Assessments of electronic databases established in some Member States are mostly not covering the years before 2014.
- It is not feasible to make an accurate estimate of the level of illegal imports.
    - As a consequence, the levels of demand and emissions presented throughout the reporting and modelling analysis do not capture demand and emissions from illegal imports (as flagged in the stakeholder workshop).
- The analysis of economic effects is based on simplified statistical analysis, given more detailed modelling tools to capture more fully the impacts of the Regulation throughout industry and supply chains were not available.
- For the assessment of cost of technological change generalisations were made by representing each modelled sector by one typical installation size, assuming to represent the full sector. Thus, the full variety of existing installation types and sizes cannot be fully covered. Assumptions on parameters affecting investment and operating cost rely on expert judgement and industry input where provided.
- Not possible to split costs by business size, MS or measure with a high degree of confidence. Technical compliance cost were assessed by application sub-sectors which hardly correlate

with business sizes, For administrative burdens, cost data collected was predominantly provided by larger firms through the stakeholder engagement. As a proxy, the costs for small and medium firms were scaled according to the approximate relative size of these organisations, based on the reporting thresholds.

- There is no published data or studies analysing the administrative burden placed on different stakeholders by the Regulation. To close this gap, data was requested from stakeholders over the course of the study. However, the database remained limited in places, in particular in the estimation of costs to industry, both due to limitations in evidence available around he costs per undertaking, and the number of undertakings affected. For some measures, the costs were therefore estimated by expert opinion on the basis of publicly available data.

5 Analysis and answers to evaluation questions

5.1 Effectiveness

The effectiveness analysis seeks to determine how successful EU action has been in achieving or progressing towards the original objectives of the intervention. It should highlight the progress made to date and how the Regulation has contributed to the changes observed. If the objectives of the Regulation have not been achieved, then the intention is to assess the extent to which progress has fallen short of the target and what factors have influenced this outcome.

EQ1. To what extent have the objectives of the Regulation been met? To what extent can the observed effects be attributed to the Regulation and its individual elements?

5.1.1 EQ1a. To what extent have the 'HFC Phase down' and 'Placing on market and control of use' requirements discouraged the use of F-gases and encouraged use of alternatives?

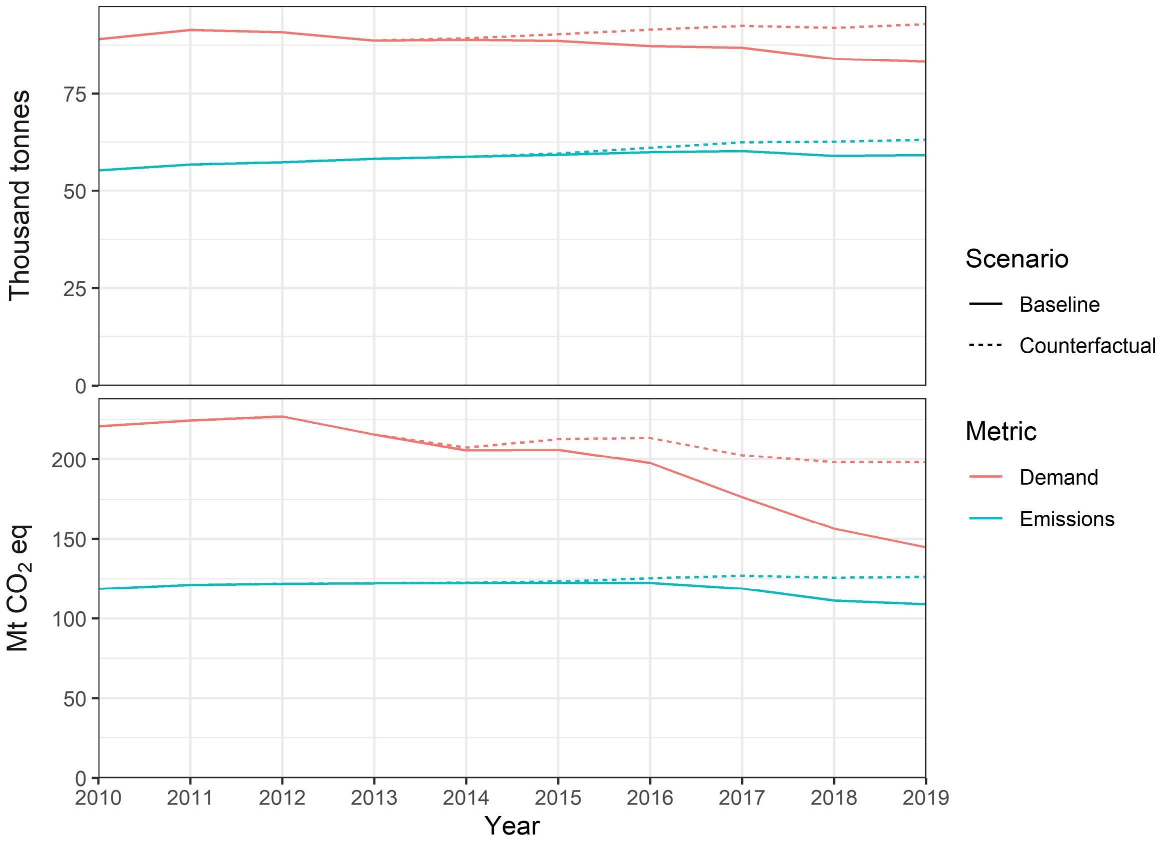
5.1.1.1 *EQ1a(i). What has been the combined effect?*

Demand and emissions of F-gases in the period of 2010 to 2019 show little change both in tonnes and CO_2 equivalents under the **counterfactual** scenario (Figure 11 and Table 22). In contrast, under the **baseline** scenario (i.e. scenario with the 2014 F-gas Regulation included), a significant reduction in both metrics can be seen, starting in the years after the Regulation entered into force in 2014. The divergence is more strongly pronounced in CO_2 eq, as is expected since the measures of the Regulation target F-gases with high GWPs more strongly by linking them to the CO_2 equivalency metric (as is the case for e.g. containment measures, prohibitions and particularly the HFC phase-down), incentivising F-gas alternatives with lower GWPs or alternatives that are not F-gases. Apart from this, the Regulation also led to a reduction in emission rates, both for new equipment and at end-of-life that contributed to the overall reduction in emissions, calculated by the model.

The relative drop in demand is more pronounced than for emissions: While the sum of the demand for F-gases decreased by 6 % and 13 % expressed in tonnes and CO_2 eq, respectively, from 2014 to 2019, the sum of emissions decreased by 3 % and 6 % (Table 22). This is expected since demand is defined as the sum of first fill quantities of F-gases in new equipment and replacement of lifetime emissions of F-gases from all existing equipment (i.e. servicing). Emissions occur over the lifetime of equipment and at end of its service life. It is therefore to be expected that there is a lag time between a reduction of demand and a resulting reduction of emissions.

In the years from 2010 to 2013, there is no difference between the scenarios because the Regulation was not yet in effect. In 2014, first small effects are seen, and the counterfactual shows higher demand and slightly higher emissions than the baseline. This may also be seen as an effect of the Regulation, because at that time the new rules were already known, so some market actors may have started to react quickly. The observed early effects can be traced to the introduction of propane (R290, GWP 3) in moveable units and, from 2015, HFC-32 (GWP 675) in small split systems as a replacement of R410A in the sector of stationary air conditioning. In the following years until 2019, both demand and emissions of F-gases increasingly fall from year-to-year.

Figure 11: Total demand and emissions of fluorinated greenhouse gases in the period of 2010 to 2019 under the baseline and the counterfactual scenario



Source: AnaFgas modelling

Table 22: Modelled demand and emissions of fluorinated greenhouse gases in the EU from 2010 to 2019 under the baseline and the counterfactual scenario and the difference between the scenarios

	Modelled demand								**Modelled emissions**							
	Baseline		Counterfactual		Difference				Baseline		Counterfactual		Difference			
Year	kt	Mt CO_2 eq	kt	Mt CO_2 eq	kt	Mt CO_2 eq	kt	Mt CO_2 eq	kt	Mt CO_2 eq	kt	Mt CO_2 eq	kt	Mt CO_2 eq	kt	Mt CO_2 eq
2010	89	221	89	221	0	0	-	-	55	119	55	119	0	0	-	-
2011	91	224	91	224	0	0	-	-	57	121	57	121	0	0	-	-
2012	91	227	91	227	0	0	-	-	57	122	57	122	0	0	-	-
2013	89	216	89	216	<1	<1	<1%	<1%	58	122	58	122	<1	<1	<1%	<1%
2014	89	206	89	208	<1	2	<1%	1%	59	123	59	123	<1	<1	<1%	<1%
2015	89	206	90	213	2	7	2%	3%	59	123	60	123	<1	<1	<1%	<1%
2016	87	198	91	214	4	16	5%	8%	60	123	61	125	1	3	2%	2%
2017	87	176	92	203	6	26	6%	15%	60	119	62	127	2	8	4%	7%
2018	84	157	92	198	8	42	10%	27%	59	111	63	126	4	14	6%	13%
2019	83	145	93	198	10	53	12%	37%	59	109	63	126	4	17	7%	16%
Total (2014-2019)	**519**	**1 087**	**548**	**1 233**	**29**	**146**	**6%**	**13%**	**357**	**707**	**368**	**750**	**11**	**44**	**3%**	**6%**

Source: AnaFgas modelling

F-gas demand and emissions by sector

Looking at the different sectors, **refrigeration** had the largest share in demand and emissions in CO_2 equivalents prior to the Regulation (Figure 12) and over its period of implementation (Table 23). This largely due to the size of the sector. As such, this sector also observed the largest absolute reductions over the implementation period. However, when looking at the relative reduction (i.e. within the sector), other sectors show a larger reduction (Figure 13).

The Regulation had by far the largest effect on central systems in commercial refrigeration for demand and emissions. This was delivered through a replacement of R404A (GWP 3 922) with HFC-134a (GWP 1 430), R448A (GWP 1 387), R449A (GWP 1 397) and R513A (GWP 631) but also with CO_2 (R744) and hydrocarbons. For other subsectors, the effect was much smaller, with industrial systems having the second largest reduction, mainly due to the replacement of R404A with ammonia (NH_3, R717), CO_2 and R513A, and in rare cases with HFC-1234ze (GWP 7). All other subsectors together contributed to the remaining reduction, with condensing units and trucks and trailers making up the largest share for demand and trucks and trailers, followed by ships for emissions. As is the case for central and industrial systems, the replacement of R404A was the main driver.

Stationary air conditioning (including heat pumps) showed the second highest demand, and **mobile air conditioning** the third highest, but the emissions were lower for stationary than for mobile air conditioning. The Regulation had a large effect on GWP reduction in stationary applications, while there was almost no effect for mobile applications.

The major driver for the reduction in stationary AC was the replacement of R410A (GWP 2 088) with HFC-32 (GWP 675) in new small split units. For new moveable units, the replacement of R410A with propane (R290) was the main driver (prohibition according to Annex **III**(14)). For new large split- and VRF-units, there was little reduction in demand but a comparatively large reduction in emissions. This is due to the assumed reduction in emission rates for this subsector because of ecodesign and product optimization, since first replacements of R410A with HFC-32 only started in 2019. Packaged systems (including rooftop units) showed moderate reduction in demand and emissions. With the exception of displacement chillers (mainly replacement of R410A, R407C and HFC-134a with natural refrigerants), all other subsectors each contributed little to the total reduction in stationary AC. Generally, stationary AC applications have low assumed emission rates.

For mobile AC, from 2017, the demand is lower than the emissions. This is not the case when expressed in metric tonnes but for CO_2 eq, this can be explained by the complete replacement of HFC-134a (GWP 1 430) with HFC-1234yf (GWP 4) in new car AC systems starting in 2017. From this point on, there is no first fill of HFC-134a in this subsector, thereby greatly reducing the demand, but the stock of existing vehicles still mainly consists of systems emitting HFC-134a.

While demand for and emissions of high-GWP F-gases from mobile air conditioning units have decreased (Figure 12), this effect is not due to the Regulation, but to the MAC Directive, which banned the use of F-gases with a GWP higher than 150 in all new vehicles from 2017. Hence, this sector shows almost no reduction under the Regulation. In total, until 2019, the MAC Directive has led to a reduction in the demand for F-gases of around 44 Mt CO_2 eq and in emissions of around 14 Mt CO_2 eq.

While the **foam** sector is comparatively small regarding overall demand and emissions (Figure 13), it showed the second largest relative reduction in demand and highest reduction in emissions in CO_2 eq in the years 2014 to 2019 (see also Figure 13). This is largely due to the decreasing use of high-GWP HFCs such as HFC-365mfc (GWP 794), HFC-245fa (GWP 1 030) and HFC-134a (GWP 1 430) and the increasing use of unsaturated HFCs and HCFCs (HFC-1234ze and HCFC-1233zd and more recently also HFC-1336mzz) and hydrocarbons (e.g. isobutane).

The absolute reduction in demand for F-gases in the **propellants, solvents and fire protection** sector was substantial, but this sector showed the highest relative reduction in demand. Reduction in absolute emissions was the second highest of all sectors. This was mainly due to the replacement of HFC-227ea (GWP 3 220) with the fluorinated ketone FK-5-1-12 ($C_6F_{12}O$, GWP <1 (WMO, 2018)) in fire extinguishers and replacement of HFC-134a mainly by HFC-1234ze(E) in technical aerosols, following the prohibition of HFCs with a GWP over 150 by 1 January 2018 in this sector. The latter had by far the largest contribution to the reduction in emissions.

For the sector **SF_6**, due to the extremely high GWP of SF_6, the demand is very high. It must be noted that there is no demand for SF_6 in soundproof windows since mid-2007, due to the prohibition since 4 July 2007 and only emissions from existing equipment remain. There is no difference between the scenarios since the Regulation introduced no new prohibitions for this sector and SF_6 is not covered by the HFC phase-down.

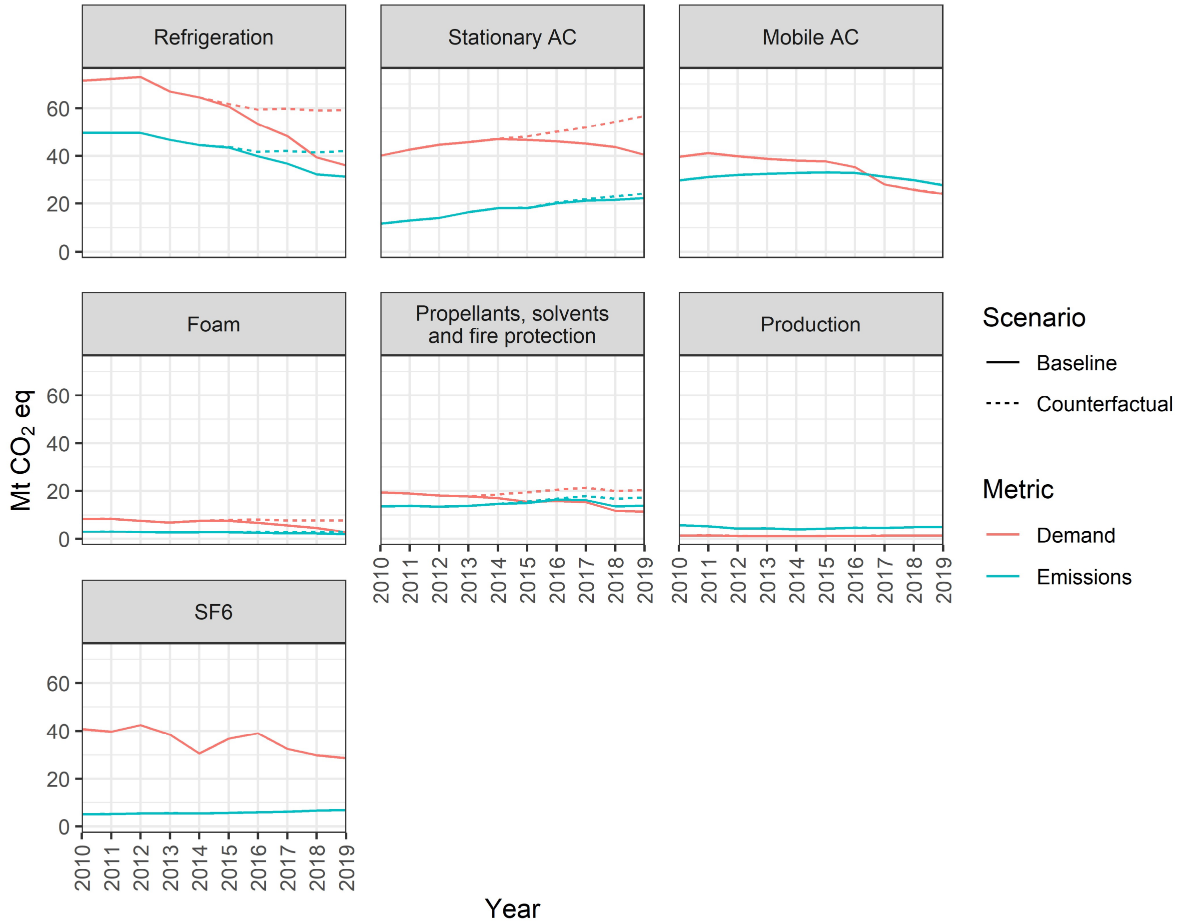
The **production** sector includes emissions from the manufacturing of HFCs, HCFC-22 and SF_6, emissions of CF_4 and SF_6 from primary aluminium production, as well as demand for and emissions from semiconductor and photovoltaic manufacturing. Quantities are comparatively low and there are no differences between the scenarios, so there is no reduction.

Table 23: Modelled sum of demand (D) and emissions (E) of F-gases from 2014 to 2019 for the different sectors under the baseline (BL) and counterfactual (CF) scenario and percent of respective total (%)

Mt CO_2 eq	Demand						Emissions					
Sector	BL	%	CF	%	CF-BL	%	BL	%	CF	%	CF-BL	%
Refrigeration	302	27%	364	29%	61	42%	228	32%	255	34%	27	62%
Stationary air conditioning (incl. heat pumps)	269	24%	308	25%	39	27%	122	17%	126	17%	4	10%
Mobile air conditioning	189	17%	190	15%	<1	<1%	188	27%	188	25%	<1	<1%
Foam	62	6%	63	5%	12	8%	14	2%	17	2%	3	7%
Propellants, solvents and fire protection	87	8%	120	10%	33	23%	90	13%	99	13%	9	21%
SF_6	197	18%	197	16%	0	-	37	5%	37	5%	0	-
Production	7	1%	7	1%	0	-	28	4%	28	4%	0	-
Total	**1 114**	**100%**	**1 250**	**100%**	**146**	**100%**	**708**	**100%**	**751**	**100%**	**44**	**100%**

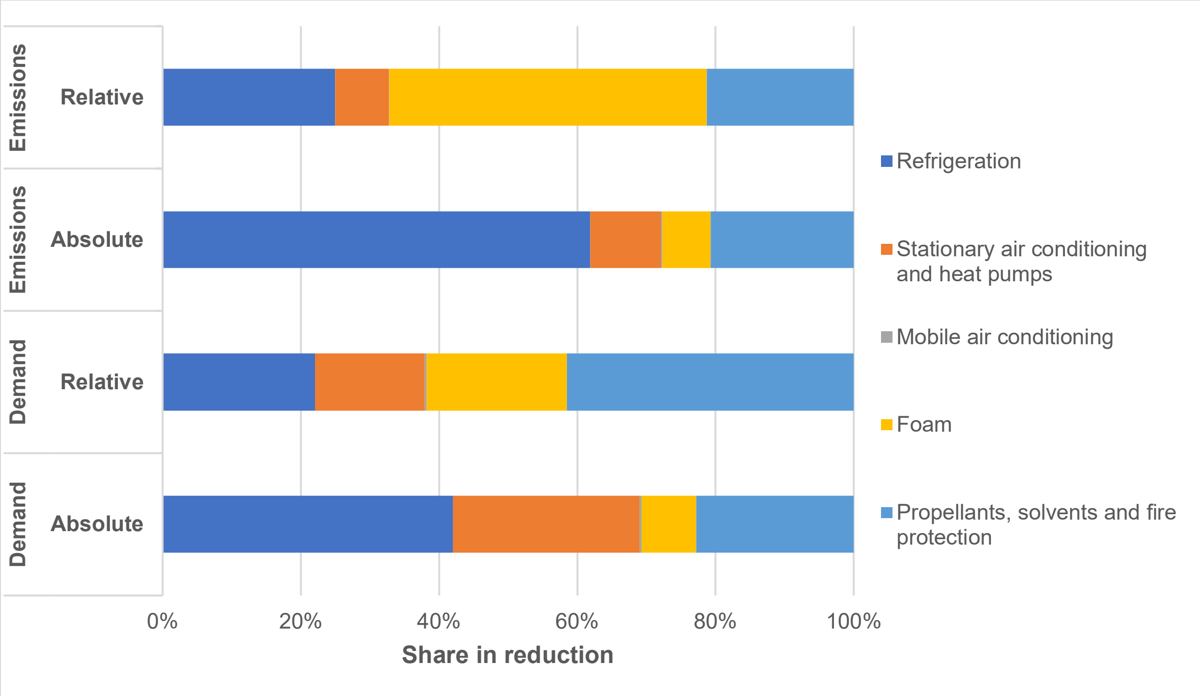
Source: AnaFgas modelling

Figure 12: Demand and emissions of fluorinated greenhouse gases by sector in the period of 2010 to 2019 under the baseline and the counterfactual scenario in CO_2 eq



Source: AnaFgas modelling

Figure 13: Share in reduction of demand and emissions of F-gases in CO_2 eq per sector both absolute (share of total reduction) and relative (reduction within the sector)



Source: AnaFgas modelling

Cumulative reduction in demand and emissions and comparison with previous EU F-gas study

Based on the modelling, from 2014 to 2019, the Regulation led to a cumulative reduction in demand and emissions of F-gases of 146 and 44 Mt CO_2 eq, respectively (i.e. difference between actual and counterfactual, Table 24). Most of the reduction took place in refrigeration applications, where the Regulation specifically led to a reduction in the use of the high-GWP blend R404A.

Table 24: Total reduction of demand and emissions of fluorinated greenhouse gases due to the Regulation in the different sectors from 2014 to 2019

	Demand reduction		Emissions reduction	
Sector	Mt CO_2 eq	Share of total	Mt CO_2 eq	Share of total
Refrigeration	61	*42 %*	27	*62 %*
Stationary air conditioning (incl. heat pumps)	39	*27 %*	4	*10 %*
Mobile air conditioning	<1	*<1 %*	<1	*<1 %*
Foams	12	*8 %*	3	*7 %*
Propellants, solvents and fire protection	33	*23 %*	9	*21 %*
SF_6	0	-	0	-
Production	0	-	0	-
Cumulative reduction (2014 to 2019)[1]	**146**		**44**	

Notes:
[1] Cumulative difference between baseline and counterfactual scenario from the current AnaFgas model
Source: AnaFgas modelling

5.1.1.2 *EQ1a(ii). What has been the contribution of the ‘Placing on market and control of use’ requirements (Article 11-13)?*

The effectiveness of most of the placing on the market (POM) and control of use prohibitions in Article 11 to 13 can be assessed by using the data reported by importers and producers under Article 19 of the Regulation. It should be borne in mind, however, that undertakings which would have knowingly violated those prohibitions may also not have reported correctly under Article 19. Furthermore, **the actual effect of prohibitions cannot be clearly separated from those of the phase-down**, as the latter provides a strong incentive to use more climate-friendly gases and avoid F-gases in sectors where this is relatively easy and economical to do, which coincides to a large degree with the sectors where there are prohibitions in the Regulation.

Article 11 in conjunction with Annex III – restrictions on the placing on the market

Article 11 (1) establishes the link to Annex III and sets out an exemption for military equipment.

Exemptions from the bans also relate to equipment that has lower lifecycle CO_2 eq emissions than equivalent equipment meeting ecodesign requirements and containing HFCs (Article 11 (2)). The conditions would require that an ecodesign measure has been adopted (e.g. Commission Regulation (EU) 2019/2024 of 1 October 2019 laying down ecodesign requirements for refrigerating appliances with a direct sales function)[21]. No requests for such exemptions were made so far.

Article 11 (3) allows temporary exemptions from the prohibitions under certain conditions. It should be noted that no official substantiated requests for exemptions were made by a competent authority or a Member State under the current Regulation.

Article 11 (4) specifies that distributors can only sell to certified undertakings and that F-gases can only be purchased by certified undertakings for the purpose of installation, servicing, maintenance or repair of equipment containing F-gases or relying on F-gases. While Regulation (EC) No 842/2006 referred to containment and recovery operations, the Regulation related to operations requiring certification (i.e. installation, servicing, maintenance, repair and decommissioning). Recovery and leak checking are excluded unless they involve any of the specified activities. Article 11 (4) also underlines the shared responsibility of distributors and installers for delivering the refrigerant to a certified undertaking. In practice, and even though there is no outright requirement to do so in the Regulation, this often means, and is required by some national laws (e.g. Italy), that distributors keep records containing relevant information of the purchaser such as the certificate numbers and the respective quantities of F-gases purchased (Article 6(3)).

In some Member States updated lists of certified undertakings are available at the authorities in dedicated databases (e.g. France (AREA, 2016), Italy (Ministry of Ecological Transition, 2019)), in other Member States distributors need to actively check the existence and validity of the certificate with the authorised body that issued it. These systems and in particular the legally unclear situation of garages acquiring HFCs and their need to have attestations, was found to create loopholes for illegal activities and handling of gases by unskilled workers and has been criticized by industry and environmental associations in past years. Germany will amend its national legislation in 2021 to ensure better tracking of refrigerant sales and purchases along the supply chain by requiring further documentation and record keeping (German Federal Ministry for the Environment, Nature Conservation and Nuclear Safety:, 2021).

In the following, specific provisions stemming from Article 11 in conjunction with Annex III are treated in detail.

[21] Commission Regulation (EU) 2019/2024 of 1 October 2019 laying down ecodesign requirements for refrigerating appliances with a direct sales function pursuant to Directive 2009/125/EC of the European Parliament and of the Council https://eur-lex.europa.eu/legal-content/EN/ALL/?uri=uriserv:OJ.L_.2019.315.01.0313.01.ENG

Table 25: Analysis of achievement of prohibitions

F-gas sector	Prohibition	Evidence
Fire protection	**Annex III No 3:** Fire protection equipment containing HFC-23 from 1 January 2016	Reported data from producers and importers show only marginal quantities since 2015 which may have been used for servicing. Overall F-gas quantities supplied to the fire protection sector declined strongly.
Refrigeration and air conditioning	**Annex III No 10:** Domestic refrigerators and freezers containing HFCs with GWP of 150 or more from 1 January 2015	Imports of F-gas refrigerants above the GWP threshold of 150 in domestic refrigeration equipment were reported in quantities of < 20 tonnes per year and have shown a strong decline since 2016. This could mean that the provision may not have been fully complied with (initially) but might also indicate misreporting (wrong categories) and/or production of equipment for export. However, only reported data from the database category '11B1: Stationary equipment for refrigeration, direct design: standalone/monobloc units for domestic use' are available for the analysis here which might not be identical with the equipment covered by the prohibition.
	Annex III No 11: Refrigerators and freezers for commercial use (hermetically sealed equipment) containing HFCs with a GWP of 2500 or more from 1 January 2020; containing HFCs with a GWP of 150 or more from 1 January 2022	HFCs with a GWP of 2,500 and more (in this case most relevant: R404A) have declined and are on track to meet the prohibition date of 1 January 2020. No HFC refrigerants with GWP < 150 have been reported yet. It should be noted that reported data from several database categories relating to commercial and industrial use do not exactly reflect the type of equipment in scope of the prohibition. Low amounts reported for 2014 may be due to incomplete reporting for that first year of the reporting obligation for equipment importers. Furthermore, equipment manufactured within the EU is not covered by the data.
	Annex III No 12: Stationary refrigeration equipment containing or relying on HFCs with GWP of 2500 or more except equipment intended for applications designed to cool products to temperatures below - 50°C from 1 January 2020	HFCs with GWP of 2,500 and more (in this case most relevant: R404A) have decreased and are on track to meet the prohibition date 1 January 2020. It should be noted, however, that reported data may include equipment for low temperatures below - 50°C which are exempted from the prohibition. National datasets from France, Germany and Poland confirm the decrease of use of R404A.
	Annex III No 13: Multipack centralized refrigeration systems for commercial use with a rated capacity of 40 kW or more containing or relying on F-gases with a GWP of 150 or more, except in the primary refrigerant circuit of cascade systems where fluorinated greenhouse gases with a GWP of less than 1500 may be used, from 1 January 2022	It is not possible to derive indicative information based on data reported by importers of refrigeration equipment under Article 19 of the Regulation as none of the reporting categories allows identifying such systems. The EU Commission's 2017 assessment of availability of cost-effective, technically feasible, energy-efficient, and reliable alternatives to multipack centralised refrigeration systems (European Commission, 2017) found that there are several cost and energy efficient alternatives available on the market. As a result of the assessment, it was concluded by the EU Commission that it is not necessary to amend the provision pursuant to Annex III of the Regulation. This is confirmed by data from Shecco on market uptake of CO_2 systems, which reported that Europe had installed around 29,000

F-gas sector	Prohibition	Evidence
		transcritical CO_2 systems by 2020, more than the rest of the world combined (Shecco, 2020). Data for 2021 suggests the increase has continued, with over 40,000 systems now considered to be operating in the EU (Koegelenberg, 2021).
	Annex III No 14: Moveable room air conditioning equipment (hermetically sealed which is moveable between rooms by the end user) containing HFCs with GWP of 150 or more from 1 January 2020	Within the reporting obligations set in Article 19 no F-gas refrigerants with a GWP below 150 were imported between 2014 and 2019 for moveable AC equipment. However, the amounts of moveable AC equipment relying on F-gases strongly declined in 2019. Imports of equipment relying on natural refrigerants (with a GWP < 150)[22] are outside the scope of the reporting data. Given the strong decline observed for 2019 in imports of equipment with gases above the GWP threshold of 150, however, the prohibition appears to be effective. Evidence from the reported data for the prohibition date of 1 January 2020 is currently still missing.
	Annex III No 15: Single-split AC containing less than 3 kg of F-gases with GWP of 750 or more from 1 January 2025	Reported data show that HFC-32 (GWP 675) has been introduced to the market from 2014 and has started replacing R410A (GWP 2,088) in large amounts since 2018 reaching a share of about 80 % of F-gas refrigerants in imported AC equipment of that category. Furthermore, 2019 imports of R-410A in that equipment category were about 80 % below 2016. It can be concluded that the EU27+UK is clearly on track for meeting this condition, five years ahead of the prohibition date.
Foams	**Annex III No 16:** Foams containing HFCs with GWP of 150 or more except when required to meet national safety standards. XPS from 1 January 2020; other foams from 1 January 2023.	According to the reported data, the amounts of the three main HFCs with a GWP above 150 supplied into the EU foam sector have been declining in particular after 2017. In 2019, supplies into the foam sector of HFC-134a, HFC-245fa and HFC-365mfc are at less than 50 % of the 2017 amounts (measured in tonnes of gas). Common replacements include unsaturated HCFC-1233zd and unsaturated HFC-1234ze, both covered in Annex II of the Regulation. These gases were not used before 2014 at all and have since gained significant market shares (equating to almost 50 % in 2019). While evidence for the prohibition date after 2020 is still missing, it can be concluded that the EU27+UK is on track to meet the prohibition requirement. A comparison of the gases used in 2019 compared to those in 2013 (before stockpiling in 2014), shows that the gases used has greatly changed, which is attributable to the measures of the Regulation. These findings were confirmed by the industry association PU Europe.
Aerosols	**Annex III No 17:** Technical aerosols that contain HFCs with GWP of 150 or more, except when required to meet national safety standards or when used for medical applications from 1 January 2018	As supported by reported data, the amounts of HFC-134a (GWP 1,430) supplied into the EU for use as non-medical technical aerosol has declined from 2016 to 2018 by more than 95%. Supplies of HFC-134a as non-medical aerosol after entry into force of the 1 January 2018 prohibition have been at levels below 100 tonnes per year (or below 0.15

[22] For moveable AC equipment, in particular propane (R-290) with a GWP of 3 is the key replacement for HFCs.

F-gas sector	Prohibition	Evidence
		Mt CO_2 eq per year)[23]. As a replacement for HFC-134a, and possibly also as a replacement for the declining amounts of HFC-152a, in particular low-GWP unsaturated HFC-1234ze has been phased in by EU industries from 2015. However, certain formulations still rely on small quantities of HFC-134a in mixtures with an overall GWP below 150 and/or for safety reasons. These findings were confirmed by the aerosol industry association (FEA).

In the targeted interviews, most Member State competent authorities confirmed the effectiveness of the placing on the market and use prohibitions. Some indicated that the definition of 'placing on the market' should, however, be aligned with the definition used in the Ozone Regulation, as there is currently no means of control along the supply chain, which hinders effective enforcement.

Further prohibitions could be considered, while one competent authority also mentioned a general ban on all uses (with exemptions) as a possible option. Another competent authority pointed out that placing on the market prohibitions applying equally to all Member States could impose problems as high ambient temperatures and heat waves have become more frequent in southern EU countries, and that therefore regional circumstances would need to be taken into account based on scientific evidence, leading e.g. to differentiation of prohibition dates.

Article 12 – labelling and product and equipment information

Article 12 of the Regulation, implemented by the Commission Implementing Regulation (EU) No 2015/2068[24], outlines labelling requirements for products and equipment that contain, or whose functioning relies on, F-gases. Although labelling requirements were already introduced by Regulation (EC) No 842/2006, they became more stringent and detailed with the introduction of the current Regulation. The additional labelling elements were mostly included to mirror new requirements, e.g. the quota system and its exemptions because without such labelling it would not be feasible to enforce these new requirements. Table 26 compares the labelling requirements of both Regulations.

Table 26: Comparison of labelling requirements under the previous and the current Regulation

Regulation (EC) No 842/2006 (Article 7)	Regulation (EU) No 517/2014 (Article 12)
- Products and equipment containing F-gases shall not be placed on the market before they are labelled	- Products and equipment containing F-gases or whose functioning relies on F-gases shall not be placed on the market before they are labelled - If products or equipment are intended for exempted uses listed in Article 15 (4) it has to be indicated on the label
Scope of labelling	
- Refrigeration products and equipment containing PFCs and preparations containing PFCs - Refrigeration and air conditioning products and equipment (excluding vehicles), heat pumps, fire protection systems and fire extinguishers containing HFCs - Switchgear containing SF_6 or preparations containing SF_6 - All F-gas containers	- Refrigeration equipment - Air-conditioning equipment - Heat pumps - Fire protection equipment - Electrical switchgear - Aerosol dispenser containing F-gas (not metered dose inhalers for delivery of pharmaceutical ingredients) - All F-gas containers - F-gas based solvents - Organic Rankine Cycles (ORC)

[23] The reporting data does not allow to judge whether or not the supplied amounts fall under the exemption related to national safety standards.
[24] COMMISSION IMPLEMENTING REGULATION (EU) 2015/2068 on the format of labels for products and equipment containing fluorinated greenhouse gases, https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32015R2068&from=EN

<table>
<tr><th>Regulation (EC) No 842/2006 (Article 7)</th><th>Regulation (EU) No 517/2014 (Article 12)</th></tr>
<tr><td></td><td>- Foams and pre-blended polyols
- Reclaimed or recycled F-gases
- F-gases for destruction
- F-gases for export
- F-gases for military use
- Etching of semiconductor material or the cleaning of chemicals vapour deposition chambers within the semi-conductor manufacturing sector
- F-gases for feedstock use
- F-gases for producing MDIs</td></tr>
<tr><th>Commission Implementing Regulation (EC) 1494/2007</th><th>Commission Implementing Regulation (EU) 2015/2068</th></tr>
<tr><td colspan="2">Labelling elements</td></tr>
<tr><td>- Text ‘contains fluorinated greenhouse gases covered by the Kyoto Protocol’
- Industry nomenclature
- Quantity of F-gas (in kg)
- Addition ‘hermetically sealed’ if applicable
- RACHP insulated with foam blown with F-gases ‘foam blown with fluorinated greenhouse gases’
- Where F-gases may be added outside the manufacturing site and the resulting total quantity is not defined by the manufacturer, the label shall contain the quantity charged in the manufacturing plant and shall provide space on the label for the quantity to be added outside the manufacturing plant as well as for the resulting total quantity of fluorinated greenhouse gases
- Official language of the EU Member State</td><td>- Text ‘contains fluorinated greenhouse gases’
- Industry nomenclature
- Weight of the F-gases (in kg) and CO_2 eq (tonnes)
- When equipment is pre-charged with, or when its functioning relies upon, F- gases and such gases may be added outside the manufacturing site and the resulting total quantity is not defined by the manufacturer, the label shall contain the quantity charged at the manufacturing site, or the quantity for which it is designed, and shall provide space on the label for the quantity added outside the manufacturing site as well as for the resulting total quantity of F-gases
- When a product containing F-gases or pre-blended polyols is also to be labelled pursuant to Regulation (EC) No 1272/2008, the information pursuant to Article 12(3), (5) to (12) of Regulation (EU) No 517/2014 shall be indicated in the section for supplemental information on the label referred to in Article 25 of Regulation (EC) No 1272/2008
- Text ‘100 % reclaimed’ or ‘100 % recycled’ and the address of recycling facility in Union for reclaimed or recycled F-gases not containing any virgin F-gases
- Text ‘Imported for destruction only’ for F-gas quantities imported for destruction
- Text ‘for direct bulk export outside EU only’ for F-gas quantities being supplied by a producer or importer to an undertaking for direct export in bulk out of the Union
- Text ‘For use in military equipment only’ for F-gas quantities which are to be used in military equipment
- Text ‘For etching/cleaning in semiconductor industry only’ for F-gas quantities which are to be used for etching and cleaning purposes in semiconductor industry
- Text ‘For feedstock use only’ for F-gas quantities serving as feedstock
- Text ‘For MDI production only’ for F-gas quantities intended for the delivery of pharmaceutical ingredients in metered-dose inhalers (MDIs)
- For RACHP insulated with foam blown with F-gases ‘foam blown with fluorinated greenhouse gases’</td></tr>
<tr><td colspan="2">Labelling location</td></tr>
<tr><td>- The labels may also be placed on, or adjacent to existing nameplates or product information labels, or adjacent to servicing access locations
- Air conditioning products and equipment as well as heat pumps with separate indoor and outdoor sections connected by refrigerant piping, the label information shall be placed on that part of the equipment which is initially charged with the refrigerant</td><td>- The labels may also be placed on, or adjacent to existing nameplates or product information labels, or adjacent to servicing access locations</td></tr>
</table>

No data exists on the overall compliance with labelling requirements. According to one customs authority, customs officers perform such controls as part of their duties The same stakeholder also noted it is not possible to differentiate the control on the F-gas labelling as this is usually done in combination with the requirements of REACH, CLP and harmonisation requirements.

It is also challenging to directly assess the positive effect of the labelling specifically. Stakeholders (targeted interviews) generally consider labelling to be effective and important for proper enforcement by the Member State competent authorities. As an example of its usefulness, one competent authority stated that adding the GWP and CO_2 eq on the label was important for service technicians to understand the climate impacts of F-gases, while another stated that labelling alone was unlikely to have influenced purchasing decisions. Labelling is furthermore important to facilitate custom controls.

However, concerns have been raised in relation to labelling and compliance with Article 12 of the Regulation. There is evidence of the occurrence of false labelling and/or mis-declarations, linked to illegitimate trade in F-gases (see EQ2a below for a more detailed discussion of this issue). Such illicit actions serve the purpose of circumventing the underlying requirements that the labelling requirement is mirroring. In this vein some stakeholders have argued that the current quota system encourages mislabelling to avoid licensing controls (EIA, 2018). For instance, by mislabelling HFC-134a as HFC-1234yf importers may attempt to avoid being covered by the quota requirements since HFC-134a is covered by the quota system, whereas HFC-1234yf is not. Moreover, by mislabelling one HFC with a relatively high GWP by another HFC with a relatively low GWP, less quota will be needed.

It is not feasible to estimate the overall level of illegal trade and hence illegal mislabelling. One example of mislabelling occurred in 2018, as the Polish National Revenue Administration and Customs Authorities reported six cases of incorrect labelling. These cases involved 2,400 refillable cylinders (28,000 kg) of R134a and 1,400 refillable cylinders (16,800 kg) of R410A (Cooling Post, 2019). The Polish customs authority also stated in the targeted interview that the authority has been detecting lack of compliant labelling very frequently: even if labelling is present, it often does not meet all labelling requirements.

Although mislabelling is an issue, it cannot be attributed to the design of Article 12 specifically. The examples referred to within the EIA investigation (EIA, 2016) suggest a willingness to mis-identify products on behalf of those conducting illegal activity, and it is therefore likely that the illegal behaviour would have been perpetrated irrespective of the specific labelling requirements. However, to enforce the prohibitions contained with Annex III and to effectively implement the phase-down, labelling requirements are needed. The behaviour taken to circumvent the labelling requirements can therefore be attributed as an attempt to avoid compliance with the wider aims of the Regulation, with the misuse of labels a means to avoid detection for failing to comply with the wider phase down requirements.

Thus, the labelling requirements should not be considered to be the issue, with the solution more likely to focus on improved enforcement and other mechanisms to counter illegal trade more directly. Indeed, stakeholders (OPC) agree that labelling has been effective in contributing to the achievement of the Regulation objectives, and in fact identifying incorrect or incomplete labelling has been one important way of identifying illegal shipments by customs.

Article 13 – control of use

Refrigeration servicing and maintenance prohibition for gases with GWP > 2,500

According to Article 13 (3) of the Regulation, the use of F-gases with a GWP of 2,500 or more for servicing or maintenance of refrigeration equipment with a charge size of 40 tonnes of CO_2 eq or more is prohibited as of 1 January 2020. Exemptions from this provision are in place for military equipment or equipment intended for applications designed to cool products to temperatures below - 50°C as well as for reclaimed or recycled gases, which are allowed to be used until 1 January 2030.

This servicing and maintenance prohibition targets the refrigerants R404A (GWP 3,922) and R507A (GWP 3,985) in particular but is in practice also relevant for PFCs as well as R422A (GWP 3,143) and

R422D (GWP 2,729) which are replacements for R22. Similar to the requirements of Article 11, the effectiveness of this prohibition can be checked against the data reported by importers and producers under Article 19 of the Regulation where blending, imports, exports, reclamation and end-of-year stocks[25] of F-gases has to be reported.

The trends for EU supply of R404A, R507A, R422D and R422A, which are all used for servicing and maintenance of refrigeration units, and their respective composition of the mentioned transactions (imports, exports, etc.) since 2014 are depicted in the figures below.

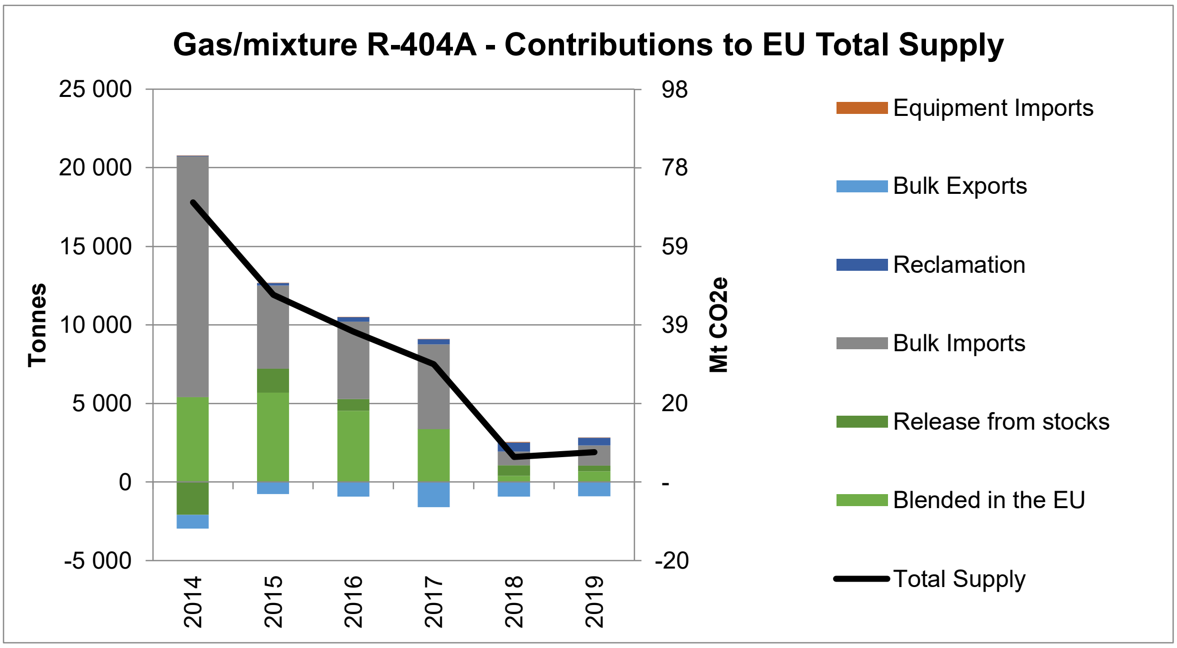
Supply of R404A to the EU27+UK has dropped by about 85 % from 2015 to 2018 and 2019. During the same time the reported amounts of reclaimed R404A have approximately tripled in the same period and reached a share of about 30 % of remaining R404A supply in 2018 and 2019.

The size of the EU market for R507A was approximately 20 % of the R404A market in the 2014 to 2019 period. Supply of R507A to the EU27+UK has dropped by about 90 % from 2015 to 2019. In the same time the reported amounts of reclaimed R507A have increased about six-fold in the same period and reached a share of about 15 % of remaining R507A supply in 2019.

Both R422D (Figure 16) and R422A (Figure 17) practically disappeared from the EU market in 2017. The size of the EU market for R422D in 2014 was by about the factor five lower than the R507A market, while the 2014 EU market for R422A was below the R422D market by approximately the factor of ten.

The reduction of R404A, R507A, R422D and R422A is however not entirely the result of the prohibition, but also lower use for new refrigeration equipment due to the prohibition there and the phase-down pressure on high GWP substances. However, the low remaining quantities of these gases used indicates clearly also that refill activities of virgin gases have very significantly declined. Some main importers have stopped providing this gas altogether[26].

Figure 14: EU27+UK supply of R-404A (GWP 3,922)

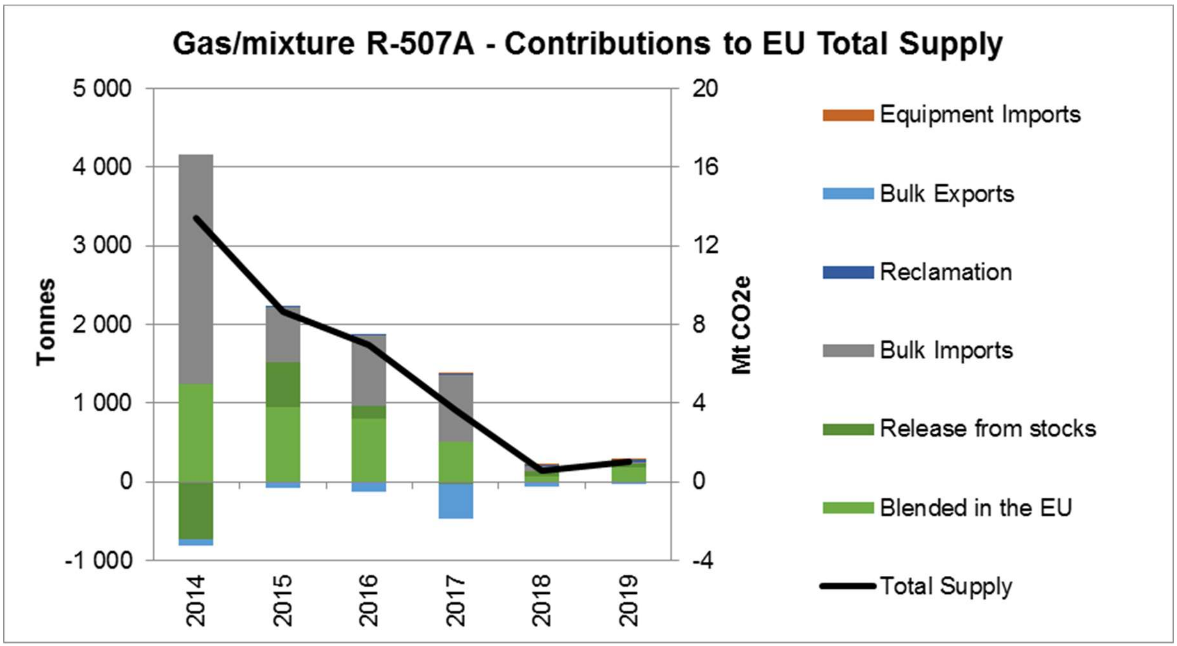


Source: [EEA 2020 confidential dataset], own calculations

[25] Stocks are reportable for producers and importers of F-gases.

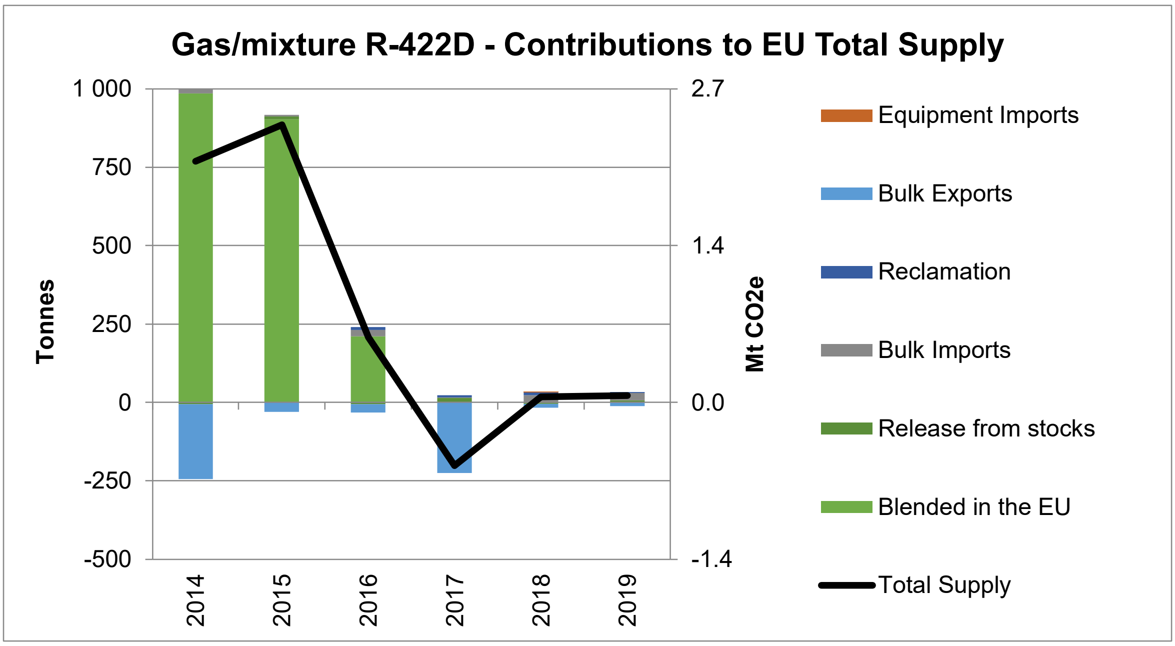
[26] E.g. Chemours from 1 January 2020 https://www.chemours.com/en/news-media-center/all-news/press-releases/2019/chemours-announces-suspension-of-high-gwp-refrigerants-r-404a-and-r-507a-supply-in-the-eu-as-of-janu and Honeywell from 2018 onwards https://www.honeywell-refrigerants.com/europe/think-about-tomorrow-today/

Figure 15: EU27+UK supply of R-507A (GWP 3,985)



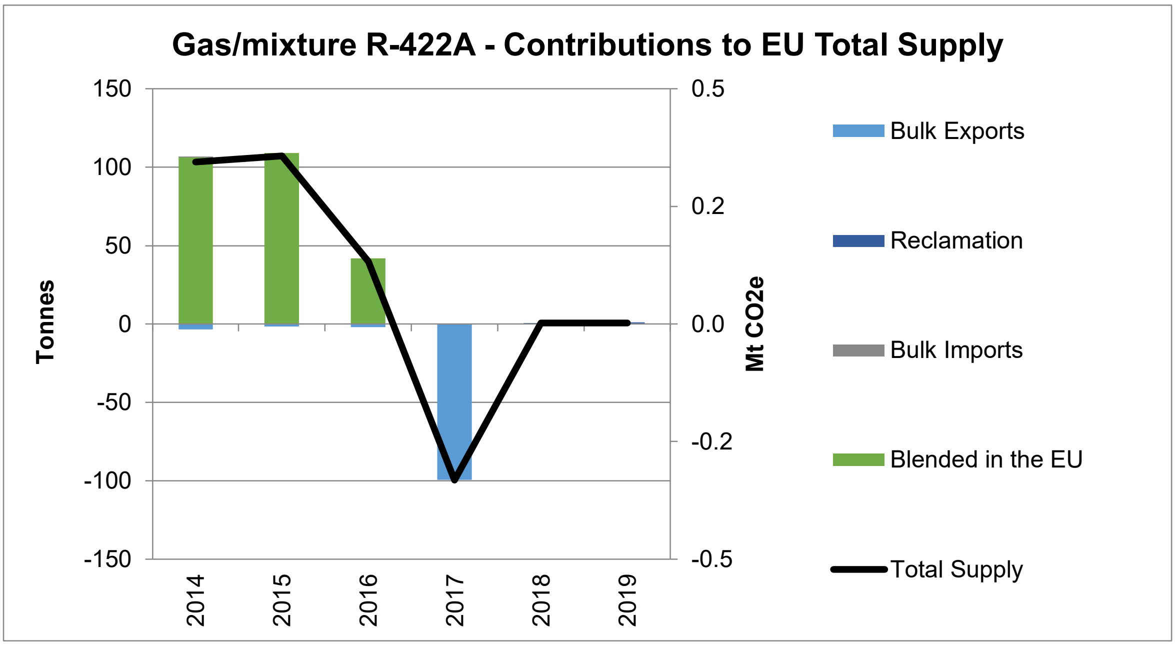
Source: [EEA 2020 confidential dataset], own calculations

Figure 16: EU27+UK supply of R-422D (GWP 2,729)



Source: [EEA 2020 confidential dataset], own calculations

Figure 17: EU27+UK supply of R-422A (GWP 3,143)



Source: [EEA 2020 confidential dataset], own calculations

The effectiveness of the service and maintenance prohibition for F-gases with GWP of 2,500 or more is also supported by the finding that demand for HFC-HFO blends R448A (GWP 1,387) and R449A (GWP 1,397) has increased in recent years. Operators of systems containing or relying on R404A or R507A were said to have planned the conversion of their existing equipment over several years in anticipation of the service ban (e.g. the Romanian supermarket chain Mega Image (Cooling Post, 2016)).

While evidence for the prohibition date 1 January 2020 is not yet available, it can be concluded that the data provided for the period 2014 to 2019 suggest that the market developments indicate that it is likely that the 2020 prohibition has been met.

SF_6 in magnesium die-casting and recycling of magnesium alloys

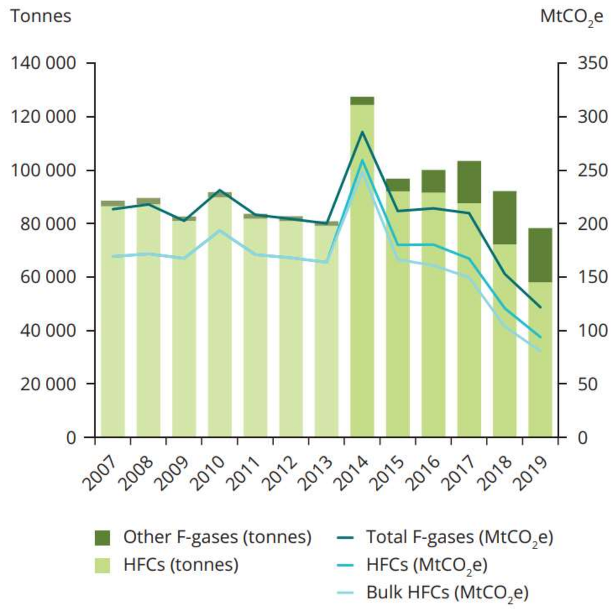
Article 13 (1) of the Regulation sets out the prohibition for the use of SF_6 in magnesium die-casting and recycling of magnesium alloys for installations using a quantity below 850 kg per year, which has applied since 2018. According to recent information from relevant undertakings, all of the remaining users converted their production to alternatives such as SO_2, HFC-134a or a special gas formulation SGE N2 (0.3 % HFC-134a, nitrogen type 50). Experts from industry confirmed this finding and explained that remaining emissive SF_6 use was for research purposes related to the manufacture of new alloys.

5.1.1.3 *EQ3a(iii). To what extent have the 'HFC phase-down' requirements (Article 14-18) discouraged the use of F-gases and encouraged use of alternatives?*

Development of GWP of HFC supply and quota use

The following figure shows the effect of the phase-down on the supply of HFCs which still dominate the supply of F-gases on the EU market (approximately three quarters in tonnes and in CO_2 eq). A clear reduction, in particular in CO_2 eq, is however apparent.

Figure 18: EU27+UK supply of F-gases (in tonnes shown as green bars and Mt CO_2 eq depicted as lines)

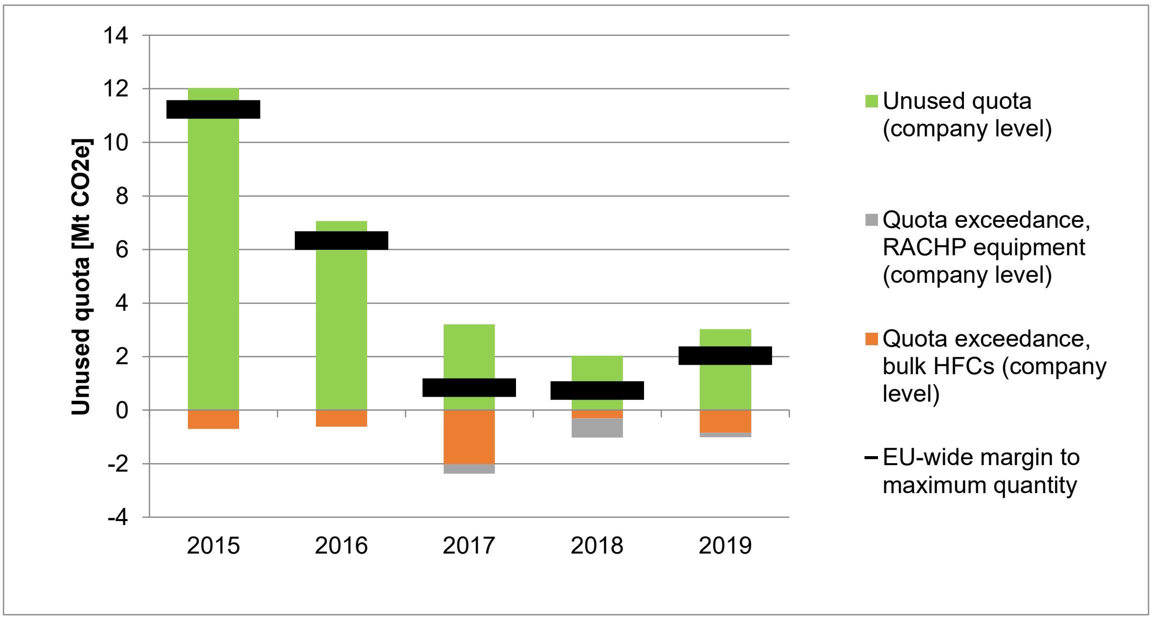


Source: [(EEA, 2020)]

As regards the use of quota, quota quantities were used less efficiently by undertakings in 2015 and 2016 (6 % and 4 %, respectively) than in later years. The reasons for undertakings not to fully use the allocated quotas were diverse and ranged from lack of knowledge (new rules, difference between quotas and authorisations, compliance with REACH obligations) to high HFC imports in 2014, a decrease in imports in 2015 and very small quantities of allocated quota (European Commission, 2017). However, with time undertakings appear to have adjusted to use their quota to the maximum. In the subsequent years, the share of unused quota was considerably lower (2017: 0.5 %, 0.8 Mt CO_2 eq; 2018: 0.7 %, 0.7 Mt CO_2 eq; 2019: 2.0 %, 2 Mt CO_2 eq).

Figure 19 presents how the EU-wide over-achievement can be broken down into quota compliance at company level. From this it can be observed that in 2015 and 2016 the sum of unused quotas was considerably greater than the quota exceedance observed for some undertakings. The margin was much closer in 2017, 2018 and 2019, in part as non-compliant RACHP equipment importers were also considered.

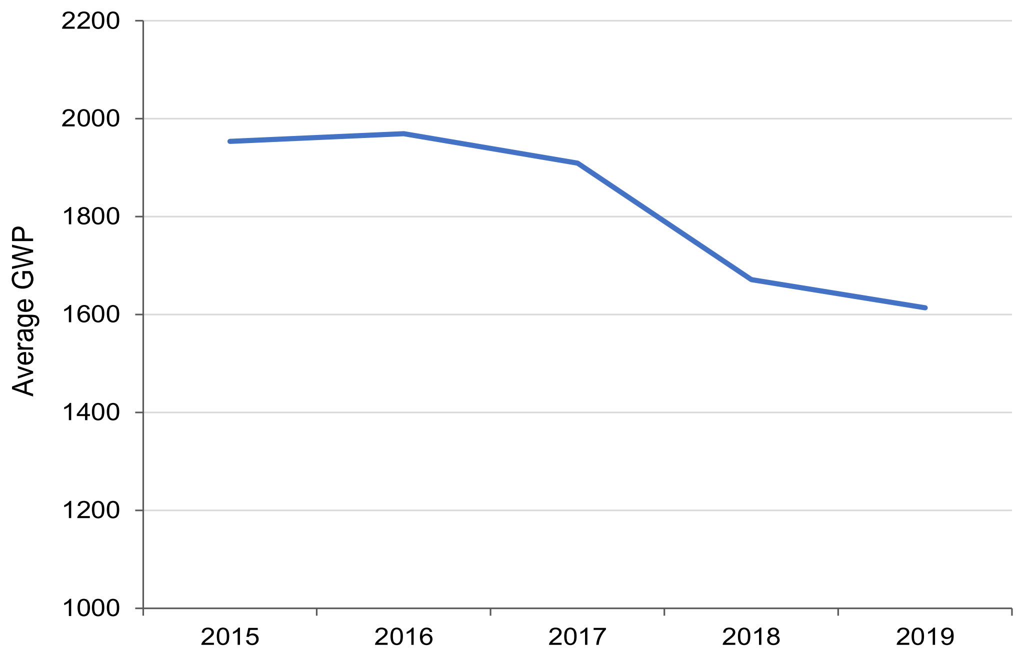
Figure 19: Balance between placing on the market of HFCs and related quotas at EU27+UK level



Source: [(EEA, 2020) public report]

The HFC phase-down has had a clear effect on the average GWP of HFCs, inter alia due to a strong reduction in HFCs with very high GWPs (mixtures containing HFC-143a and/or HFC-125) and increases in HFCs with lower GWPs (e.g. HFC-32). The following figure shows the development of the average GWP of the EU HFC supply. The data is supported by feedback from stakeholders – for example in response to the workshop, one electronics industry participant demonstrated how they had completed conversion of R507 (GWP 3985) plants to R410A (GWP 2088), with the rest of their plants following shortly.

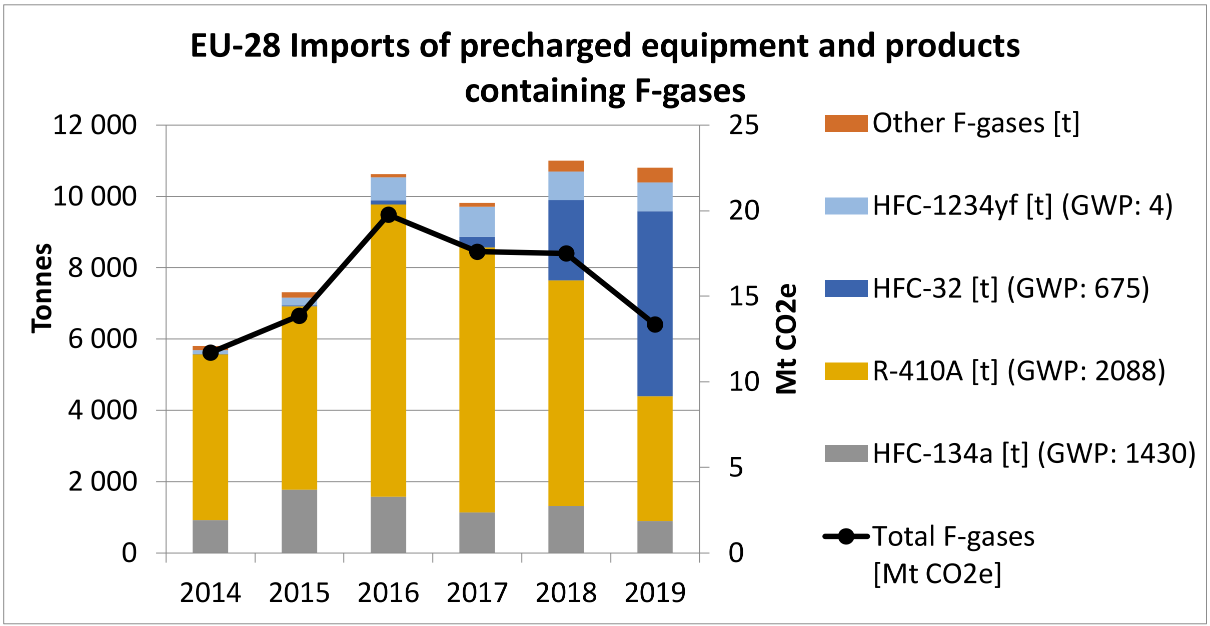
Figure 20: Development of the average GWP of the HFC supply



Source: [(EEA, 2020)]

In 2019, imports of pre-charged equipment represented only 10 % of the total imported amount (based on CO_2 eq). They have been subject to reporting since 2014, and reported amounts rose significantly until 2016, which may be attributable to more complete reporting and not to actual increases in equipment imports. Since then, there has been a clear shift to lower GWP alternatives in imported equipment, i.e. the total CO_2 eq of imported in pre-charged equipment has been declining (see Figure 21).

Figure 21: EU imports of pre-charged equipment by key refrigerants



Source: [EEA 2020 confidential dataset]

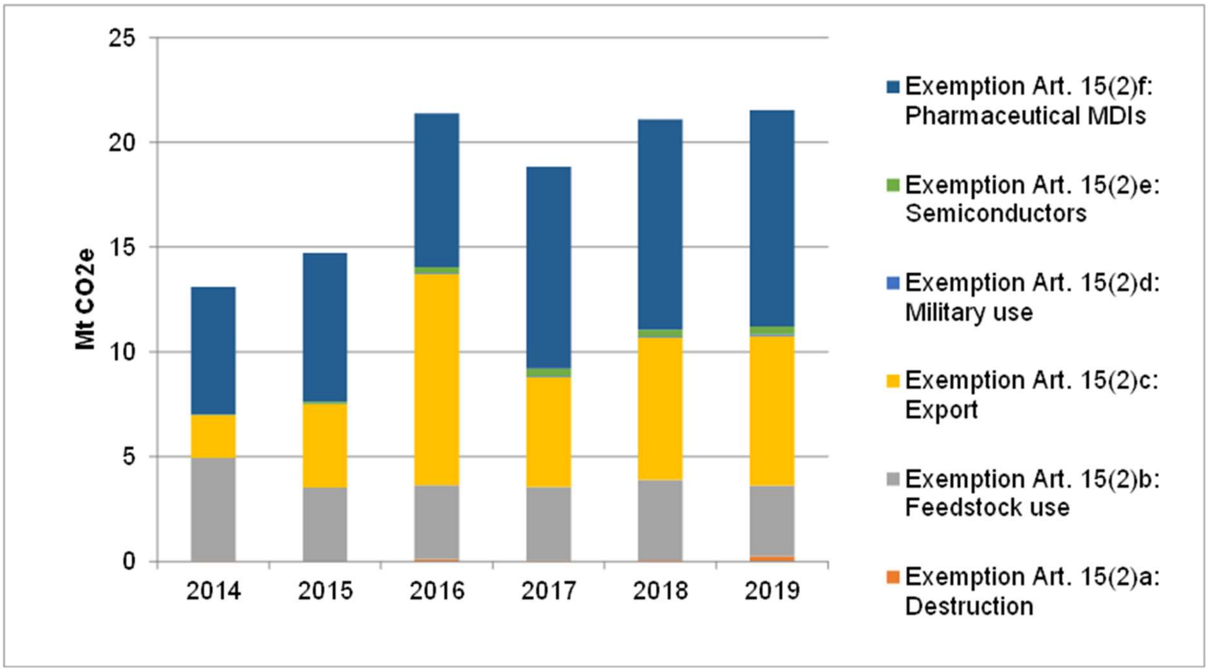
This decrease is largely the result of the ongoing switch from the traditionally used refrigerant R410A (GWP of 2,088) in imported RACHP equipment to the lower GWP HFC alternative R32 (GWP 675) and also by HFC-1234yf (GWP 4) replacing HFC-134a (GWP 1,430) in mobile AC equipment. Measured in CO_2 eq, equipment imports were 38 % below 2016.

Awareness of the functioning of the phase-down measure has been key to enable undertakings to take the right decision for them and for the climate. While the HFC price increase was a clearly demonstrated the current and future shortages to undertakings (see below), it is a challenge to ensure that all relevant business actors have the necessary information and understanding to take the most appropriate long-term business decision. To support the F-gas policy, industry associations have played a key role in providing guidance to undertakings, e.g. a campaign calling on undertakings to stop installing highly warming gases in light of the phase-down (AREA, ASERCOM, EFCTC and EPEE, 2018) (AREA, n.d.). In addition, prohibitions have brought clarity by ensuring that businesses could not make choices that would be clearly inappropriate in light of availability of suitable and economical alternatives.

Quota exemption and exports

Figure 22 depicts the development of HFCs placed on the EU market for the quota-exempted uses as defined in Article 15 (2) of the Regulation.

Figure 22: HFCs placed on the EU market under the quota exemptions of Article 15 (2)

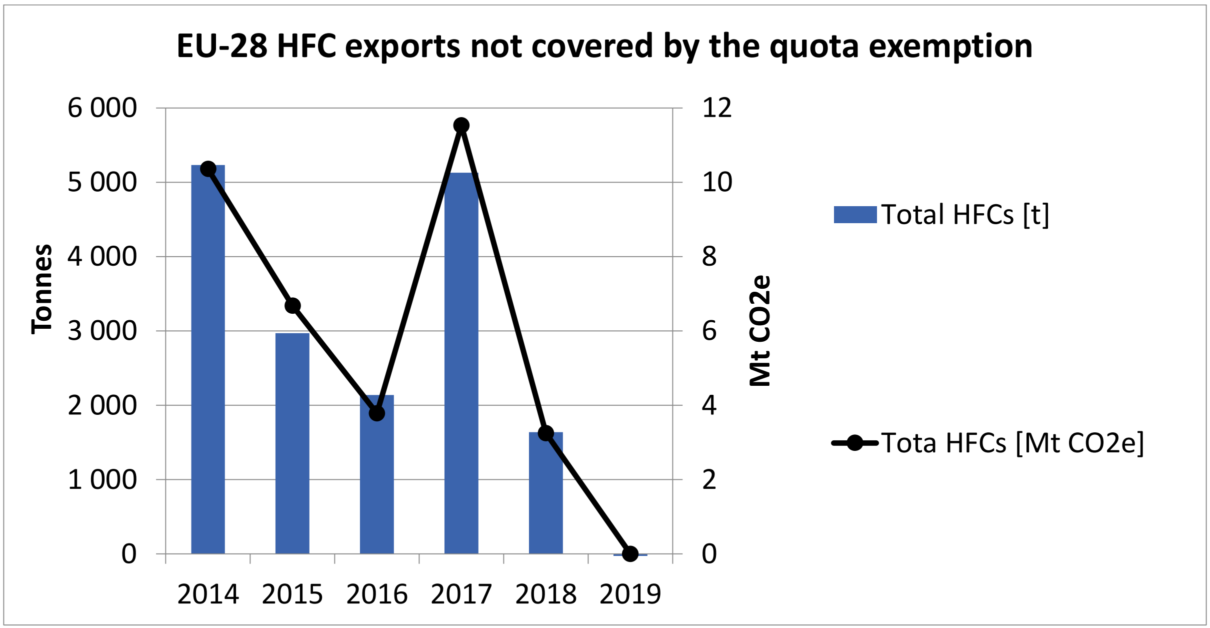


Source: [EEA 2020 confidential dataset]

The quantitatively relevant quota-exempted uses were pharmaceutical metered dose inhalers (MDIs), feedstock use and export. The exemptions for military use, semiconductor industry and destruction accounted for only 3 % of total exemptions in 2019. The HFCs amounts for MDI use have grown by about 45 % from 2015 to 2019 while feedstock use was rather constant in that period. Some stakeholders noted this was a potential cause for concern (workshop feedback) and warrants further investigation, although others signalled that pharmaceutical undertakings are already exploring moving to lower GWP propellants (the first undertakings have announced their intention to commercialise the first lower GWP MDIs by the end of 2025). Quota-exempted amounts under the export exemption has been fluctuating.

Figure 23 depicts how EU HFC suppliers (producers/importers) on one hand and EU HFC exporters on the other hand have quota-wise optimised their cooperation to ensure that by 2019 all bulk EU-HFC exports were effectively accounted for under the respective quota exemption of Article 15(2)(c) of the Regulation and thus do not put any more strain on the HFCs available for EU27+UK domestic supply.

Figure 23: EU27+UK HFC exports not covered by Article 15(2)(c) quota exemption



Note: Data summarise bulk HFC exports from the EU where the previous POM was not claimed by the respective producer or importer for the quota exemption under Article 15(2)(c) 2014 and 2017 non-exempted exports represent approximately 20 % of the EU27+UK total HFC exports of those years, about 25 % if measured in CO_2 eq.
Source: [EEA 2020 confidential dataset], own calculations

Use of F-gas alternatives

Already prior to the entry into force of the 2014 Regulation, alternatives to F-gases have been researched and introduced to the EU market in major applications. Since 2014, the market uptake of alternatives has been accelerated and in certain applications alternatives to conventional F-gases have become dominant in new equipment. The Regulation served as a strong driver for the uptake of F-gas alternatives.

For example, the strong market position of R32 (GWP 675) in split air conditioning is to be mentioned. This refrigerant features a lower GWP than the previously dominant refrigerant R410A (GWP 2 088) in this application. It has only been introduced since 2014 in prototypes and since 2016 at large scale. Today it represents the main refrigerant in new smaller split AC systems (85 % of sold units in 2020).

In most F-gas applications, natural alternatives have gained significant market shares as they represent long-term technical solutions that will remain viable despite potential F-gas scarcity under the HFC phase down and possibly further F-gas prohibitions.

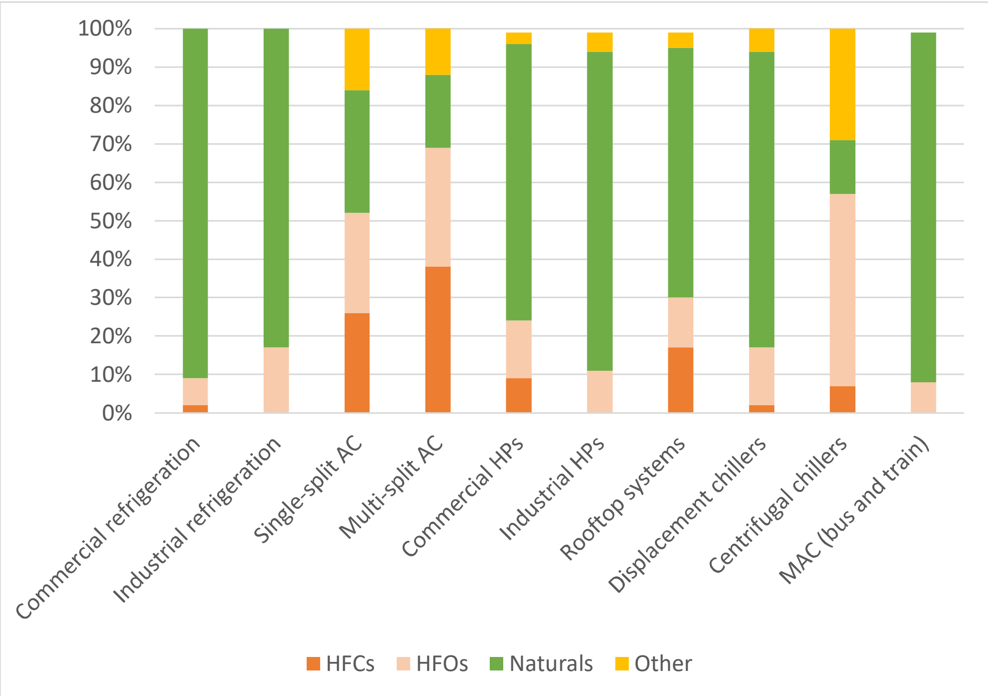
The following table shows the preferred refrigerant for use in different applications, based on a survey conducted by Shecco and published in October 2020. HFCs are the preferred option only for multi-split AC systems and hold a significant share for single-split ACs and rooftop systems, while natural alternatives are the first choice in most applications (Figure 24). It is, however, unclear how representative this data is.

Table 27: Preferred refrigerant for use in different applications based on a survey from Shecco in 2020

Application	HFCs	HFOs	HCs	CO_2	NH_3	Other
Commercial refrigeration	2%	7%	15%	72%	4%	-
Industrial refrigeration	-	17%	-	50%	33%	-
Single-split AC	26%	26%	32%	-	-	16%
Multi-split AC	38%	31%	19%	-	-	13%
Commercial heat pumps	9%	15%	39%	33%	-	3%
Industrial heat pumps	-	11%	24%	24%	35%	5%
Rooftop systems	17%	13%	35%	17%	13%	4%
Displacement chillers	2%	15%	42%	20%	15%	7%
Centrifugal chillers	7%	50%	7%	-	7%	29%
MAC (bus and train)	-	8%	33%	58%	-	-
Average	**14%**	**19%**	**27%**	**39%**	**18%**	**11%**

Source: Shecco (October 2020) https://issuu.com/shecco/docs/fgas_report_2020_201116
Note: Shecco conducted the survey with 125 industry representatives and over 80 different companies, irrespective of the refrigerant type most frequently used by the participants. The average was calculated from the data from Shecco and is not included in the source publication. The group "Other" includes naturals (such as water) that are not further specified.

Figure 24: Preferred refrigerant for use in different applications based on a survey from Shecco in 2020



Source: Shecco (October 2020) https://issuu.com/shecco/docs/fgas_report_2020_201116
Note: Shecco conducted the survey with 125 industry representatives and over 80 different companies, irrespective of the refrigerant type most frequently used by the participants. Natural options were summed over CO_2, hydrocarbons and ammonia from the data from Shecco and are not included as a sum in the source publication. The group "Other" includes naturals (such as water) that are not further specified.

In summary, the Regulation has been flexible to allow alternatives to enter the market and has in fact supported the technical changes that are observed on the market. Indeed, increasing market uptake of F-gas alternatives is an intended effect of the HFC phase down and the POM prohibitions set out under the Regulation, and this has been facilitated. This is also reflected in the fact that no requests for derogations for certain sectors have been received by the Commission to date.

Price developments of HFCs and lower GWP alternatives

Before the Regulation came into force, conventional HFCs and blends were available at low and stable prices. Since then, however, prices have shown very large changes. While no perceptible impact on the prices of the commonly used HFC refrigerants with high GWP was observed in 2015 and 2016 due to the initial low restrictions imposed by the HFC phase-down, the prices of the R134a, R404A, R407C and R410A increased significantly from mid-2017 in anticipation of the 2018 reduction step, peaking at levels 6 to 13 times higher than the original price (see Figure 25).

As the HFC phase-down is based on CO_2 eq, price increases for high GWP refrigerants were the desired effect of providing an inventive to use HFC alternatives or at least HFCs with lower GWP. The figure below also clearly shows that price developments of the four most commonly used HFCs mirrored a clear correlation between the price increase and the GWP of the refrigerant, in line with economic theory.

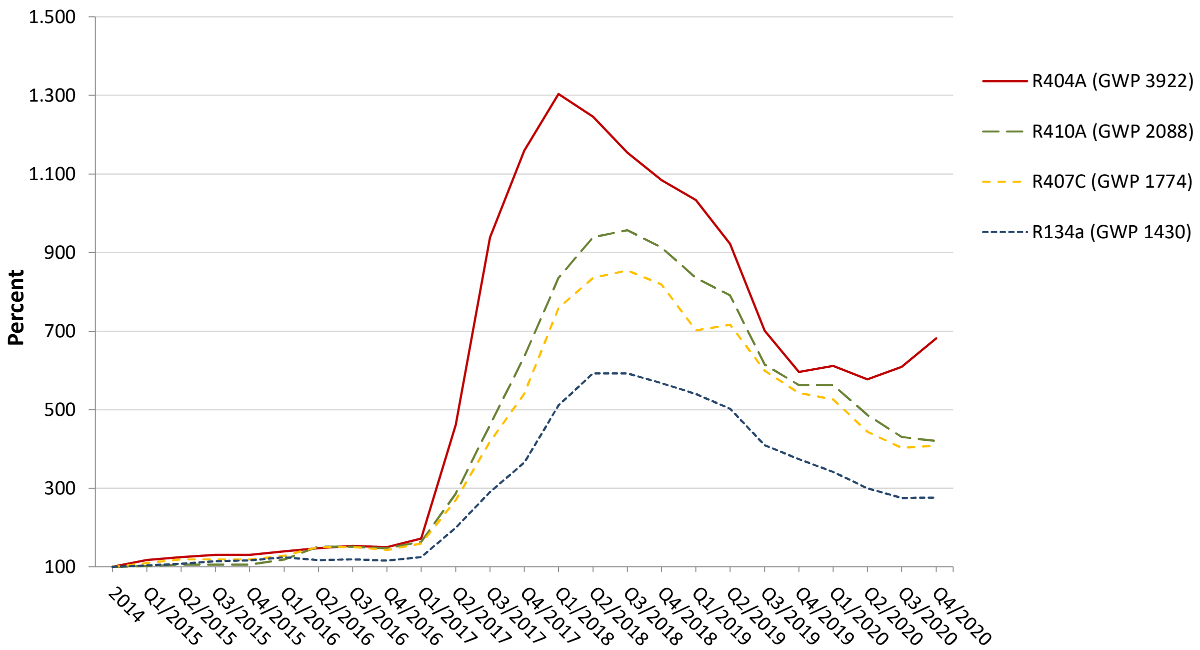
Prices of high GWP HFCs increased significantly in mid-2017 and early 2018 until reaching a peak of 6 to 13 times higher than the original price in 2015 [27]. These observed price increases for the different HFCs roughly reflected their GWP and were passed on from the upper to the lower levels of the refrigerant supply chain. From 2018 onwards, prices have decreased again but high GWP HFCs in 4th quarter 2020 continue to be 0.5-4 times (gas distributor purchase prices in 2020, depending on the HFC) higher than the world market and therefore continue to be an incentive for innovation.

Reasons for the strong price declines from mid-2018 given by the reporting undertakings in the quarterly HFC price monitoring survey included low demand for HFCs with high GWP due to stockpiling in the first years of implementation of the Regulation, improved leak prevention, illegal trade activities, switching to lower GWP alternatives in some sectors (e.g. commercial refrigeration, stationary and mobile AC, heat pumps), increased reclamation rates and – for 2020 – the economic situation under the influence of Covid-19. It is difficult to identify the exact contribution of these different drivers.

In the EU Commission's report regarding the assessment of market availability of HFCs in the Union published in December 2020, it was concluded, on the basis of stakeholder input, that after limited availability of some high GWP HFC refrigerants on the market in the second half of 2017 and early 2018, there was no shortage in the market supply of HFCs in the following years, due to the uptake and increasing availability of HFC alternatives with lower climate impacts. Hence price increases were not driven by scarcity, they were rather driven by quota induced effects (European Commission, 2020).

[27] Quarterly reports on the monitoring of HFC prices prepared by Öko-Recherche since 2016 on behalf of the EU Commission (DG CLIMA).

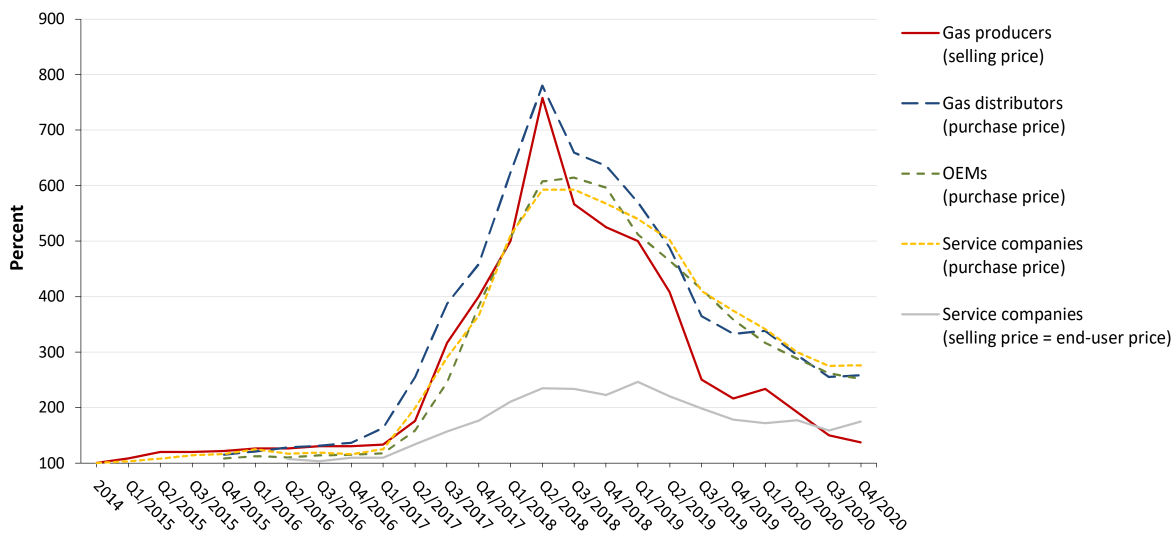
Figure 25: Price development of HFCs at service company level (price index, 2014 = 100 percent (baseline))



Source: HFC price monitoring survey on behalf of the EU Commission, own calculations

As Figure 26 displayed, price increases were passed on from the upper (gas producers and distributors) to the lower levels (OEMs and service undertakings) of the supply chain. Here it needs to be noted that, while the relative increase in selling prices at service company level has been lower than the relative increase in purchase prices (and prices for other upstream market players), the absolute increase in selling prices has been significantly higher as they were already quite high before the Regulation entered into force, i.e. prices were fully passed on to the end-users.

Figure 26: Development of average prices of R134a (GWP 1430) along the entire supply chain (price index, 2014 = 100 percent (baseline))

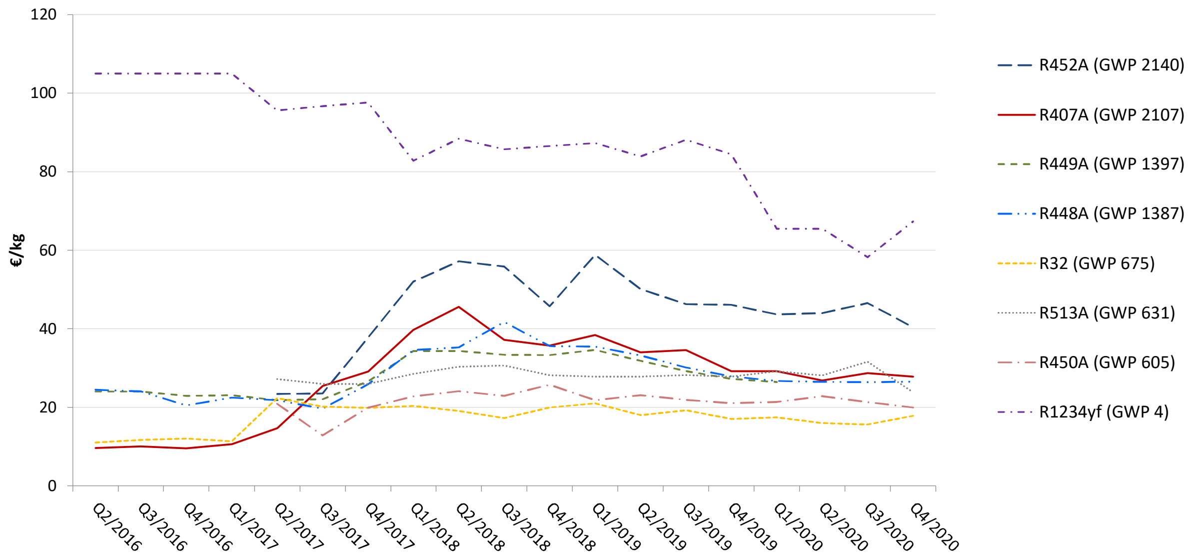


Source: HFC price monitoring survey on behalf of the EU Commission, own calculations

Since mid-2017, synthetic alternatives to conventional high GWP HFCs have been increasingly used, e.g. blends of HFCs and unsaturated HFCs like R448A/R449A as a replacement for R404A in commercial refrigeration or R32 as lower GWP HFC alternative in single-split AC systems. In contrast to the conventional high GWP HFCs, prices of synthetic alternatives have remained stable or showed rather moderate price increases between 2017 and 2020, with the exception of R1234yf for which the price has significantly decreased (- 45 %).

Although these synthetic alternatives are now widely available, declining prices of the high GWP HFCs and the growing use of natural alternatives such as CO_2, ammonia and hydrocarbons have not led to a very high demand for new synthetic blend solutions. Natural refrigerants have been widely available on the EU market and at low cost (e.g. 2-8 €/kg at gas distributor level).

Figure 27: Price development of HFC/HFO-HFC alternatives at service company level (in €/kg)

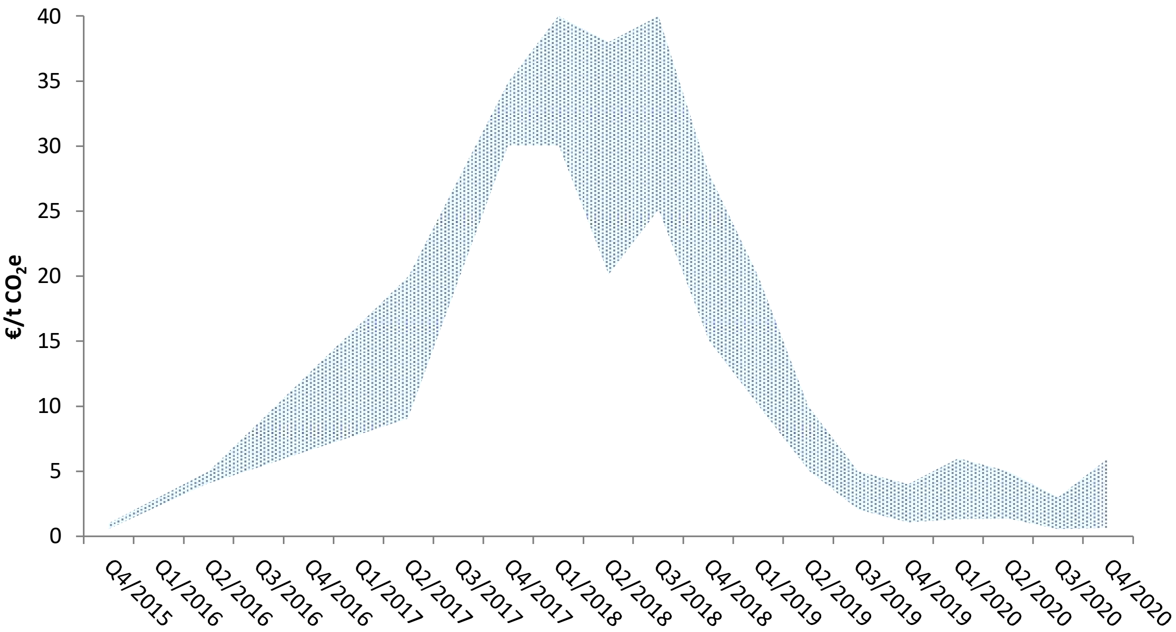


Source: HFC price monitoring survey on behalf of the EU Commission, own calculations

Quota authorisation prices for the import of pre-charged RACHP equipment rose in parallel with prices of for bulk gas until mid-2018, and importers of pre-charged products and equipment reported price levels of over 40 € per tonne of CO_2 eq at that time. Since then, prices have fallen strongly and reached a price level in in 2019/2020 that is comparable to the initial level of 2015. Shortages of HFCs reported by undertakings in 2017/2018 coincided with the peak levels of the quota authorisation prices.

Price declines for quota authorisations in 2019/2020 can be explained by the fact that equipment importers built up a reserve of 2.5 times the amount of quota authorisations used in 2018 and by a decrease in imports of pre-charged equipment (measured in CO_2 eq), mainly due to the increased use of R32 as a lower GWP alternative to R410A used in imported AC systems, while there have also been quota surpluses among bulk quota holders in 2020 that have led to low authorisation prices.

Figure 28: Price range of quota authorisations (in €/t CO_2 eq)



Source: HFC price monitoring survey on behalf of the EU Commission, own calculations

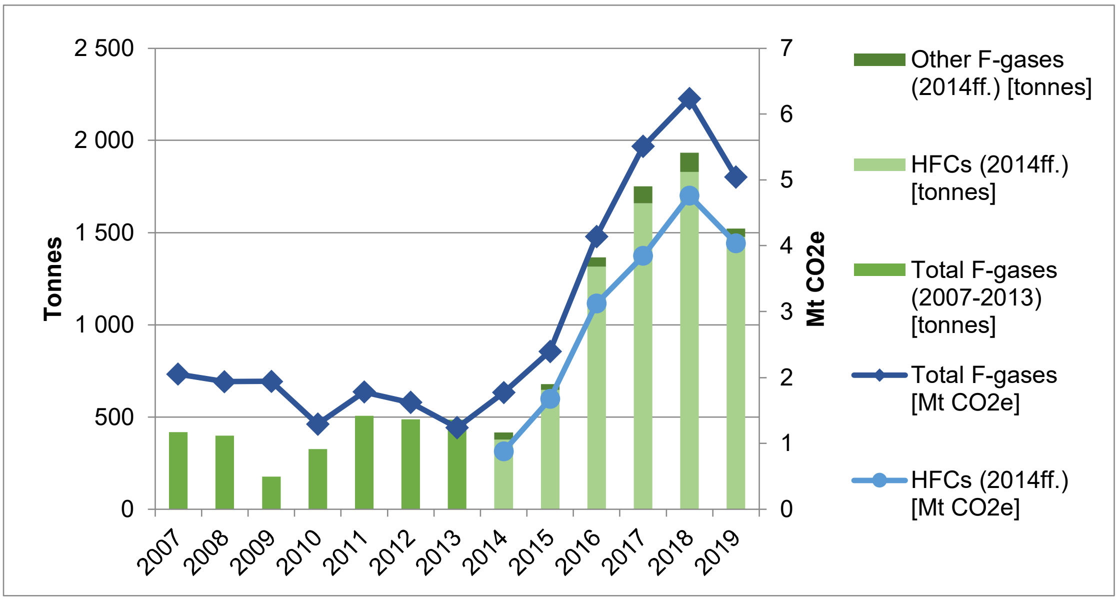
Looking at the trend of prices expressed in €/t CO_2 eq at OEM level, *the average surcharges induced by the HFC phase-down* for the most commonly used HFCs R134a, R404A, R407C and R410A in equipment increased from 0.24 €/t CO_2 eq in 2015 to about 18 €/t CO_2 eq in mid-2018 and declined again to about 10 €/t CO_2 eq by the end of 2019. Over that time period, the induced average surcharge in the period 2015 to 2019, considering the average surcharge of each of the four HFC refrigerants, was about 8 €/t CO_2 eq.

Reclamation of F-gases

Reclaimed HFCs are not subject to the limits of the HFC phase-down and even high GWP gases can still be used to service larger refrigeration equipment until 2030. Reclaimed gases can ensure the availability of essential HFCs on the market going forward, especially as the phase-down gets tighter. In its public report 2020, the EEA examined evidence related to the rise of HFC reclamation in response to the HFC-phase-down. It determined that although there has been a fluctuation in reclamation of F-gases in the EU, there was a steady increase between 2014 and 2018 (Figure 29). The EEA found that reclaimed HFCs, as reported, made up 8 % of the produced amount in 2019, equating to 3 % of the EU supply of virgin HFCs (or 9 % and 4 % respectively in CO_2 eq). HFCs make up the vast majority of reclaimed F-gases (97 %), with SF_6 contributing approximately 20 % of the GWP of reclaimed gas.

In 2019 the reported reclamation amount decreased by ~20 % compared with 2018. That said, reported reclamation amounts are based on the reclamation activities of undertakings which have a reporting obligation as gas importer. There is incomplete reporting of reclamation due to no self-standing reporting obligation for reclamation undertakings, i.e. the quantities of F-gas reclaimed may exceed those presented. The EEA public report 2020 highlighted that 'the 2019 decrease can be largely explained by the fact that one gas importer stopped including in their report amounts reclaimed by an independent sub-contractor'.

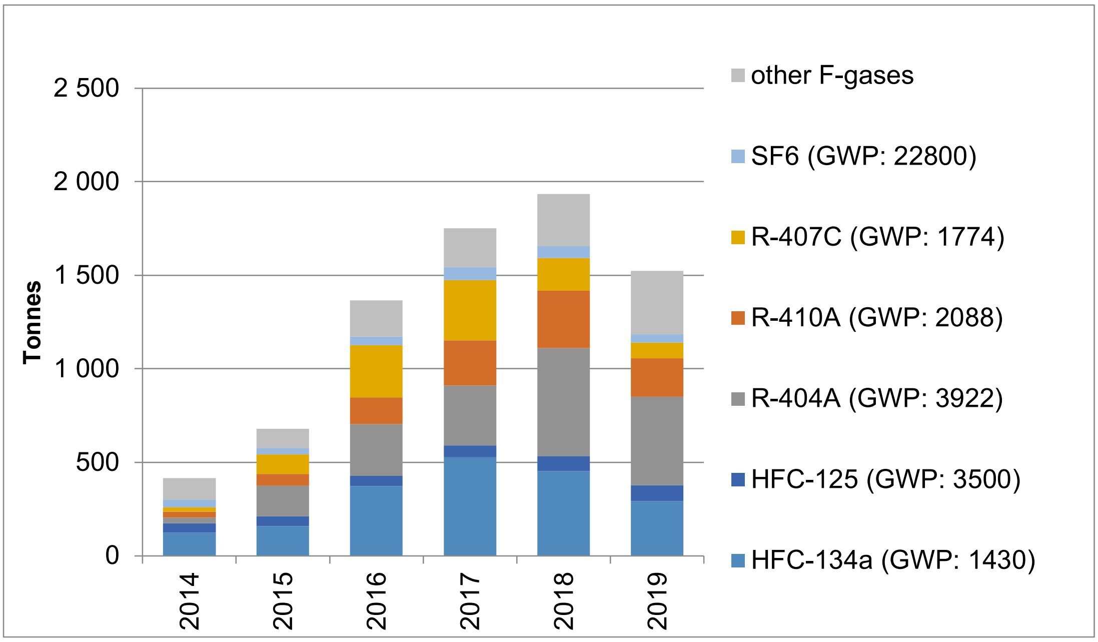
Figure 29: EU27+UK reclamation of F-gases



Note: The decrease in reported amounts for 2019 is due to incomplete reporting.
Source: [(EEA, 2020)]

Splitting by substance type, the sharp increase in reclamation from 2014 to 2018 applied particularly to R134a, R407C, R410A and R404A (Figure 30). As discussed above, the decrease in reclamation amounts reported for 2019 is due to incomplete reporting.

Figure 30: Quantities of reclaimed F-gases in the period of 2014 to 2019 in the EU (in tonnes)



Source: [EEA 2020 confidential dataset]

While the reclaimed quantities for R134a and R410A were large when compared to reclaimed quantities of other gases and mixtures, relative to the total supply of R134a and R410A in 2019, the reclaimed quantities only amounted to 1 % and 2 %, respectively. For R404A, on the other hand, reclaimed quantities made up 25 % of the total supply of R404A in 2019, underlining the effectiveness of the requirement on new and existing refrigeration equipment, where the virgin substance is no longer allowed.

According to information received as part of the quarterly HFC price monitoring survey[28] from gas distributors which provide reclamation services, the share of R410A in reclaimed refrigerants is generally very low (5-10 %) compared to other refrigerants (R134a 10-20 %, R404A 50-70 %), because refrigerant quantities contained in AC systems are generally too small for effective collection and are rather used directly for servicing other systems. In addition, R410A is mostly used in hermetically sealed heat pumps and pre-charged AC systems which require only refilling (i.e. no retrofitting activities).

In the period 2017 to 2019, the average price of reclaimed HFCs was around 35 to 40 €/kg, a bit higher than the average purchase price for virgin HFCs. Significantly lower prices (~ 15 €/kg) were paid in cases where undertakings provided the recovered gases themselves to the reclamation facilities and only paid reclamation.

Given the amounts ‘banked’ in equipment that reaches its end of life, there appears to be more untapped potential for increasing reclamation activities in the EU. Demand for reclaimed gases generally reduces the risk of illegal venting and inadvertent losses at the end of life of equipment.

In the targeted interviews, Member State competent authorities indicated that many Member States have facilities for basic cleaning processes but do not yet have a reclamation infrastructure in place, so they need to export recovered gases to countries with such reclamation facility (e.g. Germany, France, Italy, Poland, Spain and – before Brexit – also the UK). One Member State competent authority stated that the costs of reclamation (and destruction) are very high and an obstacle to the proper end-of-life treatment of F-gases as there are no facilities at national level. Through analysis of the targeted interviews it was evident that recovery and reclamation are treated or supported differently across Member States. In Germany, enforcement is the sole responsibility of the individual Federal States, whilst in Denmark a national voluntary deposit-refund scheme was established to manage used CFC, HCFC and HFC refrigerants. In Spain, recycled and regenerated refrigerants benefit from a 50% reduced tax rate. In addition, the industry association EPEE emphasized in the targeted interview that there is currently no or only little data available related to recovery, recycling and reclamation of HFCs and a better understanding and monitoring of these activities would be a first and essential step to assess avenues to boost them. The business association Shecco stated that according to its internal survey, the majority of members believed that the Regulation has increased the recovery and reclamation rates of refrigerants.Undertakings providing reclamation services expanded their business activities in the last years (e.g. (Cooling Post, 2019)). A recent initiative funded under the EU LIFE programme set up an online platform for trading of reclaimed refrigerants (Cooling Post, 2021)

5.1.2 EQ1b. How effective has the Regulation been in preventing leakages of F-gases (Articles 3-8 and 10)?

5.1.2.1 *Article 3 to 5 – containment, leakage checks and leakage detection systems*

Deployment of leak checks and detection systems

Leak checking requirements are addressing existing and new equipment and systems and represent a key measure to reduce F-gas emissions occurring during operation (lifetime emissions). The requirements relate to stationary refrigeration, air conditioning and heat pump equipment, refrigerated trucks and trailers, stationary fire protection equipment, some electrical switchgear and organic Rankine cycles. They differ in their frequency by charge size, refrigerant type and if a leakage detection system is

[28] Quarterly reports on the monitoring of HFC prices prepared by Öko-Recherche since 2016 on behalf of the EU Commission (DG CLIMA).

installed or not. Several implementing acts outline detailed procedures for the leak checks (Commission Regulations (EC) No 1516/2007[29] and 1497/2007[30]).

Evidence that the requirements were implemented is provided indirectly since documented leak rates (refill rates) were reduced (see the following sections) and compliance is thought to be rather high today. From the evidence gathered, feedback from stakeholders (workshop) elaborated on some of the actions they had taken. For example, on industry stakeholder from the electronics sector demonstrated effective compliance with Articles 4&5, undertaking daily inspections, preventive maintenance at least once per year and additional sensor systems to eliminate leaks. Nevertheless, cases on non-compliance with leakage checks are sometimes discovered (e.g. in the case of Lidl in the Czech Republic) (see Section 3.4 for further information).

In addition, it is important to note that containment requirements were strengthened in several Member States, for example in Germany, where the age of the equipment in scope is also relevant and maximum leakage rates during operation.

Leakage rates

An overview of national databases from several Member States and the leakage rates determined from these datasets is presented in Section 3.4. It has not been possible to gather information for this evaluation on leakage rates from all Member States which have electronic databases. For the development of leakage rates, data from the Polish electronic database show that annual leakage rates of the RACHP equipment have decreased significantly in all equipment categories since 2016 (Kozakiewicz, Goworek and Kania-Szarek, 2020).

Table 28: Annual leakage rates of the RACHP equipment in the Polish electronic database

	2016	2017	2018	2019	2020
Refrigeration	16.2 %	6.3 %	4.96 %	3.61 %	3.71 %
Air conditioning	5.63 %	3.22 %	2.67 %	1.51 %	1.7 %
Heat pumps	6.70 %	2.97 %	1.83 %	0.8 %	1.74 %
Total average	**12.6 %**	**5.34 %**	**4.2 %**	**3.12 %**	**3.00 %**

This is also supported by data from the German electronic recording system run by the VDKF (so-called 'VDKF-LEC'), which is used on a voluntary basis. Two datasets allow a comparison of the leak rates in the period 2009-2012 (i.e. before the Regulation entered into force) and in the period 2014-2018 (i.e. after entry into force). Both datasets contain aggregated data from various equipment types, while the operators had to agree to the release of data on their units.

Table 29: Data from the German VDKF-LEC electronic recording system

VDKF-LEC	Dataset 1 (Gschrey et al.,, 2015)	Dataset 2 (VDKF , 2019)
Assessment period	2009-2012	2014-2018
Size of dataset	34,264 systems (commercial refrigeration and stationary air conditioning)	1,000 service undertakings, 45,000 operators, 200,000 cooling circuits and a total charge of 2,520 tonnes
Annual refill rates	3.4 %	2-3 %

[29] Commission Regulation (EC) No 1516/2007of 19 December 2007 establishing, pursuant to Regulation (EC) No 842/2006 of the European Parliament and of the Council, standard leakage checking requirements for stationary refrigeration, air conditioning and heat pump equipment containing certain fluorinated greenhouse gases, https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32007R1516&from=EN

[30] Commission Regulation (EC) No 1497/2007 of 18 December 2007 establishing, pursuant to Regulation (EC) No 842/2006 of the European Parliament and of the Council, standard leakage checking requirements for stationary fire protection systems containing certain fluorinated greenhouse gases, https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:32007R1497

VDKF-LEC	Dataset 1 (Gschrey et al.,, 2015)	Dataset 2 (VDKF , 2019)
Refill details	Refills mostly occurred in older systems. About 23 % of the refill quantity were the result of catastrophic refrigerant loss.	Refill by applications: Split AC 1.53 %, commercial refrigeration 3.83 %, industrial refrigeration 2.07 %, centralized AC 1.32 %, VRF 1.75 %, other systems 2.92 %
Refill by refrigerants	The highest annual refill rate was found in R404A systems (5.3 %). R410A systems showed the lowest rate of < 1 %. Systems running on R134a and R407C had similarly low rates of just below 3 %.	R404A: 3.31 % R507A: 3.46 % R134a: 1.31 % R410A: 1.33 %.

The comparison shows that leakage rates decreased after the introduction of the Regulation, on average and in all applications.

Some detailed information on the commercial refrigeration sector is available from the 'Chilling Facts' reports published by the EIA (see Section 3.4 (EIA, 2017)). The report found that under the Regulation 'leakage continues to be a problem for some retailers, although the data presented has not been updated since 2015 and so it is unclear how seriously the problem persists. Progress has been made but more needs to be done to address leakage which impacts on the efficiency of the system in place as well as the cost and climate impact through unnecessary HFC emissions'. It is stated that certain industry leaders were able to decrease their leakage rates to the range of 5-7%. The EIA concluded that the data gathered presents a rather optimistic picture since the more environmentally proactive undertakings tend to be better at data monitoring. Moreover, the data gathered indicated that direct emissions (related to refrigerant leakages) remained on average almost equal to indirect emissions (related to energy consumption) and had not decreased compared to previous surveys. It is underlined that this information put energy-saving discussions into context and that still almost half of the total climate impact of HFC-based refrigeration systems came from leaking emissions.

Stakeholders (workshop feedback) also corroborate the positive results observed in the data, with some noting that containment has clearly improved and leakage rates reducing drastically over the period of implementation. One switchgear industry representative noted medium voltage SF_6 switchgear used state-of-the-art sealed gas-compartments resulting in practicably negligible emissions in operation, with end-of-life handling of the equipment undertaken professionally by specialized industry partners. The same stakeholder noted that during the last decades, new high an extra high voltage SF_6 switchgears have been ordered and operated with a SF_6 leakage rate less than 0.1 % per year. In Spain, from 1995 manufacturers have set out on a series of steps in switchgear design to reduce emissions in service, notably including more compact equipment (thus reducing gas content), minimising annual leak rates (to values of 0.5 % and 0.1 % in high voltage and medium voltage, respectively), as well as very substantial measures to reduce emissions in the manufacturing process.

Although the majority of stakeholders (OPC) agreed that the containment measure had been somewhat effective, a further prominent view was that further improved containment was needed. In particular, a common opinion amongst NGOs is that there is a lack of measures to promote implementation and compliance with containment obligations, including maximum leakage rates and minimum sanctions and penalties for non-compliance, such as removal of certification and fines.

Leakage prevention and energy efficiency

The link between leakage prevention and energy efficiency has been underlined by research on the effect of the refrigerant charge on the system performance. One study (Grace, Datta and Tassou, 2005) found that a certain deviation from the design value (+/- 25 %) of the refrigerant charge still allowed operation of the system, but outside of this range the performance was heavily dependent on the charge level. Preventing F-gas leakages hence does not only reduce direct emissions by avoiding refrigerant loss but also impacts indirect emissions by lowering the energy consumption of RACHP systems and thus improving their energy efficiency. Energy efficient operation of RACHP equipment is also relevant in financial terms considering the high number of operating hours of e.g. supermarket refrigeration systems. Since eco-design requirements for different RACHP product groups set out minimum energy performance standards (MEPS) for higher energy efficiency, a strong link to this legislation exists (see coherence section).

Indeed, a recent report from EIA and Shecco (2018) highlighted the link between energy efficiency and reduction in leakage, which can both be improved through improved maintenance regimes: *'There are also numerous ways to improve the energy efficiency of existing refrigeration systems, ranging from regular and thorough maintenance and servicing to improved controls and putting doors on display cases. Many supermarkets have already taken steps to improve the environmental impact of their HVACR systems and are reporting positive results including reduced refrigerant leakage and lower energy bills* (EIA & Shecco, 2020)*.'*

Effects of containment measures

As regards stakeholders' positions on containment, the measures were considered crucial and effective by Member State competent authorities in the targeted interviews. Member States reported that leak checks are performed regularly according to the required schedules and are said to be effective in the sense that they created awareness amongst operators for improved maintenance and servicing practices in all sectors covered. This opinion was shared generally by stakeholders, as evidenced by the response to the OPC where it can be observed that containment measures were seen to be effective/very effective in contributing to the Regulation meeting its objectives, receiving 80 % positive responses. One business association underlined that leakage control and record keeping were already key pillars of the first F-gas Regulation and they still are an important part of the current one.

A German technical study (Gschrey et al, 2015) confirmed the importance of the regular leakage checks required by the Regulation and associated servicing to reduce refrigerant loss and system failure. The type of service contract was not found to influence the leak-tightness of refrigeration systems.

That said, deficiencies in the existing requirements were identified through the evaluation.

One competent authority pointed out that it would be important to define more precisely the requirement 'without undue delay' for leakage repair in Article 3 (3), while another recommended that the establishment of a minimum duration between two checks should be analysed (i.e. the first check immediately after the leakage repair and the next check after a certain time). This deficiency was also highlighted by an industry stakeholder (AREA) who pointed out the lack of specific duration between checks.

An exchange between inspectors from seven EU Member States in October 2018 noted that 'leakage detection system specifications are missing in the Regulation', and as such, it is unclear which kinds of leakage detection systems would be appropriate to meet the requirements under Articles 4 and 5 (CLEEN, 2019). One Member State has also noted that currently a lack of enforcement is an issue, and that if enforcement were stricter, companies would have been more motivated to comply with these requirements. This issue was re-iterated by Member State Competent Authorities through the OPC, where it was flagged again that enforcement of containment measures needs to be stronger as undertakings are less motivated to comply when enforcement is lower.

Furthermore, it should also be noted that the leak checking requirements only apply to equipment containing Annex I gases. Thus, neither equipment containing unsaturated HFCs and HCFCs or other Annex II gases nor other low GWP alternatives not covered by the Regulation are currently within the scope of the provisions. This was corroborated with interview with a competent authority, which noted that the list of applications for which regular leakage checks are required could be extended and the reports on leakage checks could be collected and centralised in a database to facilitate access by the authorities.

Some stakeholders indicated a need for improved containment. Several business associations highlighted that collection of data on refrigerant containment and F-gas emissions have not yet been addressed.

Nevertheless, and despite the mandatory keeping of logbooks, a lack of availability of fact-based data regarding leakage rates and recovery rates was noted as an issue by an industry undertaker. Considering that leakage control has the triple benefit of reducing emissions, ensuring safety and maintaining energy efficiency, the importance to better understand this important pillar of the Regulation was emphasised.

5.1.2.2 *Article 6 – Record keeping*

As already established under the previous Regulation (EC) No 842/2006, record keeping is an obligation of equipment operators if their equipment is subject to leak checks. These records are to be stored by the operators and servicing undertakings need to keep copies for at least five years. However, the format of these logbooks is not specified in the Regulation and is based on paper documents, electronic files (e.g. Excel tables) or databases.

There is no comprehensive information on the actual use of different formats. Data from Germany, where a national database does not exist, suggest that electronic tools for record keeping have been gaining acceptance during the last years (VDKF , 2019). Furthermore, in certain Member States, electronic equipment databases have been introduced and their use is required by national legislation (see Section 3.4.2).

That said, a German technical study (Gschrey et al., 2015) discovered that documenting the location of leaks and the causes for leaks precisely in the records (logbooks) could be very useful to avoid further leakage. It was found helpful when operators noted down the reasons for calling the service company. Such calls were almost exclusively linked to problems of the functioning of the refrigeration systems. In half of the cases refrigerant loss was detected.

The difficulties enforcement authorities face with regard to checking operators' duties in line with leak checks, reporting and labelling include:

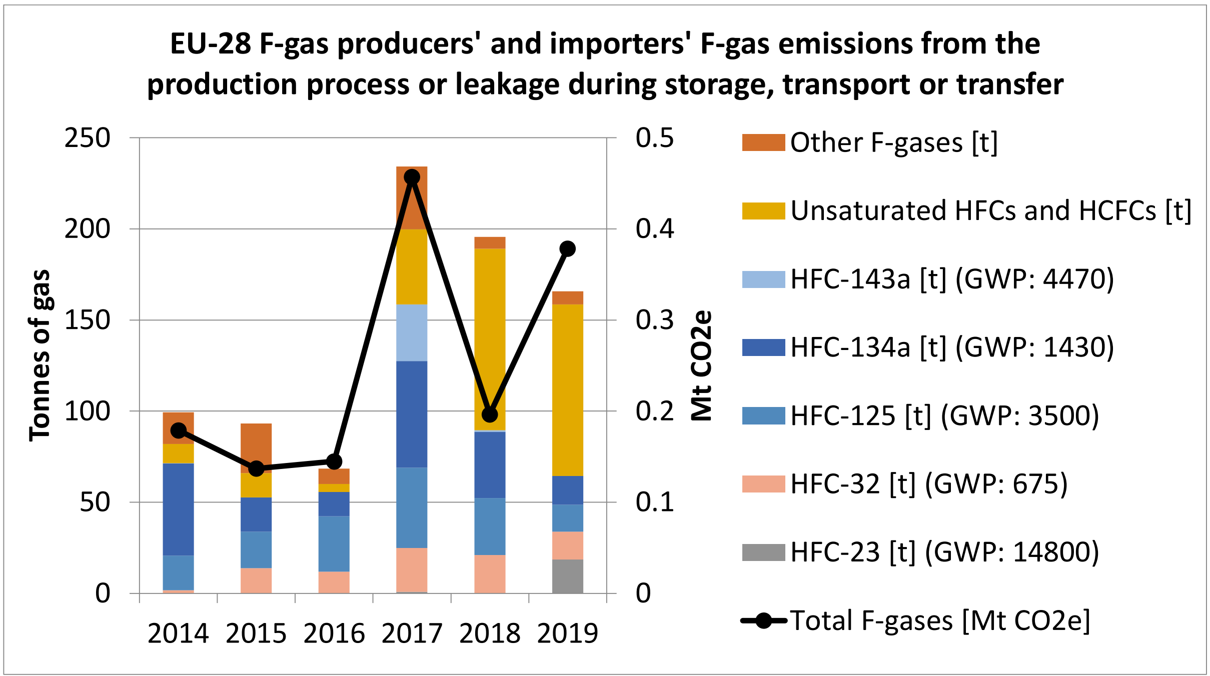
- There are only a small number of inspectors compared with the large number of operators and different types of equipment (e.g. Germany).
- In most Member States there is no register of equipment containing F-gases, making it difficult to locate where equipment is in operation.
- In Member States where equipment registers are established some initial delays in registrations were overcome.
- A large amount of equipment, in particular heat pumps, is being used by private persons, meaning that they cannot be identified and the enforcement operators cannot carry out their duties (CLEEN, 2019).

In response to the stakeholder engagement, an industry association (AREA) highlighted that a lack of a centralized database(s) at EU or Member State level was a challenge, preventing the development of a comprehensive overview of the development of emissions from F-gas leakages could be achieved.

5.1.2.3 *Article 7 – Emissions of fluorinated greenhouse gases in relation to production*

Information on upstream F-gas emissions from EU F-gases producers' and importers' sites for the years starting 2014 can be gained from the data reported by importers and producers under Article 19 of the Regulation as depicted in Figure 31.

Figure 31: EU27+UK F-gas emissions by producers and importers



Note: Data relate to reporting category 6U: Leakage during storage, transport or transfer. Since 2019, producers' emissions of uncaptured amounts of F-gases (by-)production are included, where those uncaptured amounts were not destroyed.
Source: [EEA 2020 confidential dataset], own calculations

F-gas emissions from production between 2014 and 2019 were reported at levels between approximately 50 and 250 tonnes per year (0.1 and 0.5 Mt CO_2 eq). The increase of F-gas emissions measured in CO_2 eq visible in Figure 31 between 2018 and 2019 is due to producers' uncaptured emissions of HFC-23 (trifluoromethane) which had not been subject to reporting for the years before 2019.

It should be noted that unsaturated H(C)FCs make up more than half of reported upstream emissions (measured in tonnes) since 2018 (Figure 31), while this gas group covers less than 25 % of the EU27+UK F-gases supply[31]. As provisions in Articles 3 to 8 and Article 10 for the prevention of emissions apply only to the F-gases of Annex I, those provisions do not cover unsaturated HFCs and HCFCs which are listed in Annex II. It has also to be noted that upstream emissions of imported F-gases are not covered. Lower industrial standards elsewhere may mean significantly higher losses than observed in the EU for imported gases.

While Article 7 (1) applies to EU producers only and demands that F-gas emissions should be avoided by producers to the greatest extent possible, Article 7 (2) applies to both EU gas producers and importers and focuses specifically on the HFC-23 by-production during the manufacture of F-gases and Annex II gases, regardless if this manufacture takes places in the EU or outside. For any F-gas or Annex II gas that is to be placed on the EU market, producers and importers are obliged to provide evidence that HFC-23 produced as a by-product was either destroyed or recovered for use, using best available techniques (BAT) (European Commission, 2015).

On the question of whether Article 7(2) has proved to be effective and sufficient, only a few Member State competent authorities were able to provide feedback on its implementation. Member State competent authorities reported that the provision is unclear as to what kind of information is required, and to whom and how this evidence is to provided. Member State competent authorities highlighted there was no template for a declaration of conformity (similar to the one that has to be submitted for imports

[31] According to the EEA (2020), the share of unsaturated HFCs and HCFCs in EU-28 total F-gas supply (measured in tonnes) has risen to levels of 19 % in 2018 and 23 % in 2019.

of pre-charged products and equipment), which compounded the lack of clarity and comparability of the evidence to be provided. Competent authorities highlighted it is therefore probably not a focus of enforcement, but rather a challenge, especially as customs are unable to check the accuracy of the statements submitted (especially by non-EU producers, e.g. from China). Industry stakeholders confirmed that there is insufficient guidance what 'evidence' actually means.

Environmental NGOs recommended strengthening of the provisions related to destruction of HFC-23 as a by-product since an unexpected increase of HFC-23 emissions lately described in scientific literature (K.M. Stanley et al, 2020) might refer to illegal trade in violation of Article 7(2) of the Regulation. As the issue is also subject to international obligations under the Montreal Protocol, the requirements should be spelled out more clearly and include destruction efficiency and approved technologies to allow for traceability to evidence and mandatory reporting. The schemes established for biofuels and biomass and illegal timber would serve as examples here.

The Polish customs authority reported that evidence of destruction of HFC-23 by-production is checked at the time of import controls for registration and/or labelling, but no targeted checks of the Article 7(2) requirement are carried out. During these general import controls, some imports could be detected without declaration. Awareness of importers for providing this evidence is generally very low. While another competent authority also highlighted the lack of third-party verification of the reported destruction quantities to be a challenge, although industry stakeholders noted such an obligation could be very difficult and disproportionate, especially for buyers of small quantities.

In contrast, in an interview with a business association it was pointed out that massive reductions of HFC-23 emissions already took place at production level in the EU. For HFC-23 destruction overseas at production facilities incineration systems are installed and evidence is provided by means of a declaration on destruction. However, Article 7 does not specify what requirements are to be met. The situation is also becoming more complicated along the supply chain when more market players are involved. It is not spelled out what refrigerant importers need to do with a signed statement issued by manufacturers. Hence a template and further guidance in the legislation was considered useful. In addition, the business association mentioned that any third-party verification would be difficult to organise and disproportionate, especially for buyers of small HFC quantities. However, as new legislation in China, where main production of HFCs is taking place, could become adopted later this year and would change the situation since it will require mandatory destruction of HFC-23.

5.1.2.4 *Article 8 – Recovery*

Recovery provisions were introduced already under the first F-gas Regulation 842/2006 but became expanded in the F-gas Regulation 517/2014 to cooling circuits of refrigeration units of refrigerated trucks and trailers (Art. 8(1)b). Recovery represents a prerequisite for recycling, reclamation or destruction of the gas extracted from the equipment. It must be carried out by certified personnel. Technical requirements are further specified in the standard EN 378-Part 4 on operation, maintenance, repair and recovery. Important parameters such as the history of the system and the conditions of the refrigerant prior to recovery are listed which help determining if recycling or reclamation of the refrigerant should be considered.

Recovering refrigerant can be a lengthy procedure and various methods can be utilised to improve the speed of recovery, including the push-pull method where the recovery unit 'pulls' vapour from the recovery cylinder and produces high-pressure discharge gas that 'pushes' liquid out of the system and back into the recovery cylinder. Furthermore, specialist recovery units for recovery from systems with bigger volumes at higher speed are used where the time to recover the refrigerant may be critical and installation shut down time is limited. Service providers for this type of rapid recovery have expanded their business in the EU in recent years (Cooling Post, 2019). The contractor association AREA published guidance on recovery and recycling in 2018 (AREA, 2018). From the increasing relevance of reclamation, which is discussed in section 5.1.1.3 above, it can be concluded that recovery must have taken place before. Also, all amounts subject to destruction were recovered prior.

However, quantitative information on recovered quantities and quantities undergoing basic recycling is hardly available since no reporting obligation applies. In electronic equipment records from Poland, recovered quantities from all types and sizes of equipment amounted to ca. 200 metric tonnes (corresponding to over 400 kt CO_2 eq) in 2020. The amounts in earlier years were slightly lower, possibly due to a somewhat lower number of companies reporting to the database.

Data from France (ADEME 2020, 2021) show that recovery increased in the last years. The proportion of refrigerants recovered in the course of maintenance work was higher than recovery at disposal.

Table 30 – Quantities of fluorinated gases recovered during maintenance work and at disposal of equipment in France

Recovered quantities	2018		2019	
	tonnes	%	tonnes	%
Maintenance	1,642	69	1,839	73
Disposal	748	31	667	27
Total	2,390	100	2,505	100

Little information on non-compliance with recovery provisions is available. Cases relating to non-compliance with recovery requirements from end-of life equipment and illegal shipment of hazardous waste were reported from Spain (Cooling Post, 2016, 2020).

Some industry initiatives and projects are addressing recovery and reclamation such as a scheme established by Daikin since 2019, the so-called Loop project (Cooling Post, 2020) (Daikin, n.d.). This manufacturer initiative relates to refrigerant recovery from end-of life or existing systems through its installer network, upcycling and reclamation to virgin quality. Subsequently, the reclaimed refrigerants are allocated to new VRF systems manufactured and sold across Europe. The use of reclaimed refrigerants initially addressed selected VRF units of this manufacturer only, however the scheme has been expanded to all VRF units by this manufacturer produced and sold in Europe since November 2020. Also, EU neighbour countries are included. The programme is said to save 250 tons of virgin refrigerant annually.

The so-called LIFE3R project (Retradeables, n.d.) funded by the EU has established an online trading platform for reclaimed refrigerants in June 2021 which is currently operating in Czech Republic, Slovakia and Hungary.

In Sweden, an initiative of a group of automotive associations facilitates refrigerant recovery and reclamation by providing recovery cylinders with a three-month cycle period (Cooling Post, 2021). About 22 contractors are participating in the scheme. The recovered refrigerant is analysed and reclaimed by a specialized company. It is emphasized that the scheme is easing the bureaucratic process related to waste treatment by reclassification as “used, recovered refrigerant used as raw material for further processing” so that a formerly lengthy process to be done by each company is now being performed by the reclamation facility which holds end-of life waste and environmental permits.

A specific issue around recovery relates to foams. Insulation material in buildings in many EU Member States contains insulation foams that are blown with HFC blowing agents, mainly HFC-134a, HFC-236fa and HFC-365mfc. After the ban on use of CFCs via the Montreal Protocol in the 1990s, some manufacturers moved to the use of HFCs while others introduced natural alternatives such as CO_2 and hydrocarbons. The FGR already bans placing on the market of HFCs with a GWP higher than 150 in extruded polystyrene foam (XPS) from 1st January 2020, and this ban will extend to other types of foams from 1st January 2023. This prohibition, however, relates to new products, but does not ensure the safe disposal and recovery of HFCs present in insulation material that is currently in use or will be put into use up until 2023. Article 8(3) states requires recovery of F-gases at end-of-life from foams where it is “technically feasible and does not entail disproportionate cost”, but the market has in general not responded to this by providing a proper disposal process. As a result, the HFCs currently trapped in insulation foams are likely to be released to the atmosphere unless comprehensive recovery policies aimed at preventing these emissions are put in place. However, recovery from foams today mostly refer to appliance foams.

5.1.2.5 *Article 10 – Certification and training of natural and legal persons*

A survey of Member State authorities carried out for a 2016 EU Commission report (European Commission, 2016) found that there were already 160,000 trained and certified F-gas technicians working on RACHP, covering a total of 40,000 undertakings. This equated to an average of 40 F-gas technicians and 10 undertakings per 100,000 population, although there were variations across Member States.

An updated estimate of the numbers of F-gas certified personnel for the stationary RACHP sector has been made based on a survey (AREA, 2021) and information provided by stakeholders. To date, it is estimated around 360,000 personnel have been trained across 120,000-130,000 undertakings (EU + UK). The majority of personnel certificates for refrigeration, air conditioning and heat pumps related to Category I (88 %), while Category II (7.5 %), Category III (1.2 %) and Category IV (3.6 %) were of minor importance. No complete data set is available, but there is also evidence of training in other sectors for individual Member States (see section 3.4.3 for further detail).

In terms of accessing trained personnel, the 2016 EU Commission report identified that 16 Member States reported that they used a central personnel and company register to provide access to lists of certified F-gas technicians and undertakings. This is considered an efficient way of end-users accessing certified technicians as, in Member States where these systems do not exist, end-users would need to contact the relevant certification body.

The positive performance of the training and certification was re-affirmed by stakeholders engaged in the evaluation (OPC) who strongly agreed that these measures had been effective regarding its objectives. However, issues were identified both in the 2016 European Commission report and in this evaluation.

First, the 2016 report found that across 14 Member States there were 90 training centres for theoretical training, but only 50 which provided practical training. No further evidence was found as part of this evaluation as to whether this issue remained.

Second, the requirement to ensure that technicians understand the safe handling of alternatives to F-gases was less common in 2016. It was found that 71 % of Member States provided training for ammonia but only 0.2-3 % of Member States provided training for other alternatives. The report identified wider shortcomings which may have presented barriers to adequate training uptake for alternative refrigerants, including: the lack of access to available and appropriate training materials (for example due to lack of availability in different languages), a lack of practical training facilities, and a lack of trained engineers and technicians involved in installation, maintenance, and equipment design. Connected to this, the report also noted that the lack of specific EU minimum requirements with respect to training on alternatives may result in discrepancies in practice at Member State level.

Since 2016, training activities around alternatives has continued. The EU funded REAL Alternatives training, a voluntary training programme on F-gas alternatives, covers both flammable refrigerants, including hydrocarbons and low GWP flammable refrigerants now widely in use such as R32 /HFOs/blends, and carbon dioxide modules[32]. The programme includes training sessions in person as well as an e-learning element. Up to March 2020 (when in person training ceased throughout Europe due to Covid-19 pandemic restrictions on centres and travel), about 600 technicians passed this personnel training on F-gas alternatives across 17 EU Member States. Around 240 of these personnel exams were passed in Spain and this number continues to increase, as Spain is the only country that currently has legislation in place requiring mandatory training for low GWP alternatives. An E-learning

[32] The REAL Alternatives training does not cover the use of ammonia as a refrigerant as it is argued that currently already training in ammonia is available and the demand is said to be limited due to its specialist applications.

element is also provided and after passing the content, a 'certificate of attendance' can be downloaded without taking an exam. The online e-learning contents have been followed by 6,080 persons.

Data related to training on alternatives has also been collected through stakeholder engagement (aggregated data from associations in EU countries that were able to provide an estimate). This is presented in the table below.

Table 31: Proportion of F-gas certified personnel trained on alternatives

	Ammonia	CO_2	Hydrocarbons (small hermetic systems)	Hydrocarbons (larger systems)	Unsaturated HFCs
2015/2016	2.3	2.2	0.7	0.05	0
2020 (AREA)	7	6.9	6.2	5.3	3.5

This data suggests that the share of trained personnel increased in recent years increased but remains rather low (acknowledging that precise data on this matter is not available). This is reflected elsewhere in the literature – for example a recent survey by Shecco highlighted 47% of respondents reported there was not training on hydrocarbon refrigerants available in their country (Shecco, 2018). The persistence of this issue to the present was corroborated by stakeholders (workshop, interviews with industry, OPC), who suggested that certification could still be improved through expansion to cover all refrigerants. For example, one stakeholder (feedback to workshop) highlighted that there is currently a low level of training of service personnel and certification for A3 refrigerants, such as R290. This is not yet part of any EU certification scheme with regards to installers and service undertakings, since the refrigerant does not fall under the requirements of the Regulation and Regulation (EU) 2067/2015. a large proportion of stakeholders (OPC) consider this to be an important challenge for the implementation of the Regulation (although an equally large proportion did not see this as a significant challenge).

Third a further issue may be the quality of training received by all personnel. Although data is available on the numbers trained, no complete evidence is available on the quality and content of training. However, one example of concern is the experience of participants the EU funded REAL Alternatives training. The programme requires that technicians already hold F-gas certificates (to ensure background knowledge of the underpinning theory and practice around safe handling of refrigerants and principles of system and component operation). However, the trainers expressed concerns that the level of knowledge of participants was very low regarding safety, awareness of standards etc. Stakeholders (OPC) also highlighted a need to focus on improving training programmes.

5.1.3 EQ1c. How effective have the reporting and verification obligations (Articles 19-20) and the F-gas Consultation Forum (Article 23) been in supporting the achievement of the objectives of the Regulation?

The number of undertakings reporting under the Regulation approximately doubled from 77 in 2007 to 153 in 2013 (see section 3.5). After the revision of the Regulation, however, the number of reports increased by approximately a factor of 20 until 2019. The large increase observed in the import of products or equipment pre-charged with F-gases is due to the large number of active undertakings that were not covered under the old Regulation and which gradually became aware of their new reporting obligation. For bulk import, the increase was a reaction to the quota system. This has resulted in a proliferation of new undertakings acting as HFC importers.

A completeness check of reporting data has been performed in the context of a study on potential illegal HFC imports for DG CLIMA (Öko-Institut, 2019). HFC bulk imports reported under the Regulation were found to be highly consistent with HFC import data recorded by EUROSTAT. For a further discussion of potential illegal HFC imports, see section 5.1.7.3.

Figure 9 in Section 3.5 shows how the 10 kt CO_2 eq (= 10 000 t CO_2 eq) threshold for HFC producers and importers of bulk HFCs affects the completeness of verification. Until 2018, the number of active undertakings with POM below the threshold was relatively constant, between 40-60. The share of undertakings that were subject to obligatory verification increased from 86 % to 94 % in the period 2015 to 2018 and the share of POM covered by obligatory verification was at 99.8 – 99.97 %. In 2019 however, the coverage of POM by verification changed significantly due to the number of new entrants applying for 2019 quota went up strongly[33] and thus the standard quota allocation to new entrants dropped below the level of 10 000 tonnes of CO_2 eq and thus under the reporting threshold. In 2019, the share of undertakings obliged to provide a verification report dropped to 14 % of all undertakings placing HFCs on the market and the share of POM of HFCs covered by obligatory verification dropped to 92 %. A significant number of undertakings may therefore evade the ex-post data verification which may be a source of concern in the light of illegal trade claims.

Figure 10 in Section 3.5 presents comparable information for the verification coverage of HFCs in RACHP equipment imports. Note that the amount of HFCs in imported RACHP equipment has been at approximately 10 % to 15 % of total POM, measured in CO_2 eq. Since 2017, imports were below the threshold of 100 tonnes of CO_2 eq for about 5 % of undertakings reporting in the BDR on HFCs in RACHP equipment and thus not subject to the verification obligation (and neither subject to the Article 19 reporting verification). The share of the GWP of HFCs in imported RACHP equipment not subject to obligatory verification was as low as 0.02 – 0.03 % in the years 2017 to 2019.

About one third of obligated equipment importers failed to submit the verification report to the BDR in 2017-2019. The share of the GWP of HFCs in RACHP equipment covered by verification reports submitted to the BDR, however, was higher at 86-89 % as it was mostly equipment importers with relatively low amounts of HFCs who failed to submit the verification report. During the yearly compliance exercise, the EU Commission informed Member States of all undertakings that did not submit their verification reports and requested appropriate action.

It should be noted that no clear legal prescriptions are in the Regulation relating to the quality of the verification reports, the exact scope of verified data and the levels of assurance to be applied. The EU Commission has published a respective guidance both for equipment and bulk verification. However, formal obligations are in place only on how equipment importers report in the BDR on the result of the verification. The use of the BDR verification reporting tool is mandatory for producers and bulk importers only when explicitly requested by authorities. The auditing process itself and the content of the verification report are not regulated beyond the guidance issued by the EU Commission and some minimum criteria relating to the qualification of auditors set out in the Regulation, in short: auditors must be either accredited under the EU Emissions Trading System (EU ETS) or under national law relating to financial auditing. A direct integration of the verification process into the reporting process, as commonly practiced under the EU ETS, is not in place under the Regulation.

Stakeholders generally considered that reporting and verification has been an effective measure, however opinion varies amongst stakeholder types. Business associations and industry, alongside citizens, overall agree that the measures have been effective, but the sentiment amongst NGOs is mixed and overall a slight majority of Member State Competent authorities suggest the measure has not been very effective. Stakeholders noted that the verification of F-gas reporting is behind the reporting obligation and that whilst verifications are generally effective, reporting is not if it is not verified. This sentiment was mirrored in the interviews, whereby Member State competent authorities interviewed generally considered reporting and verification to be effective and noted initial problems of undertakings with the requirements were said to have decreased over time. However, the following issues were raised:

[33] For further discussion of the increase in the number of quota applicants see refer to EQ2b

- For the BDR system, it was indicated that it is not very user-friendly and as English is the only user language available, this caused problems for some undertakings (especially smaller ones).
- The existing difference in thresholds for authorisations and reporting on imports pre-charged equipment (100 vs. 500 tonnes of CO_2 eq) has led to confusion.
- The lack of obligation for all registered undertakings to submit a 'NIL'[34] report leads to administrative burden for competent authorities when checking the reports which would be avoidable.
- The verification requirements were said to be difficult to understand in part, especially for smaller undertakings, but also verification undertakings, resulting in a lower quality of the reports. In this context, the current guidance document of the EU Commission was considered not sufficient, as it mainly addresses larger undertakings.

  Conversely, there was also feedback that the guidance documents were clear and helpful for companies. In addition, it has not always been clear to companies that they can also commission auditors outside their own country.
- It was said that the prices undertakings have to pay for the verification of their F-gas reports vary greatly and lead to disproportionately high costs, especially for smaller undertakings, as there are only a few undertakings that specialise in the verification of F-gases.
- Article 19 does not yet foresee any verification requirements for destruction companies.

A national study commissioned by the Dutch competent authority found that the quality of verification reports varies widely in terms of the format used and the accuracy of data checks as large flexibility is given to the auditors. Another finding was that the different terms used in the Regulation, such as 'completeness', are not very clear and leave room for interpretation. Furthermore, it was stated that is not always clear to the competent authorities on which basis the auditors are accredited, as this information does not have to be stated in the verification report. And, as uploading of verification reports is not mandatory, this means an additional step is required for the competent authorities when checking compliance.

One auditor company interviewed considered that the legal framework and the individual requirements for verification have proven to be effective and the current Regulation provides clear rules. The guidance documents published on the EU Commission's website are considered sufficient, consistent and clear to support companies with the necessary information. The "Find an auditor" module in the F-gas Portal which allows all registered producers and importers of bulk HFCs to search the list of registered auditors in order to identify and contact them has also proved helpful to companies. With regard to verification costs it was noted that the first audit is more expensive than the subsequent ones, with the possibly for discounts for subsequent audits (10-15 %). Verification costs increase with the complexity of the procedures to be verified, i.e. they depend on the size of the audited company, the number of gases/appliances, the number of verification procedures and their complexity.

As noted above under section 5.1.1.3 and in the stakeholder workshop, there is incomplete reporting of reclamation due to no self-standing reporting obligation for recycling and reclamation undertakings.

5.1.4 EQ1d. To what extent have Member State actions contributed to the achievement of the objectives (covering Articles 9, 20 and 25)?

[34] A nil report is a notification by a company that it considers itself not obliged to report under the Regulation.

5.1.4.1 *Article 9 - Producer responsibility schemes*

According to Article 9 of the Regulation, it is the responsibility of Member States to encourage the establishment of producer responsibility schemes for the recovery of F-gases and their recycling, reclamation or destruction. There is not, however, any mandatory requirement in the Regulation for Member States to extend responsibility for F-gases to the producer. Consequently, practices among Member States tend to vary. Evidence regarding producer responsibility schemes for 6 Member States was gathered through the targeted interviews (see section 3.6.1).

Only four MS confirmed that through their encouragement, a producer responsibility scheme was in place specifically for F-gases (DE, DK, FR and PT). A further two MS confirmed that a scheme was being planned (EE and MA). A different MS highlighted that although not a producer responsibility scheme, there was a financial incentive to encourage recovery of F-gases (ES). The fact that only a minority of MS have actively encouraged the establishment of such schemes has significantly curtailed the effectiveness of this Article of the Regulation over the evaluation period. This trend is likely to reflect that such action is not mandatory, an experience also observed in relation to the ODS Regulation (where only two MS – DE and FR – were highlighted to have implemented such schemes for ODS (see European Commission, 2020)).

One MS (FI) highlighted that although no producer responsibility scheme had been implemented by public authorities, some recovery, recycling, reclamation and destruction of F-gases does take place.

In a minority of cases, private sector action has sought to fill the gaps. Daikin established the LooP scheme (Daikin, n.d.) (stakeholder interview) in 2019 for refrigerant recovery, reclamation and reuse is based on the network of Daikin stores throughout Europe as well as partnerships with installers and reclamation facilities. It focusses on the refrigerant R410A in VRF systems so far. The EU-funded LIFE 3R project contributes to the scheme as it establishes an online platform for the trading of recovered and reclaimed refrigerants.

Producer responsibility schemes under the WEEE Directive run by municipalities or public authorities do exist in most, if not all, MS and typically cover at least domestic refrigerators, freezers and sometimes also larger refrigeration equipment as well as air conditioners. An example of this is in NL, where producers and importers of large household electronics (including refrigerators) who first place household appliances on the market legally obliged to collect and recycle used appliances in accordance with the legally required quality standards. As such (as also highlighted in the ODS evaluation), many Member States rely to a large degree on measures introduced under the existing waste legislation, partly even before the Regulation applied, as regards the promotion of recovery, recycling, reclamation and destruction of F-gases. That said, there is not however any mandatory requirement in the Waste Framework Directive and related Directives for Member States to extend responsibility of used F-gases to the producer. Furthermore, as in the case of NL, the effectiveness of these schemes to encourage recycling, reclamation and recovery of F-gases (and indeed waste more generally) may be undermined by weak implementation and enforcement of linked waste legislation.

No data could be found regarding the quantities of substances recovered and reclaimed through these schemes, nor their effectiveness in doing so.

Stakeholders (OPC) in the main considered that recovery and producer responsibility schemes had been effective, but not all agreed (for those that believed these schemes were not effective, it is not clear whether this referred to the fact some MS did not have schemes in place, or the performance of existing schemes). Stakeholders (OPC) also highlighted that the Waste Framework Directive was recently amended to set out minimum requirements for extended producer responsibility schemes (EPR). It was suggested that the corresponding measure under the Regulation could also include certain minimum requirements on collection, reclamation, recycling, disposal facilities, equipment provision to certified technicians, reporting and awareness raising in more detailed legislation.

5.1.4.2 *Article 25 - Penalties*

According to Article 25(1) of the Regulation, Member States shall lay down the rules on penalties applicable to infringements of the Regulation and shall take all measures necessary to ensure that those penalties are implemented while ensuring that they are effective, proportionate and dissuasive. The Member States were requested to notify their penalty provisions to the EU Commission by 1 January 2017 at the latest. All Member States notified national measures on penalties for infringements of the Regulation within the set deadline of 1 July 2017, with the exception of Italy and Romania, which received formal notice by the EU Commission in July 2019. In response, the two notifications were received in late 2019 and early 2020, respectively (Cooling Post, 2019). An EU pilot was opened in September 2021 for Romania due to the perceived insufficiency of penalties on quota non-compliance.

Although provisions have been made, stakeholders (all types, but in particular business associations, industry and NGOs) generally considered that penalties were the least effective measure under the Regulation.

Member States have introduced penalties for infringements of the Regulation and as allowed by the Regulation, the levels of penalties set vary between Member States. However, stakeholders (interviews with industry) expressed concerns about the lack of harmonised penalties across Member States. Given the Regulation does not provide for minimum penalties, stakeholders consider the Regulation has not provided for a level playing field across the EU. Some stakeholders (interviews) noted there is a growing appetite for setting penalties at EU level, at least for quota violations and illegal trade activities. This was considered justified given the HFC phase-down is an EU-wide measure with quota allocation managed by the EU Commission. In the targeted interview with the EIA, the NGO also referred to the EU Timber Regulation[35] as best practice example, as it does not set binding penalties but takes an indicative approach and recommends sanctions (progressive fines in proportion to environmental damage, confiscation, immediate suspension of trade permits) for various infringements.

Furthermore, stakeholders (OPC) also questioned the dissuasiveness of penalties, in particular relative to the high-profit margins achieved in some parts of the industry. A lack of enforcement and less stringent penalties in certain Member States have made it appealing to contravene the Regulation, undermining the achievement of its objectives of the Regulation. Indeed, the variance in penalties across MS has been noted as one of the factors that has facilitated the issue of illegal trade (explored in detail in EQ2a).

Stakeholders have also identified a range of other issues associated with the penalties set by individual Member States:

- The different judicial approaches and legal mechanisms related to the penalties have made it difficult to ensure that penalties in all Member States serve the purpose of being dissuasive.
- Courts determine the final penalty within a wide range and selecting between criminal and administrative fines.
- There is a variance in penalties across infringements of different provisions.

No overall data exists on the number of contraventions of different provisions. Through the targeted interviews, Member State competent authorities provided insights on the types of non-compliance under Article 25 (1). Cases of infringements that have been identified were identified across a wide range of the provisions: smuggling at borders, import of HFCs in non-refillable containers, lack of record keeping (Article 6), import without statement on destruction of HFC-23 by-production (Article 7), handling equipment by non-certified personnel (Article 10), import of prohibited products and equipment (Article 11 and Annex III), incorrect labelling (Article 12), cases of quota and quota authorisation exceedances, i.e. import without sufficient quota or quota authorisations (Article 14 and 15), import without registration

[35] Regulation (EU) No 995/2010 laying down the obligations of operators who place timber and timber products on the market, https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:32010R0995

(Article 17), and incorrect or lack of reporting or verification (Article 19). One Member State competent authority reported that many cases of non-compliance were related to misinterpretation of the requirements of the Regulation, while another stated that for inspectorates, non-complaint actions are often difficult to discover so that they rely on reports from e.g. competing undertakings, indicating infringements.

Furthermore, no data exists on the total numbers of inspections carried out in different Member States. However, stakeholders (interview with Member States) suggested that the extent of inspections varied between Member States and also depended on national enforcement resources. One Member State indicated in this respect that the electronic national database has proven to be a good source for detecting non-compliant cases as undertakings that do not register or fill in service and leakage control data are in breach with the national law. It was also noted that there are typically hundreds of entities to be checked and controlled, while personnel resources at the ministries and environmental inspectorates are limited to carry out controls.

In addition to the penalties to be imposed by Member States, Article 25 (2) of the Regulation states that undertakings exceeding their quota face a penalty of twice the exceedance amount, applied to the subsequent quota allocation by the EU Commission. Since the Regulation entered into force, the quantities of quota exceedances identified based on Article 19 reporting data and non-compliant undertakings are set out in Tables in Section 3.6.2. The analyses have shown that there are undertakings that have already overrun their quota quantities in the first few years and therefore receive no or only very small allocation quantities, while for others the quota reduction only accounts for a small proportion of the total allocation quantity.

5.1.4.3 *Article 20 - Data collection systems to monitor F-gas emissions*

Article 20 of the Regulation stipulates that Member States shall establish reporting systems for the relevant sectors referred to in this Regulation, with the objective of acquiring (to the extent possible) emissions data that can be used as valid basis for F-gas emissions reporting to the UNFCCC. The emission reporting currently relies on export estimates for emission factors in most cases rather than actual emissions data based on the equipment stock present in the country.

Although some Member States have established equipment registers (see section 3.6.3 which presents an overview of different data collection systems in place based on information from National Inventory reports as well as feedback received in the targeted interviews with Member States competent authorities) data from these systems are not (yet) commonly used for the UNFCCC reporting. However, as feedback from industry stakeholders has shown, a strengthening of the EU wide data on F-gas emissions is necessary to identify emissions sources and their significance. Hence, the establishment of standard electronic data collection scheme would help to facilitate this objective.

5.1.4.4 *Additional national measures*

Recital 24 of the Regulation does not prevent Member States from maintaining or introducing more stringent measures at national level. Some EU Member States have introduced additional measures to complement the EU provisions that have been effective to support the reduction of F-gas emissions and uptake of lower GWP alternatives. In the targeted interviews, Member State competent authorities provided updates on their national legislation, which are presented in the following in more detail.

- In **Belgium**, there are some considerations about introducing taxes on GHG emissions that also include F-gases, but no concrete plans yet.
- **Bulgaria** has plans to introduce additional measures that go beyond the Regulation in the near future.
- **In Denmark** it has been decided to increase the tax on imports of HFCs in bulk and equipment from 150 DKK/t CO_2 eq (~ 20 €) to 180 DKK/t CO_2 eq (~ 25 €) from 1 July 2021. While

the tax has been a fixed value so far, it will then be linked to the CO_2 price. The minimum import threshold (10,000 DKK) will be abolished, as it was an incentive to circumvent the tax and caused enforcement difficulties. In addition, the previous maximum limit of 600 DKK will be removed, so that even the high GWP gases (such as R23, SF_6) will be taxed according to their GWP, which means that they will become very expensive. While the Danish tax scheme has shown a huge impact on reducing HFCs in imported spray and foam canes, it was said that the price increase induced by the Regulation has had a much larger impact on RACHP equipment. In addition to the tax rates, Denmark already introduced bans in 2002 for certain applications with a charge size of more than 10 kg HFCs, while exempting HFOs.

- Due to the lack of provisions at EU level so far, **Estonia** has introduced explicit national requirements for customs to control the placing on the market and labelling of F-gases at the border. In addition, Estonia plans to nationally prohibit the transfer, trade and possession of non-refillable F-gas containers and to provide the legal basis for enforcement authorities to conduct covert test purchases to identify potentially illegally traded F-gases and subsequent confiscation (and auctioning). Estonia also reported that national certification requirements are stricter than those laid out in the Regulation.

- The training and certification scheme in **Finland** goes beyond the Regulation as it covers all mobile equipment and related activities, including recovery, installation and repair. All car garages need to be certified, whereas the Regulation requires only attestation. As member of the Nordic Council of Ministers, Finland released new public procurement guidelines in 2020 which exclude HFC refrigerants in refrigeration and air-conditioning and heat pump products where alternative low GWP or zero GWP refrigerants are approved.

- **France** has considered the introducing a tax on HFCs placed on the French market 1 January 2021, but this has been postponed to 1 January 2023 as a voluntary industry commitment is currently in place. The HFC tax is expected to increase over time (from 15 €/t CO_2 eq in 2023 to 30 €/t CO_2 eq after 2027) and will likely target HFCs used in bulk and pre-charged equipment and for new equipment as well as for servicing existing equipment but would exclude HFOs and recycled and reclaimed refrigerants. In addition, some applications will be exempted from the tax, including military equipment, semiconductors, pharmaceutical aerosols and refrigerated trucks. Moreover, a 40 % tax rebate is being granted to end-users from 1 January 2019 to 31 December 2022 if they purchase new refrigeration and air-conditioning equipment based on HFC-free alternatives such as HFOs, CO_2, ammonia and hydrocarbons.

- **Italy** has established a national database to collect all information related to the provision of Article 6 on record keeping and to record sales of F-gas and non-hermetically sealed equipment charged with F-gas in accordance to Article 11 (4) and (5).

- In **Germany**, additional national measures were implemented through the Chemicals Climate Protection Ordinance which foresees limits for annual leakage rates. Since 2008, the German Ministry of Environment has been funding measures for RAC systems as part of the National Climate Initiative (NKI). On 1 January 2019, a revised Directive (‘Kälte-Klima-Richtlinie’) entered into force. The new funding guidelines stipulate that only stationary RAC as well as mobile AC systems (in buses and trains) based on non-HFC refrigerants may be subsidised.

  National reporting obligations for undertakings in addition to the reporting requirements according to the Regulation are set out by the German Environment Statistics Act (Umweltstatistikgesetz, UStatG). Statistics offices send questionnaires to undertakings producing, importing, exporting and using F-gases. The assessment is carried out annually in spring and statistical data is usually published in November for the previous year.

From 2021, it will be prohibited in Germany to purchase or resell F-gases imported into the EU which do not comply with the requirements of the Regulation. In order to facilitate controls, information on manufacturers and importers of F-gases as well as information on the legality of the imported goods must be documented and passed on in the supply chain.

- **Poland** has introduced a number of specific requirements regarding F-gases which go beyond the requirements set out in the Regulation, including mandatory annual reporting on use, recovery, recycling, reclamation and destruction and on the import to and export from Poland (including from/to EU Member States) of F-gases and other fluorinated substances, both in bulk and in products or equipment, regardless of quantity. It is prohibited to supply or make F-gases available to natural persons, except for when the person holds an F-gas certificate or training attestation or if the 'supplying or making available' is in the framework of servicing the equipment owned by that natural person.

  For the recovery of F-gases from mobile RACHP equipment and fire protection equipment, certification of personnel is mandatory (except of mobile AC systems in passenger cars for which training attestation is needed). Containers, products and equipment containing F-gases must be labelled once they enter the Polish territory. In addition, customs are requested to control imports of F-gases in bulk and in products and equipment to Poland from EU as well as non-EU countries.

  Poland has also introduced an emission fee for F-gases (32 PLN/kg or 7 €/kg) and established two electronic databases, the Central Register of Equipment Operators (CREO) and Database of Business Reports (DBR). Due to safety reasons, military entities are not obliged to keep electronic logbooks in CREO or to report to the DBR, but instead are obliged keep 'paper' logbooks and submit annually data and reports to Ministry of Defence from where the aggregated data are submitted to the Ministry of Climate and Environment.

- **Portugal** has introduced national legislation stipulating additional mandatory leak check obligations after installation or retrofitting of equipment to prevent F-gas leakages.

- In **Spain**, a tax came into force in 2014 applying a tax rate of 20 €/t CO_2 eq to all F-gases (incl. HFCs, PFCs and SF_6) in bulk with a GWP greater than 150 used for the servicing and maintenance (i.e. refilling) of equipment, while excluding the first refrigerant charge of new equipment. In 2018, the Spanish government decided to reduce the HFC tax by 25 % to 15 €/t CO_2 eq. (Cooling Post, 2018). In addition, since 2020, the Spanish government has been subsidising the replacement of refrigeration equipment based on high-GWP HFCs in supermarkets. From 2021, there is a subsidy programme for the use of HFOs and natural refrigerants, which expenditure depending on the annual budget. In addition, a number of projects have been supported by the national green fund, which promotes mitigation activities in non-ETS sectors to reduce emissions in various F-gas using sectors. In addition to transposing the Regulation, two voluntary agreements (VAs) have been signed in Spain with the competent environmental authority (workshop feedback):

  - In 2008, VA 2008-2012 defined a commitment to reduce emissions in relation to the trends forecast by the Environment Ministry, setting a target that was exceeded by more than 25%. At that time, the electricity sector parties to the VA were the equipment manufacturers (since 2007 represented by Association of Manufacturers of Medium and High Voltage Electrical Equipment Goods (AFBEL), formerly as part of Spanish National Association of Manufacturers of Capital Goods (SERCOBE)), the power distribution undertakings (Spanish Electricity Industry Association i.e. UNESA) and the Spanish electricity grid (Red Eléctrica de España i.e. REE)

  - In 2015, VA 2015-2020 was chiefly intended to ensure an environmentally appropriate end of life for equipment with SF_6 gas. For this reason, the VA was also signed by ASEGRE and other end-of-life managers.

- **Sweden** introduced additional F-gas related measures, including requirements on leak checks in conjunction with installation, reconstruction and other interventions and on leakage checks and certified competence, also applying to all mobile equipment containing F-gases. The results of periodic inspection must be reported to the supervisory authority, which also must be informed before the installation of equipment containing refrigerants of than 14 tonnes of CO_2 eq. It is prohibited to sell F-gases as refrigerants to recipients other than those laid down in national legislation (i.e. persons refilling F-gases in RACHP equipment; the manufacturer of RACHP equipment and persons engaged in the purification or destruction of F-gases). In addition, equipment manufactured in, imported into or brought into Sweden must be provided with accurate and easily understandable operating and maintenance instructions.

Additional action on F-gases is also made through Green Public Procurement (GPP). Such mechanisms were discussed at the 2016 Consultation Forum (Gluckman Consulting & Ricardo-AEA). The briefing report for the forum identifies two sets of policies which could impact on the demand for F-gases: requirements in the EU GPP scheme (covering four product groups – food and catering, transport, electrical and electronic equipment and water-based heaters) and public procurement at Member State level. With respect to the latter, a survey received responses from 8 Member States identifying GPP activities, but in limited detail. Even then, the paper also makes the distinction between the inclusion of requirements in GPP criteria, and the actual use of these requirements in practice by consumers (for which there is little monitoring undertaken).

The lack of response and limited detail was concluded as a signal of a lack of comprehensive, significant use of GPP to reduce F-gas demand and promotion of alternatives. That said, it should be noted that there have been further improvements since, for example the Nordic Council of Ministers, which includes representatives from Denmark, Finland and Sweden published new Green Public Procurement (GPP) guidelines in 2020 that exclude HFC refrigerants in refrigeration and air-conditioning and heat pump products (Nordic Council of Ministers , 2020).

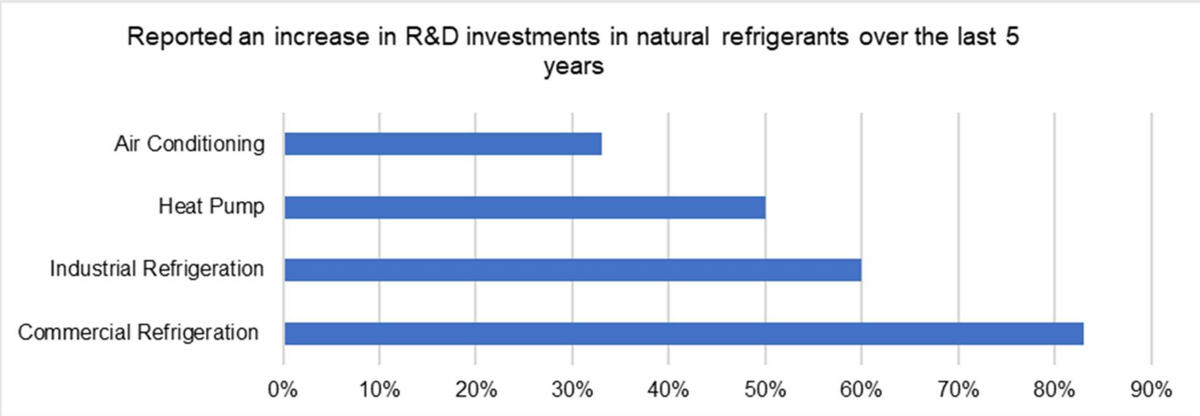
5.1.5 EQ1e. How effective has the Regulation been to enhance sustainable growth, stimulate innovation and develop green technologies by improving market opportunities for alternative technologies and gases with low or zero GWP?

The success of the Regulation in helping to stimulate innovation and develop green technologies is evidenced in the observed uptake in alternatives to high GWP F-gases, including low GWP F-gases, HFOs and natural alternatives. For example, demand for HFC-HFO blends R448A (GWP 1,387) and R449A (GWP 1,397) has increased in recent years for refrigeration servicing and maintenance. Further detail is presented above in EQ1a.

The market for natural refrigerants has continued to grow following the implementation of the Regulation. According to a 2016 Report (Shecco, 2016), the number of undertakings working with natural refrigerants has increased from 400 to 650 between 2013 to 2016. Data has shown that Germany is the country where the highest number of undertakings working with natural refrigerants are based (118), with the next highest EU Member States being Italy and Denmark (with 79 and 54 undertakings respectively). The report concluded that overall, the Regulation has led to an increase in businesses switching to HFC-free technologies, with additional suppliers entering the market following its implementation.

The market for alternatives to high GWP F-gases has developed as a consequence of greater R&D spending in response to the Regulation. The 2016 Shecco report found that within the commercial refrigeration sector over 80 % of undertakings have increased their levels of investment in research and development within the last five years (2011-2016). More specifically the report notes that undertakings involved with heat pumps have enhanced their R&D investment to focus more strongly on natural refrigerants. The chart below provides a breakdown of undertakings which reported increases in R&D investments in natural refrigerants.

Figure 32: Proportion of undertakings which reported an increase in R&D investments in natural refrigerants



Source: Shecco (2016)

More recent reports by Shecco demonstrated how this innovation activity and investment in R&D has driven Europe to become a global leader in the adoption of other low-GWP alternatives. For example:

- As of 2019, Europe had adopted around 2,200 low-charge ammonia systems, relative to a global total of 4,000 (Shecco, 2019). While ammonia systems have been common in larger installations for decades, low-charge systems have only been introduced more widely in the EU during the last decade.
- Europe had installed around 29,000 transcritical CO_2 systems by 2020, more than the rest of the world combined (Shecco, 2020), an increase from around 140 installations in 2008, with significant growth from the >16,000 systems reported in 2018. Data for 2021 suggests the increase has continued, with over 40,000 systems now considered to be operating in the EU (Koegelenberg, 2021). Strong growth in these systems is evidenced by growth in the largest sector – supermarkets – where the number of systems increased from around 2,885 in 2013 (Shecco, 2014) to around 26,100 (90% of 29,000) systems in 2020 (Shecco, 2020). The number of CO_2 transcritical supermarkets in the EU, Norway and Switzerland, meanwhile, has tripled in the last three years. It is now estimated to represent 12% of the overall food retail market (Shecco, 2018). In addition to the different types of transcritical CO_2 systems, technologies like ejectors are being used to increase the efficiency of the systems;
- Alongside transcritical CO_2, hydrocarbons (in particular propane) has emerged as a viable refrigerant for supermarkets. Thousands of stores worldwide are reported to have deployed plug-in air-cooled R290 display cases at the point-of-sale or in other spot merchandising capacities (Hydrocarbons21, 2020). By early 2017, it was reported that there were around 700,000 hydrocarbon integral units in European supermarkets, but with only 500 stores containing these systems with water-cooled loops (albeit the number was reportedly growing) (Peters, 2017). Back in 2013/2014, around 500,000 propane plug-in units were deployed in the EU (Shecco, 2021).
- Propane (R290) has been used frequently in moveable air conditioner by European equipment producers and is widely available on the European market (it is expected to be the refrigerant of choice going forward in response to the POM prohibition set out by the Regulation) (European Commission, 2020). Propane is increasingly being used in other sectors, for example with one HVAC manufacturer reporting that 60% of current production is R290, with the aim of reaching 90% in five years (Hydrocarbons21, 2021), with a range of other manufacturers of chillers and heat pumps also reporting a market shift as a result of the EU F-Gas Regulation (Shecco, 2018).

Figure 33 - Low-charge ammonia systems: 2,200 + systems globally (2019)

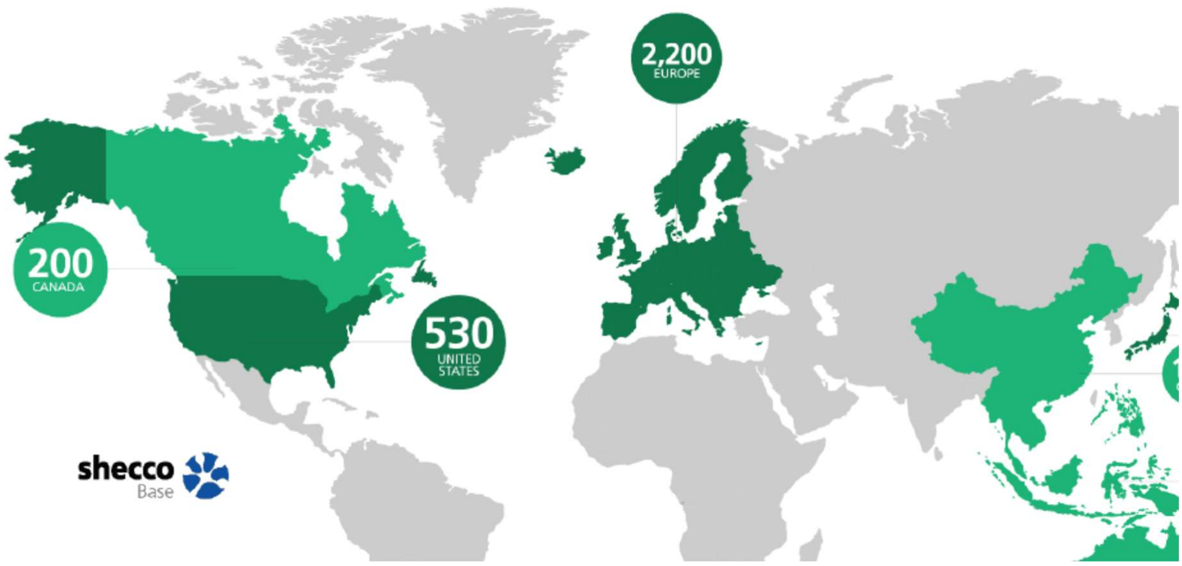
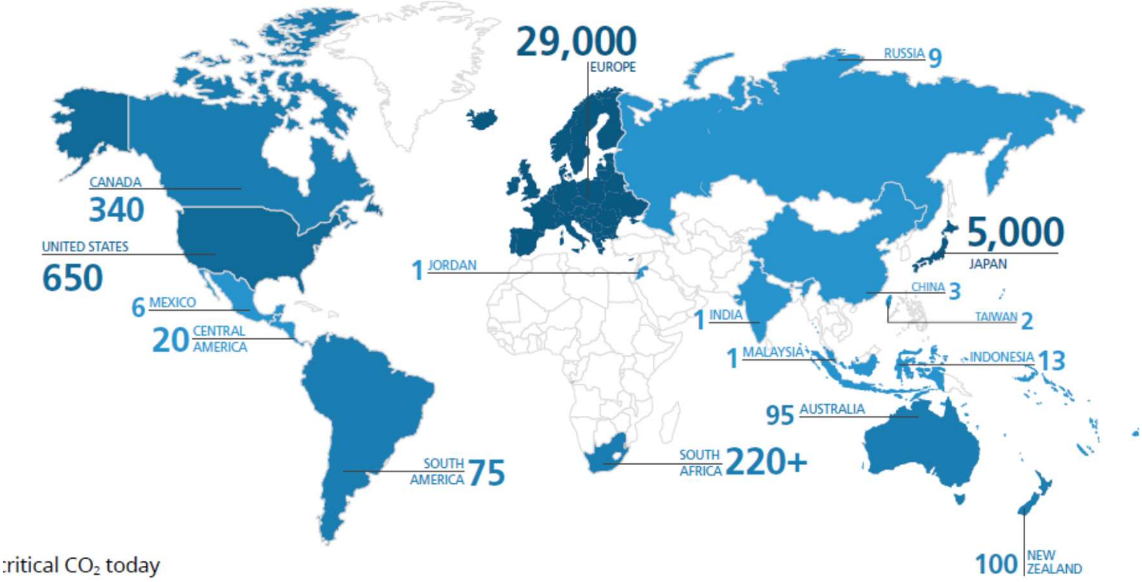


Figure 34 - Commercial refrigeration: Global adoption of transcritical CO_2 systems in 2020



The maturity of the market in Europe which has developed in response to the Regulation is demonstrated by the Report's observation that the large number of suppliers has helped to increase the efficiency of the alternative technologies that have been developed.

Stakeholders of all types (Competent Authorities, industry and NGOs) agreed that the Regulation has stimulated the development of green and more energy-efficient technologies and improved market opportunities for lower or zero GWP alternatives whose prices have decreased over time. For example, through the OPC an electricity network operator stated that the Regulation has provided a need for industry to develop new technologies to decrease or substitute the use of F-gases. Further to this, stakeholders have noted the Regulation has provided certainty for undertakings and an NGO stakeholder suggested that EU manufacturers are now leading the world in several technologies (workshop).

Stakeholders highlighted that the promotion of the Regulation and awareness raising proved to be necessary, especially at the beginning of the implementation.

Industry stakeholders also highlighted the importance of additional Member State level activity in promoting the uptake of alternatives, include noting incentive schemes or subsidies which are available in some Member States such as Austria, the Czech Republic, France, Germany or Portugal which support low-GWP alternatives.

Although stakeholders have indicated an uptake in alternative technologies, feedback has also acknowledged there are limitations of the Regulation and wider which have somewhat curtailed the uptake of alternatives. For example, two industry associations pointed out that incentive schemes and subsidies cannot and will not remove barriers such as national building codes, safety standards, certification schemes and installation restrictions for switching to lower GWP alternative refrigerants. Industry stakeholders have also noted that some regional differences could be observed and depend in some cases on national safety standards and technical expertise of service technicians who install and maintain the equipment. In addition, feedback has also suggested that the incentives are mainly national/regional, leading to non-harmonised use of refrigerants and thus fragmentation of the EU market

It was noted that innovative developments were mainly on the side of gas and equipment manufacturers, rather than in service undertakings and operators. Furthermore, innovation has not been universally observed across all sectors – for example stakeholders noted that the situation could be better in particular for SF_6 alternatives in medium voltage switchgear, where a 'lack of technical solutions' limited more positive achievement against the Regulation's objectives. Two industry associations pointed out that for applications for ultra-low temperatures (below -50 °C), the development of feasible alternatives with low GWP is still a major challenge.

In all applications (and especially in those where few alternatives to F-gases were commonly used before), the ***HFC phase down*** in particular has triggered innovation and new technical solutions. An example of the effect of the phase down has been the interest in (and demand for) innovative cooling solutions (especially in the commercial sector which has been particularly active in addressing sustainability issues (e.g. Metro (Metro AG, 2018))), which has increased significantly in recent years. As a consequence of the HFC phase-down, the simple replacement of one (high-GWP) refrigerant by another (lower GWP) refrigerant became no longer a sustainable long-term technical solution in many cases. A broader perspective on refrigerant availability, carbon footprint, energy efficiency and system integrity as part of sustainability strategies triggered innovation in the field of refrigeration and air conditioning and entirely new concepts for meeting the refrigeration and air conditioning requirements emerged, linked to energy storage, use of solar energy, building design, etc. Such innovative systems include, for example: display cases linked to a water-loop system (e.g. Hydroloop by Freor, Lithuania; presented at virtual trade show, August 2020) or heat-pump based combined refrigeration and air conditioning systems for small stores (e.g. EsyCool Green, Viessmann, 2018 IKU award for efficient energy systems).

Also in other sectors, an increasing number of manufacturers have looked to offer low GWP solutions. For example, in heat pump applications most manufacturers shifted away from conventional F-gases and introduced refrigerants such as R32, R545C and mainly R290. Vaillant introduced their R290 heat pumps at the trade fair ISH in 2019 (Valiant Group, 2019) at which Stiebel-Eltron also presented their heat pumps running on R454C (Stiebel Eltron, 2018); Swegon launched R290 heat pumps of up to 200 kW (Cooling Post, 2021); and Chinese manufacturer PHNIX announced the launch of R32 and R290 products for their EU market portfolio (Cooling Post, 2021).

A 2017 Commission report (European Commission, 2017), assessing the 2022 requirement to avoid high-GWP HFCs in some commercial refrigeration systems stated that: *'it is apparent that there are multiple technological alternatives available today, which are already used in the commercial refrigeration sector across the …t. These include transcritical CO_2 centralised systems, indirect centralised systems and stand-alone systems which all are feasible, reliable and energy-efficient alternatives..'* This underlines that the overarching impact of the HFC phase-down has been serving as a stronger trigger for innovation than prohibitions addressing single substances or specific applications.

5.1.6 EQ1f. To what degree has the Regulation facilitated convergence towards a potential future international agreement?

At the time the Regulation was adopted in 2014, no international agreement was in place to manage F-gas emissions globally. There was a strong resistance to regulate HFCs, in particular from economies in transition (Brazil, South Africa, India and China, so-called BASICs, bloc of four large newly industrialised countries), in particular before a climate accord was in place. As such a key objective at the time of amendment was to influence the global negotiations and contribute to forward steps towards an international agreement under the Montreal Protocol.

The Kigali Amendment to the Montreal Protocol came into force in 2019, having been successfully negotiated in 2016 at the Twenty-Eighth Meeting of the Parties (MOP) to the Montreal Protocol on Substances that Deplete the Ozone Layer (UNEP, 2016).

The EU's own Regulation was already adopted in 2014, placing the EU at the forefront of the negotiations. However, EU advocacy for the future Kigali Amendment is further supported by its action preceding the Kigali conference. On the basis of its Regulation, which represented the EU consensus, in 2015 the EU submitted its 'Proposed amendment to the Montreal Protocol' (UNEP, 2015) which advocated for action to tackle HFC emissions as soon as possible through implementing measures aimed at reducing the production and consumption of HFCs.

During the negotiations, the Regulation demonstrated to other countries that alternatives were available sufficiently in order to envisage an ambitious phasing down of F-gases in many sectors. It underlined the EU's claim that phasing down HFCs currently represented one of the most cost-efficient and affordable ways to reap enormous climate gains. Reference was made to the EU's own Regulation (by EU representative and Commissioner Mr. Arias Cañete), who pointed out that the Regulation had already sent a signal to the market to begin development of alternative technologies, which would become more cost-effective and available in time. A wider international agreement would help to speed this process up.

In 2016, a consolidation of the amendment proposals submitted by Parties to the Montreal Protocol was provided which combined EU proposals with those put forward by North American, Indian and Pacific islands states (UNEP, 2016). This proposal helped to provide the substance behind the Kigali Amendment and provides a further indication of the role of the EU in shaping this agreement.

For the final negotiations, the Regulation was again the basis (and provided the 'red lines') for the EU to be vocal supporters and advocates of the proposed Kigali Amendment at the Twenty-Eighth Meeting of the Parties (MOP) to the Montreal Protocol (MP) on Substances that Deplete the Ozone Layer. The EU Member States were prepared to support this amendment through financial contributions to developing nations.

The implementation of the Regulation enabled the EU to present a joint approach at the Kigali Conference. Rather than providing a number of competing visions from different Member States, a unified EU position provided a stronger voice to push for international consensus. The success of the Regulation, with the HFC phase-down considered to be operating as intended (EIA, 2018) helped to showcase the potential for advancement of F-gas emission reductions through international cooperation. The creation of an effective framework for tackling F-gas emissions, for example, through the development of quota allocation systems, efficient reporting systems and certification and training requirements has provided evidence of the mechanisms which could work in practice for international agreements.

Stakeholders (OPC, interviews) corroborated the positive role that the Regulation played in the formulation of the Kigali Amendment. In particular, Member State competent authorities (interviews) unanimously emphasised the positive role of the Regulation for the adoption of the Kigali Amendment. The fact that the EU already had the Regulation in place contributed to the development of a joint proposal, helped to focus forces at EU level and at the same time served as a convincing example of best practice. The EU's experience in implementing the Regulation helped to agree on the aspects that the rest of the world was encouraged to adopt. This result was corroborated through the OPC< where stakeholders across all types unanimously agreed that the Regulation had had facilitated the agreement to phase down HFCs under the Montreal Protocol.

EQ2. What factors have contributed to or hindered the achievement of the objectives of the Regulation? What have been the unintended/unexpected effects?

5.1.7 EQ2a. What external factors have contributed to the success or not of the Regulation?

5.1.7.1 *Barriers in safety codes*

Safety aspects are important regarding the manufacture, transport and storage, putting into service, installation, maintenance and the full duration of regular use of equipment and systems containing or relying on F-gases. In addition, safety requirements exist for employers to ensure occupational health including requirements for production, logistics and end of life treatment of such equipment.

The implementation of the FGR is intended to increase the use of low-GWP and zero-GWP alternatives and to limit the use and emissions of F-gases. Certain natural F-gas alternatives such as hydrocarbons (e.g. propane, isobutane), ammonia and CO_2 are either flammable and/or toxic and thus require additional technical knowledge and safety measures in order to be used in a safe and energy efficient way. Standards use refrigerant flammability and toxicity properties to define refrigerant classifications and practical limits for different systems, as shown in the following table.

Table 32: Classification as defined in safety standards

	Lower toxicity	Higher toxicity
No flame propagation	A1	B1
Lower flammability (burning velocity of < 10 cm/s)	A2	B2
Flammable (burning velocity of ≥ 10 cm/s)	A2L	B2L
Higher flammability	A3	B3

International standards

Table provides an overview of international standards relevant for the RACHP sector. International standards are typically not used directly but most countries will adopt a standard nationally or regionally. For national adoption, modifications or deviations might be included. Note that group safety standards comprise safety aspects applicable to several products or systems, whereas product safety standards refer to a specific product or system.

Table 33: Overview of international standards for RACHP equipment and systems

International standards	Product safety standards						Group safety standard			
Sector	IEC 60335 -2-11	IEC 60335 -2-24	IEC 60335 -2-40	IEC 60335 -2-89	IEC 13043	ISO 20854	ISO 5149-1	ISO 5149-2	ISO 5149-3	ISO 5149-4
Domestic refrigera-tion		x					x	x	x	x
Commercial refriger-ation				x			x	x	x	x
Industrial systems							x	x	x	x
Transport refrigera-tion							x	x	x	x
Air-to air AC equip-ment and heat pumps			x				x	x	x	x
Water heating heat pumps			x				x	x	x	x
Heat pump tumble driers	x						x	x	x	x
Chillers			x				x	x	x	x
Vehicle air condi-tioning					x					x
Refrigerated con-tainers						x	x	x	x	x

The Ozone Secretariat prepared a tabular overview of standards in 2018 (UNEP, 2018) and provides an online tool on relevant standards which is continuously updated.

A 2017 TEAP Safety Standards Task Force Report (UNEP, 2017) *concluded that "the current international safety standards impose varying degrees of restriction on the application of certain medium and low-GWP alternatives, depending upon the type of refrigeration system and the location of refrigerant in the equipment. Whilst it is "technically feasible" to use almost all class A flammable refrigerants in all applications, the critical issue is whether or not a given alternative can be used in a safe and cost-effective way using state-of-the-art system architectures."*

It was found that the most restrictions occurred at that time for the following applications:

- A2 and A2L refrigerants in domestic refrigeration
- All flammable refrigerants in commercial refrigeration appliances
- A2 and A3 refrigerants in commercial refrigeration systems
- A2 and A3 refrigerants in small air conditioning and heat pump appliances and systems,
- all flammable refrigerants in large air conditioning appliances, and
- all flammable refrigerants (except HFO-1234yf) in MAC systems.

The report also found that an accelerated revision of national standards and regulations would facilitate the use of lower GWP (flammable) refrigerants and assist parties to the Montreal Protocol in achieving the agreed freeze and phase down steps under the Kigali Amendment. Given a typical 5-year lead time for product development, international safety standards to be published in 2019-2020 were found to play a crucial role in the development of national regulations applicable from 2024 (i.e. freeze year for non-A5 parties under the Kigali Amendment).

EU standards

Standards at EU level are based on international standards but might also deviate in certain aspects. The following overview lists the most relevant EU standards for the RACHP sector.

Table 34 – EU safety standards

EU standards	
EN 378	Refrigerating system and heat pumps – safety and environmental requirements. EN 378 provides guidance to define parameters such as the maximum refrigerant charge. It is harmonized with EU legislation to some extent. The category A2L was included to harmonize with international standards such as ISO 817.
IEC EN 60335-2-24	Safety requirements for household and similar electrical appliances
IEC EN 60335-2-40	Safety requirements for electrical heat pumps, air conditioners and dehumidifiers
IEC EN 60335-2-89	Safety requirements for commercial refrigerating appliances
EN 1127-1	Explosive atmospheres – explosion prevention and protection
EN 60079	Requirements for electrical systems used in potentially explosive atmospheres
EN 13463	Non-electrical equipment for use in potentially explosive atmospheres
EN 13313	Refrigerating systems and heat pumps - Competence of personnel

In relation to the transition to alternatives, the role of international and European standards, national safety legislation and building codes in Member States was investigated by a 2016 Commission report (European Commission, 2016) which found *'that standards (at international, European and national level) regarding the use of flammable refrigerants appear to be an important barrier to the uptake of climate-friendly alternatives to HFCs.'* In particular it was noted that EU standards for RACHP restrictions no longer appear justified on the grounds of safety. The report concluded these standards require further updating in line with: (a) technological development and (b) based on empirical appreciations of the actual risks showing that acceptable safety levels can be maintained while using flammable refrigerants.

Subsequently, the EU Commission issued, at the end of 2017, a mandate request (M/555)[36] to the standardization organizations under Regulation (EU) No 1025/2012 on European Standardisation to have a European standardisation deliverable on the use of flammable refrigerants, in particular those classified as A3, in RACHP equipment. The intention of this request was to enable a wider use of flammable refrigerants in refrigeration and air-conditioning equipment. To respond to the mandate M/555, the standardization organisations created a working group "CEN Technical Committee 182 Working Group 12- Flammable Refrigerants Standardization Request M/555" and established several Ad Hoc Groups (AHGs) which had been working from May 2018 to late 2020. The technical work related to an assessment of existing standards and the drafting of technical specifications for the safe installation and operation of RACHP equipment containing flammable refrigerants. In March 2021, the final documents were issued[37, 38] which, however, are perceived by some stakeholders (experts and environmental NGOs) to not sufficiently bring forward the issues addressed in the standardization request and to undermine the smooth functioning of the internal market. As stated in their introductions, "The purpose of this document is to provide information to ensure acceptable risk levels applying flammable refrigerants" is regarded as an unambitious response to the standardisation request. It was explained that the legal wording of the final version of the Standarisation Request undermined its strength in several ways: The difference between a European Standardisation deliverable and a European standard is that national transposition of the technical specifications is not required in the former. Furthermore, technical specifications in an European Standardisation deliverable cannot contradict existing

[36] COMMISSION IMPLEMENTING DECISION C(2017) 7284 of 14.11.2017 on a standardisation request to the European Committee for Standardisation and to the European Committee for Electrotechnical Standardisation as regards use of flammable refrigerants in refrigeration, air conditioning and heat pump equipment, https://ec.europa.eu/growth/tools-databases/mandates/index.cfm?fuseaction=search.detail&id=578

[37] CEN/TS 17607:2021 Operation, servicing, maintenance, repair and decommissioning of refrigeration, air conditioning and heat pump equipment containing flammable refrigerants, complementing existing standards.

[38] Published document CEN/TS 17606:2021: Installation of refrigeration, air conditioning and heat pump equipment containing flammable refrigerants, complementing existing standards.

European standards so that fulfilling the mandate to update existing standards was actually not achieved.

Alongside, the EU-funded project LIFE FRONT provided, *inter alia*, relevant data such as a leak size/concentration database to support evidence-based risk assessment for the use of flammable refrigerants as well as a report with recommendations on how to safely raise the charge limits of A3 refrigerants (LifeFront, 2020).

Recent and ongoing updates of international and EU standards

At international level, the group standard ISO 5149 on refrigerating systems and heat pumps is subject to review and has partly been updated in 2020. This standard can be applied for systems not covered by specific product standards. It contains a general methodology to determine the maximum flammable charge limit.

The overarching refrigeration and air conditioning standard EN 378 was updated in 2017 to include the refrigerant R744 (CO_2) and is currently again subject to review (CENELEC, Ongoing). A primary focus of this revision is the broader use of A3 refrigerants (amongst others), particularly for equipment not explicitly covered through product standards. However, the process is slow and not expected for completion before 2024. The revision process of the EN 378 includes the work from the Technical Committee WG 12 under the above-mentioned M/555 with technical specifications for flammable refrigerants.

Concerning commercial refrigeration, in 2019, the International Electrotechnical Commission (IEC) revised its safety standard IEC 60335-2-89 and increased the charge limit for flammable refrigerants in **self-contained commercial refrigeration appliances**. The charge limits have increased from 150 g to 500 g for A3 refrigerants. For mildly flammable alternatives (A2 and A2L), the limit has increased from 150 g to 1.2 kg. Further changes relate to commercial ice makers which are now covered by the scope of the standard. The requirements for systems with charges <150 g remain the same as previously.

It should be noted though that the international IEC standard is a voluntary international recommendation. This new edition of the standard defines a series of specific additional measures needed to allow higher charge levels without increasing risk as set by the previous standard. To have any legal power, it needs to be reflected in each country's local safety regulations such as EN 60335-2-89 in the EU. This standard has become a harmonized standard through the EU Machine Directive (MD; Annex ZZB). Some in the industry believe this revision will make the transition to low GWP refrigerants much easier than under the previous 150 g limit (Embraco, 2021).

A proposal for the international product standard IEC 60335-2-40, which sets out particular requirements for electrical heat pumps, air conditioners and dehumidifiers, was published in 2020. A high number of comments to this Committee Draft was received and are currently being addressed. It is expected that the Final Draft International Standard (FDIS) will be submitted in early 2022, followed by a voting period in spring 2022 and final publication in June 2022. Just as for the above-mentioned IEC 60335-2-89, this standard also needs to be reflected in local safety regulations and will thus require adoption of a standard EN 60335-2-40. Such standard will help equipment manufacturers to develop and introduce product solutions relying on flammable refrigerants for the EU market.

The update of the international product standard IEC 60335-2-24, that sets out particular requirements for refrigerating appliances, ice-cream appliances and ice makers, is still not finalized. However, the drafts include new requirements easing the use of A2L refrigerants. It is likely that a revised standard is published in April 2022.

National building codes and regulations

In most cases, national building codes and regulations do not pose barriers for the use of alternatives to F-gases. Member States competent authorities stated in most cases that national regulations do not go beyond the requirements at EU level.

However, the situation was found to be different in three Member States:

- **France**: The use of flammable refrigerants (A2L and A3) remains restricted in public and high-rise buildings so that the installation of equipment with A2L/A3 and other flammable refrigerants in those buildings is being prevented. The current code CH35, covering public buildings, is perceived by industry as very challenging and would only allow installation of A2L refrigerants at high cost and A3 refrigerants at even higher expense. The code GH37, covering high-rise buildings, still forbids any installations with flammable refrigerants. Thus, both codes require updating.
- **Spain**: As of spring 2021, certain barriers for low-GWP alternatives to F-gases still existed despite some updates of national legislation. The Real Decreto 552/2019[39] was reviewed to include the A2L category and to allow for the use of A2L refrigerants. However, the use of A3 refrigerants remains restricted. Furthermore, the modification of the Regulation related to new standard for A2L for domestic equipment like splits air conditioning or heat pumps was introduced in 2019[40].
- **Italy**: As of, spring 2021, A2L refrigerants are partly allowed in various public buildings as some updates of national legislation took place. The Interior Ministerial Decree 10 March 2020 (“Fire prevention provisions for air conditioning systems included in activities subject to fire prevention controls”) updates the technical provisions of fire prevention in air conditioning and air conditioning systems where the use of non-flammable or non-flammable and non-toxic refrigerants is permitted for the fluids classified A1 or A2L according to ISO 817 "Refrigerants - designations and safety classification " or equivalent standard. Furthermore, Annex I of Interior Ministerial Decree 3 August 2015 (“Approval of technical standards for fire prevention, pursuant to article 15 of Legislative Decree no. 139 of 8 March 2006”), as modified by Ministerial Decree 18 October 2019, provides that, in the areas of activities where occupants may be exposed to the effects of refrigerant gases, these refrigerants classified A1 or A2L according to ISO 871 should be used.

The following specific Ministerial Decrees (D.M.) in Italy continue restricting the use of low-GWP alternatives to F-gases.

Table 35 – Italian Ministerial Decrees related to safety standards

National code	Coverage	Comment
D.M. 26/08/1992	Schools	“… only non-flammable and non-toxic refrigerants can be used in air conditioning and refrigeration systems …”
D.M. 9/04/1994	Hotels	
D.M. 19/08/1996	Buildings for Public Shows	
D.M. 18/09/2002	Hospitals	
D.M. 22/02/2006	Offices	
D.M. 27/07/2010	Malls	
D.M. 16/07/2014	Kindergartens	
D.M. 7/07/2014	Airports	
D.M. 18/07/2014	Freight	
D.M. 10/03/2020	“Fire prevention provisions for air conditioning systems included in activities subject to fire prevention controls”	

[39] https://www.boe.es/buscar/doc.php?id=BOE-A-2019-15228
[40] https://www.boe.es/diario_boe/txt.php?id=BOE-A-2018-16791

Annex I of D.M. 3/08/2015	"Approval of technical standards for fire prevention, pursuant to article 15 of Legislative Decree no. 139 of 8 March 2006", as modified by D.M. 18/10/2019.

In this way, certain barriers remain such as:

- The use of hydrocarbons is not possible anywhere,
- The use of A1 and A2L refrigerants is allowed in certain locations (see table above),
- The use of A3 or ammonia is only allowed in industrial installations without public occupancy.

An exchange with experts from Austria came to the following conclusions: Experts who have been planning RACHP systems with natural or flammable refrigerants for a long time reported that the burden of proof for the safe planning of such systems lies with the planner, who must prove that all safety standards are met. Due to the fact that the safety requirements for refrigeration systems with natural or flammable refrigerants are regulated by many ordinances and law, some of which are not adapted to the current best available techniques, have different focusses, or do not necessarily apply to the installation of a refrigeration system, and are therefore not very specific. The final scope of the requirements depends on the specific knowledge of the specific problems of the authority expert in system construction at the respective municipality, where plans for a new installation are being approved.

These experts often have different expertise (i.e. are trained in different technical fields), and depending on the district, requirements are either raised or planning proposals from the planners are accepted as they are, based on trust in the experience of the planner. In any case, the regulations specify how an installation should be built and planned, but there is not really a regulation that gives the operator guidelines for safe operation, which can lead to problems in insurance issues in the event of an accident. Here, too, training of the official experts is necessary, as sometimes counterproductive specifications are made, such as sprinkler systems in ammonia plants, which can lead to ammonia vapour that can endanger the service personnel in the course of an accidental release, as well as lead to the total failure of the refrigeration plant.

Stakeholder views

Stakeholders (OPC) re-affirmed that unjustified barriers in safety standards and codes still present a very serious challenge to the implementation of the Regulation, and in fact some stakeholders believe this to be the most important challenge facing the Regulation. Some stakeholders such as the Clean Cooling Coalition, a network of manufacturers of natural alternatives to F-gases criticized the EU Commission mandate on standards (OPC and targeted interview)*: 'The legal wording of the Standardisation Request undermined its strength significantly. First, the main difference between a European standardisation deliverable (ESD) and a European standard is that national transposition of the technical specifications in an ESD is not required. Besides, technical specifications in an ESD cannot contradict existing European standards, which made it difficult for the Standardisation Request M/555 to fulfil its own mandate to update existing antiquated standards. This situation risks undermining the smooth functioning of the internal market and setting back the introduction of safe and energy-efficient HFC-free technologies. To prevent continued abuse of the standardisation process, the revised Regulation should require European standards be updated to require specific charges sizes be allowed by a certain date in specific sectors so that the market prohibitions and HFC phase-down can be achieved.'* It was recommended to demand an update to antiquated standards to allow for the introduction of safe and energy-efficient climate-friendly technologies, in particular those relying on A3 refrigerants. Furthermore, stakeholders flagged that European standards should support minimum technical requirements for all potential charge sizes and should be explicitly set out in the Regulation.

In the follow-up to the stakeholder workshop, the industry association Eurovent pointed out that *"regulatory and standardisation barriers which still significantly prevent flammable refrigerants from being used in heating and air conditioning equipment in many EU countries, unlike for the commercial refrigeration sector where these restrictions have already been eased."*

Stakeholders also re-iterated that these barriers are not just limited to domestic and commercial heating and cooling. An industry stakeholder from the electronics sector described how high GWP safety refrigerants were carefully chosen to limit potential hazards in their industrial systems (e.g. to limit flammability and explosivity). The stakeholder noted that utilizing non fluorinated refrigerants will require an entirely new and comprehensive process safety concept for the refrigeration system and the production process it serves. Such a re-design and construction of natural refrigeration systems would require years of planning and new spatial requirements.

However, the persistence of this barrier to date was affirmed by stakeholders engaged as part of this study (interviews with undertakings, workshop), who cited examples such as the Pressure Equipment Directive discouraging the use of A2L refrigerants by regulating them as ‘A3’, so creating a barrier in the adoption of low GWP alternatives to HFC, and a general limitation of the use of natural refrigerants.

Furthermore, stakeholders underlined that a vast number of regional and local building codes and regulations exist in most Member States which (at least partly) also inhibit the use of F-gas alternatives.

5.1.7.2 *Illegal Trade*

Any amount of illegal trade of HFCs outside of the quota system may have a negative impact on the environment and lead to an uneven playing field for market actors. Illegally imported HFCs not covered by quota undermine the HFC phase-down targets and slow down the transition to low GWP alternatives. Alongside undermining the core objectives of the Regulation, it may also bring safety concerns with regard to the quality of the products due to mislabelling and the use of unknown mixtures: an NGO representative (workshop) highlighted that it is difficult to know the size of potential damage caused as the quality of illegally imported products is unknown. Stakeholders of all types unanimously agree illegal trade has been a significant challenge to the Regulation’s ability to achieve its objectives, and for some this is the most important issue associated with the Regulation. The industry pledge to eradicate the black market for HFC’s (EFCTC, 2020) is an example of industry willingness to curtail illegal behaviour, with over 300 pledges to date and includes the EFCTC integrity line where users can anonymously report illicit activity. Use of this line is leading to results: EFCTC reported that the line received 111 Action Line reports of possible illegal HFC activities received from across Europe in 2020, the evidence from which supported some of the 13 seizures of illegal HFCs that have taken place in Europe (EFCTC, 2021) .

Illegal activities identified can take a number of forms: Illegal products (e.g. non-refillable cylinders), non-respect of license (registration) or quota needs, mislabelling of products (see also EQ1a(ii) above), misuse of special customs procedures such as transit (etc... In some cases, illegitimate traders attempt to circumvent customs altogether, with some Member States experiencing a greater problem than others.

It is not feasible to make an accurate estimate of the level of illegal activities (the inability to estimate levels of illegal in and of itself is a concern raised by an industry trade association stakeholder (workshop)). In some cases, studies and stakeholders have sought to estimate elements of the illicit activities. The EU Commission carried out its own analysis (European Commission, 2019) which compared data on the trade of HFCs available from company reporting according to the FGR was compared with other related data sets, in particular Eurostat trade data as well as Chinese export data acquired by industry from Chinese sources and provided to the Commission. The report concluded that correctly declared HFC imports were covered by quota in 2017 and 2018, hence it appeared that any illegal imports (without HFC quota) were not likely to be the result of misreporting of imports, but rather took place in the form of customs evasion (smuggling/transit circumvention). Stakeholders (workshop) agreed that from their experience, illegal trade could represent a non-negligible share of the market and is a growing concern. For some (feedback to workshop), this has been occurring at significant levels since 2018 in particular.

Although an overall estimate of illegal activity cannot be estimated, there is strong evidence that such activity has occurred over the appraisal period. Firstly, specific examples of breaches have been identified in individual Member States, as set out in the following table.

Another indicator is the increase in exports of HFCs from China to EU neighbouring countries, as pointed out by industry. This may be an indication that illegal importers are using neighbouring countries as a hub for smuggling HFCs into the EU. The EIA (EIA, 2021) pinpoints Romania as a major illegal entry point for Chinese-made HFCs, smuggled via Turkey and Ukraine, with the HFCs destined for bigger markets such as Germany, Spain, Belgium, Italy, France and the UK. That said, relatively high imports from China may also have other reasons, such as stockpiling as a result of the entry into force of the Kigali Amendment (as it happened in the EU in 2014), domestic consumption replacing HCFCs and growth of cooling industries or lower import from other countries.

Low HFC prices are also viewed by industrial stakeholders to be an indicator of illegal trade. The price monitoring survey reported prices for presumably illegally traded refrigerants in 2018. This showed a substantive price difference to ‘legal’ refrigerants covered by HFC quota – at least 50 % cheaper or supplied at a price of 15 €/kg. It was pointed out at the workshop that illegal trade has been incentivised by the higher HFC prices in the EU compared to world market prices and that volumes of illegal trade may have been one of the drivers behind the reductions in prices observed over the appraisal period (following the initial peak). However, flows of illegal imports would need to be fairly substantial to have impacted average market prices over an extended time period.

Table 36: Examples of illegal activity

Member state	Example of illicit or enforcement activity
Bulgaria	Over a tonne of HFCs R134a and R404A were seized in illegal disposable cylinders. Furthermore, Bulgaria reported 78 smuggling attempts between April and December 2018. Fines in the range of €220-250 per cylinder were levied against the offenders and the refrigerant cylinders were held by customs, awaiting destruction. Destruction costs are covered by the State budget, but there are no destruction facilities in Bulgaria (Cooling Post, 2019).
Croatia	Levied fines over the period of implementation, of €2,000 (HRK 15,000) to the persons responsible for different illegal shipments, with the totals reaching €24,000.
Greece	432 kg of R134a, R404A, R410A and R407C refrigerants were seized in non-refillable containers. Fines in the range of €6000 per instance of smuggling were imposed.
Italy	There were 16 proved cases of illegal trade in 2019 and 2020 (in accordance to paragraph 7 of decision XIV/7 of the Montreal Protocol) and 5 significant cases of illegal production, import, export or consumption have been addressed in 2019 and 2020 (in accordance to decision XXXI/3 paragraph 5(d) of the Montreal Protocol).
Netherlands	A shipment containing R134a without a quota was intercepted. In addition, in September 2020, Dutch authorities seized 10 tonnes of R404A in a truck in the Netherlands (Cooling Post, 2020). The refrigerant had been imported from Turkey and was destined for Belgium. The importer was not in the HFC Registry and did not have quota. The HFCs were incorrectly labelled and loaded and the driver of the vehicle did not have the required dangerous goods transport documents and certification.
Poland	Intercepted 425 separate shipments, totalling 107,456 kg of HFCs, equivalent to 238,482 tonnes of CO_2 eq, that breached the Regulation. The breaches included non-compliant labelling, but also included breaking quotas and illegal non-refillable containers were present in 403 out of 425 cases of illegal shipments to Poland. Smuggling of HFCs was also reported.

Furthermore, OLAF have identified a number of undertakings pursuing illegal activities, and so has a private investigative firm; which was hired by the chemical industry to address this issue.

In terms of specific substances, according to market experts, the refrigerant that appears to have been traded illegally most frequently was R134a, which is used in significant quantities in the passenger car sector to service air conditioners, followed by R404A and R410A.

A number of elements of the Regulation have been identified as not sufficiently discouraging illegal trade.

1. ***Coherence with customs rules***: there are a number of incoherence's between the Regulation and customs procedures and the lack of clear indications to customs on their role and what needs to be checked that have prevented the effective enforcement of the Regulation (discussed further in EQ9a) and control of imports. For example, customs authorities face challenges as regards what they should to do with illegal shipments that are seized causes because storage and destruction of confiscated items comes at a cost for customs authorities and may not be a long-term option.
2. Stakeholders (Interviews with industry) have argued that the current T1 transit procedure and other ***special procedures are vulnerable to misuse and exploitation***, resulting in HFCs being illegally traded within the EU. Furthermore, a CA stakeholder noted that they have limited ability to take action around illegal goods that are already placed on the market.
3. The level of ***penalties*** varies between Member States and are not always considered dissuasive (as discussed in detail under EQ1d).
4. ***Online trade*** has also posed a challenge to ensuring compliance with the Regulation. F-gas containing products are being placed on the EU market via internet marketplaces and on various platforms, which pose difficulties to identifying sellers. No data exists on the levels of online sales, but evidence suggests that this is becoming a significant issue for the industry. For example:
    a. the National Confederation of Crafts and Small and Medium Enterprises in Italy has taken the online retailer Amazon to the Court of Rome for the illegal trade in F-gases as a result of the sale of HFCs without requesting proof of certification. In one case, a television presenter was able to buy 800g of R410A in a non-refillable cylinder from Amazon without providing evidence of certification (Cooling Post, 2018).
    b. CLEEN (2019) also noted that e-commerce is presenting a challenge for enforcement as F-gas containing products are being placed on the EU market via internet marketplaces and on platforms that make it difficult to identify sellers.
    c. A recent EIA (Cooling Post, 2021) study also targeted online trading platforms, and found illegal traders offering refrigerant at well below market prices, and some vendors openly displaying images of HFCs in illegal disposable cylinders.

    Stakeholders (OPC) confirmed that unregulated online sales online are an issue and present an avenue for illegal imports which are not being followed up by local authorities.
5. ***Market surveillance*** activities were also considered by the majority of industry, NGO and Member State stakeholders (OPC) as ineffective in preventing illegal activity (although the response was mixed). Several NGO and business association stakeholders (OPC) noted that market surveillance activities have been undertaken in some Member States, and that where undertaken, these activities were believed to have somewhat reduced illegal trade. However, activities had not been undertaken in all Member States and overall were scarce. Furthermore, stakeholders highlighted the need for a coherent EU-wide, risk-based inspection and market surveillance regime. For some stakeholders (OPC), this issue is exacerbated by the lack of a real-time, per shipment HFC licensing and warning system.

As discussed in EQ1a(ii) above, mislabelling may be part of illegal activity. However, (as noted above) although mislabelling is an issue, it cannot be attributed to the design of Article 12 specifically. The behaviour taken to circumvent the labelling requirements can therefore be attributed as an attempt to avoid compliance with the wider aims of the Regulation, with the misuse of labels a means to avoid detection for failing to comply with the wider phase down requirements.

5.1.7.3 *International context*

One prominent consideration is the international context in which the Regulation was conceived, implemented, and operated.

Prior to the Regulation being adopted in 2014, the EU had previously committed to reduce GHGs by 20% by 2020 (including F-gases). It has since made further commitments, e.g. to reduce domestic emissions by 40% compared with 1990 levels under the Paris Agreement (European Commission, 2015). More recently, the EU has submitted an update of its Nationally Determined Contribution in 2020 (European Commission, 2020) including a target for a net reduction from base year emissions of at least 55% GHG reduction.

Looking more widely, the Regulation was put in place when international rules on HFCs did not exist. The recent amendment to the Montreal Protocol has also forced third countries to begin to reduce their HFC consumption and the political measures which will be required to do so (EPEE, 2018). In this way the creation of a more level playing field may alleviate some of the costs of the ongoing technology transition in the EU and present market opportunity for European undertakings as first movers and green technology providers. One concern for EU states before Kigali were the associated costs with switching away from HFCs. EU undertakings forced to innovate due to the Regulation now find that they also find markets for these innovative products in a global context.

Commitment to international agreements, alongside a desire within the EU to press forward and lead on climate change issues, has helped to drive forward regulation targeting F-gases, and have supported its objectives since its implementation. The need for the EU to lead on climate change policy has been particularly evident following an absence of US leadership in recent years, and this heightened leadership role has increased the pressure on ensuring strong levels of progress are achieved under the Regulation.

In this context, it is apparent that the original objectives (from 2011) are no longer ambitious enough, and that the Regulation should look to re-examine its targets. This is particularly true as the EU has begun to set broader, more ambitious climate targets, in order to achieve carbon neutrality in 2050 and a 55% reduction by 2030 (this is discussed in further detail under EQ7c).

5.1.7.4 *Lack of information and awareness*

To some extent, lack of information and awareness of the Regulation has posed a barrier to its success. A survey undertaken by the EIA in 2019 showed that respondents thought only 59 % of their clients[41] were adequately aware of the Regulation*s measures (EIA, 2019). Stakeholders viewed this as somewhat a challenge, however opinion was divided with a similar proportion suggesting this a significant or little or no challenge. Across stakeholder types, Competent Authorities and NGOs were more inclined to view this as a significant challenge, relative to industry and citizens. Indeed, stakeholders of all types suggested this was less of a challenge than safety codes and illegal trade. Looking in further detail at stakeholder responses, it is likely that some of this sentiment relates to awareness of the availability of alternative technologies, with respondents also noting need to address concerns relating to training and safety standards. Training around alternatives is discussed more fully in EQ1b.

5.1.7.5 *COVID-19 Pandemic*

The current Covid-19 pandemic is expected to have an impact upon trade of products and equipment

[41] Clients of respondents to the EIA consultation

containing F-gases. Indeed HVAC systems and their use come into close focus during the pandemic due to their role of circulating air in closed spaces and influencing the risks of catching COVID or other air-borne diseases (ECDE, 2020). It is important to note that the pandemic is ongoing, and the full effects are not yet known. However, some initial insights and trends are beginning to emerge.

EMI recently published a study a study which explored the impact of COVID on the EU HVACR market (Eurovent, 2020). The report, which surveyed more than 100 manufacturers across 16 countries, suggested that the UK and Turkey have fared the worst as a consequence of the pandemic, seeing the sharpest declines in new orders. Within the EU, Spain, Italy and Czechia appear most negatively impacted. In contrast, Germany, Austria and Switzerland are reported to have fared the best, with some even seeing an increase in orders over the crisis. The report explored that the strength of performance also differs by product and market type: products such as dry coolers, CO_2 gas coolers, cooling towers and air filters fared better, rooftop units saw the biggest drop in demand. Elsewhere, hospitals, data centres and the food industry have ‘profited’ from the crisis (especially with regard to additional refrigeration requirements), whereas the worst affected were offices and shopping centres and also niche applications such as cruise and air travel.

Another study by BSRIA (Cooling Post, 2020b), based on interviews with HVAC manufacturers in 20 major world markets, concluded that the six months to September 2020 following the onset of the pandemic had been ‘challenging’. As a result of the surveys, BSRIA to revised down its predictions for global air conditioning sales in 2020 and 2021. The study reported falls in sales across the board, with VRF sales down 4%, chillers down 6%, splits down 8% and rooftops down as much as 12%. That said, the report also suggests that there have been growth opportunities in some sectors, notably in Europe with the shift to home working, an increase in demand for residential air conditioning.

A global report by SEforALL also underlines the need for developing a new cold chain to support the delivery of vaccines, supporting the positive impact that the crisis has had on the demand for cooling in this sector (Sustainable Energy for All, 2020).

In addition to these market summaries, it is notable that several undertakings reported declines in sales over the period of the pandemic (noting the detrimental impact of the pandemic as a key driver). Such entities included Lennox (Cooling Post, 2020), Beijer Ref (Cooling Post, 2021) and Danfoss (Cooling Post, 2021) reporting declining sales in 2020, and Daikin (Cooling Post, 2021) for the FY ending March 2021. That said, following the peak of the pandemic, many undertakings are seeing a bounce-back in sales: indeed although Beijer Ref reported an overall fall in sales in 2020, sales reportedly stablished in Q4. Furthermore, Daikin reported a 37% leap in Q1 sales in 2021 relative to the same period last year (Cooling Post, 2021), Carel reported a 24% growth in Q1 sales this year in comparison to last (Cooling Post, 2021) and Lu-Ve reported record sales in the first half of its financial year to end June 2021 (Cooling Post, 2021). Indeed recent trade press suggests there has been a strong recovery in some sectors since the peak of the pandemic: Cooling Post (2021) report that Germany and France have seen double-digit growth in the split air conditioning market as the world begins to emerge from the coronavirus pandemic

In summary it appears that 2020 was a challenging and disruptive year for nearly the whole of the market, with many undertakings having to change and adapt their ways of working (BuildOps, 2021). That said, the pandemic appeared to present an opportunity for some and it appears the outlook for 2021 and beyond is brighter with a backlog in orders coming through and stabilization of spending.

The views of stakeholders as to their experiences as a result of the pandemic have also provided a current insight into the impacts on the market as they unfolded over the timeline of the project and appear to closely corroborate the initial results emerging through the literature.

Opinions were mixed on the impact of COVID-19. Across most stakeholder types, the perception was that F-gas sectors were not (yet) significantly affected by the pandemic, with the exception of the business association/organisation stakeholder group, who more often stated COVID-19 has had a negative impact.

It was signalled through the OPC and targeted interviews that the majority of sectors may have been negatively affected. Closer inspection of stakeholder responses revealed that this perception also varied by sector, indicating that some sectors had been more negatively than others (albeit stakeholders signalled that the majority of sectors had been negatively affected). Those most frequently noted by stakeholders as being negatively affected were: the mobile AC sector, transport refrigeration, fire protection and electronics manufacture. Other sectors identified by stakeholders as being detrimentally affected also included servicing and maintenance, leak checks at installed equipment, and installation of new air conditioning systems in hotels and offices.

In contrast, for one sector, the switchgear and related equipment sector, the majority of respondents felt this sector was not negatively impacted by COVID-19. Indeed, for some sectors, stakeholders through other engagement activities signalled that business has increased during the pandemic (food production and retail sector, cold storage sectors – including for cooling of vaccines, increased demand for air circulation in public and commercial buildings) and/or remained consistent (use in the medical sector).

Business associations also elaborated on the type of impacts the Covid-19 pandemic has placed on the EU F-gas market. Short-term impacts mentioned included shutdown of production facilities, delays and shortages in supply of material and equipment components and reduction in revenue. Other industry stakeholders reported impacts on innovation activity, such as reducing discretionary funding for R&D and postponement or cancellation of projects. Effects have also been felt in market-supporting activities, such as delays and closure of training centres, limited access for service technicians, and delayed compliance testing of products in test labs due to limited capacities and unavailable prototypes.

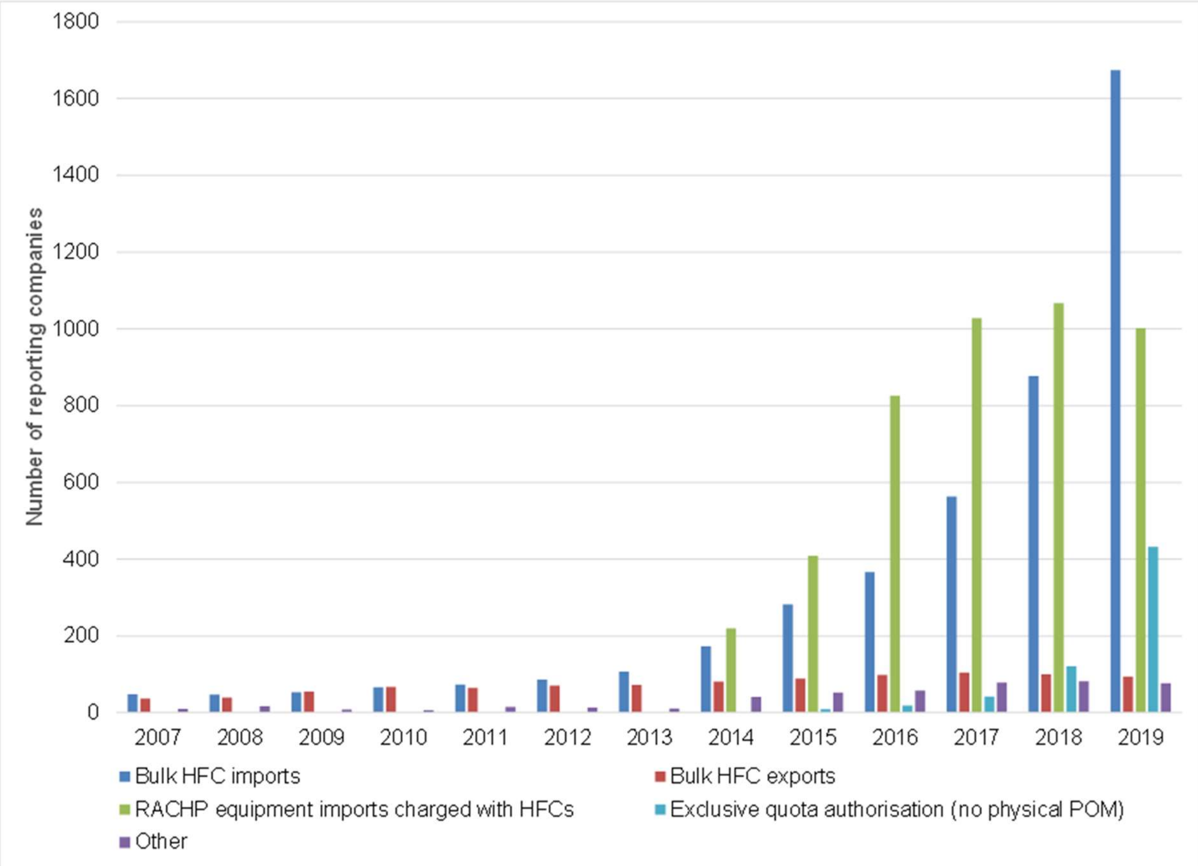
5.1.8 EQ2b. Have there been any unintended/unexpected effects of the intervention, including on trade of F-gases?

5.1.8.1 *Quota allocation and number of undertakings*

The EC's 2016 assessment of the quota allocation (European Commission, 2017) method concluded that (at that point) it was too soon to evaluate the effectiveness of the quota allocation method. Company data available to the assessment was only obtained for 2015, with the assessment conducted after one annual cycle of the quota scheme.

Some structural information on undertakings in the EU F-gas industries can be gained from the reporting data: The development of reported activities for 2007 to 2019 is shown in Figure 35.

Figure 35: F-gas related activities reported by undertakings under the Regulation



Source: [(EEA, 2020)]

While the number of undertakings participating in the company reporting prior to revision of the Regulation was relatively stable, this changed tremendously after the revision.

The number of bulk HFC importers has strongly increased from about 80 undertakings in 2012 to about 1,700 undertakings in 2019. While some undertakings possibly may have neglected their reporting obligations before the revision of the Regulation, the primary reason for this development was the design of the quota allocation mechanism which features pro-rata allocation of a new-entrants' reserve among all undertakings applying for allocation at no cost.

A strong competition can be observed for this allocation of declaration-based 'new entrants' quota. The amounts of undertakings sharing the amount reserved for new entrants-quota has approximately tripled from 2015 to 2018, and additionally more than doubled from 2018 to 2019, reaching about 2,500 undertakings. This is particularly noteworthy since the bulk HFC market is being reduced greatly between 2015 and 2030 to less than one fifth of its size.

Importers of equipment had not been obliged to report under the first Regulation. The increase in numbers of reporting equipment importers from 2014 to 2017 should be interpreted as partly reflecting the rise in awareness of equipment importers related to their reporting (and quota) obligations under the current Regulation. Since 2017, i.e. the entry into force of the quota authorisation obligation for importers of RACHP equipment pre-charged with HFC, numbers of reporting equipment importers have levelled off at around 1,000.

That said, the increase also signals several challenges for Regulation in effectively achieving its objectives (although industrial stakeholders – OPC and workshop – did not necessarily see the increase in undertakings as an issue in and of itself).

One issue with this change is that some company groups have been trying to maximise their share in new entrants' quota by registering up to hundreds of affiliates. Confidential data collected by the EEA have shown the consequence the standard new entrants' quota allocation per company for 2019 declined to 7 % of 2015 levels, while the total 2019 quota amount was at 55 % of 2015 levels. The new entrant share therefore becomes less useful to those beneficial owners not multiplying their applications. In response to those developments, Commission Implementing Regulation (EU) 2019/661[42] was passed in 2019 introducing barriers for illegitimate participation in the quota allocation. As an effect of that intervention, the further increase in quota recipients was stopped on the standard size of a new entrants' quota allocation for 2020 slightly increased to 8 % of 2015 levels.

Second, the large number of participants poses serious challenges to implementing the phase-down, as compliance checking becomes more difficult due to the numbers of undertakings to be controlled especially as more undertakings fall under the reporting and verification thresholds.

Third, there may be market players who otherwise would have had no access to the market have started to operate a business model where they buy F-gases on the world market and import them to the EU. These businesses may not necessarily be experts on the products sold or even letterbox companies, increasing the risk around Regulatory compliance and use of F-gases. Indeed, a very recent trend manifesting in 2019 data of Figure 35 is the strong increase of quota holders which do not at all engage in actual imports of bulk HFCs but only authorise the use of their quota to equipment importers. According to the provisions of the Regulation, such authorisations are lawful only in case the quota holding undertakings prove that they are in fact trading in bulk HFCs, an obligation that is cumbersome and resource intensive to enforce.

5.1.8.2 *Export to third countries*

The market for air conditioners in Africa is growing strongly (14% cumulative growth from 2005-19) and relies heavily on imports, as only few countries assemble RACs from imported parts (CLASP, 2020). The EU Regulation as well as the Ecodesign Directive, place stringent requirements on the energy performance and GWP limits for the domestic market. As explored by a report by CLASP in 2020 (CLASP, 2020), this creates a risk that older, less efficient equipment containing substances with a higher GWP is exported to the African market.

Such activity is driven by two factors: (1) international and national regulation (including the EU Regulation) which create a surplus supply of low efficiency air conditioners, as they become increasingly prohibited in most markets (a similar situation has also emerged for the export of equipment produced with refrigerants such as R410A and R404A); and (2) relatively weak environmental standards across many importing African countries compared to other international economies. This has certainly been the case historically as national measures (such as import bans) for used equipment in preparation of the implementation of the Kigali Amendment have not (yet) been put in place. There is a lack current data available on operational leakage rates of RAC in Africa, although an assessment of similar markets has suggested that leakage rates could range from 1-30% depending on their application (CEEW, n.d.), with CLASP adopting an assumed 10% rate for its modelling.

The CLASP report has identified that up to 35% of all RAC sales to 10 African countries (total imports, not just from EU) were considered to be low efficiency, with an energy efficiency ratio less than 3.0 w/w. It was also found that 47% of RAC imported contained R-22, an ozone-depleting greenhouse gas being phased out by the Kigali amendment. That said, the CLASP report identified that at least 50% of the imported low efficiency units are imported from China, with Korea, the US and Japan accounting for the other major non-African sources of low efficiency. Greece was the only EU Member State to be identified as a source of low-efficiency systems, and only contributed a very low proportion of imports. This suggests that perhaps the risk of dumping from the EU is lower than from other manufacturing countries

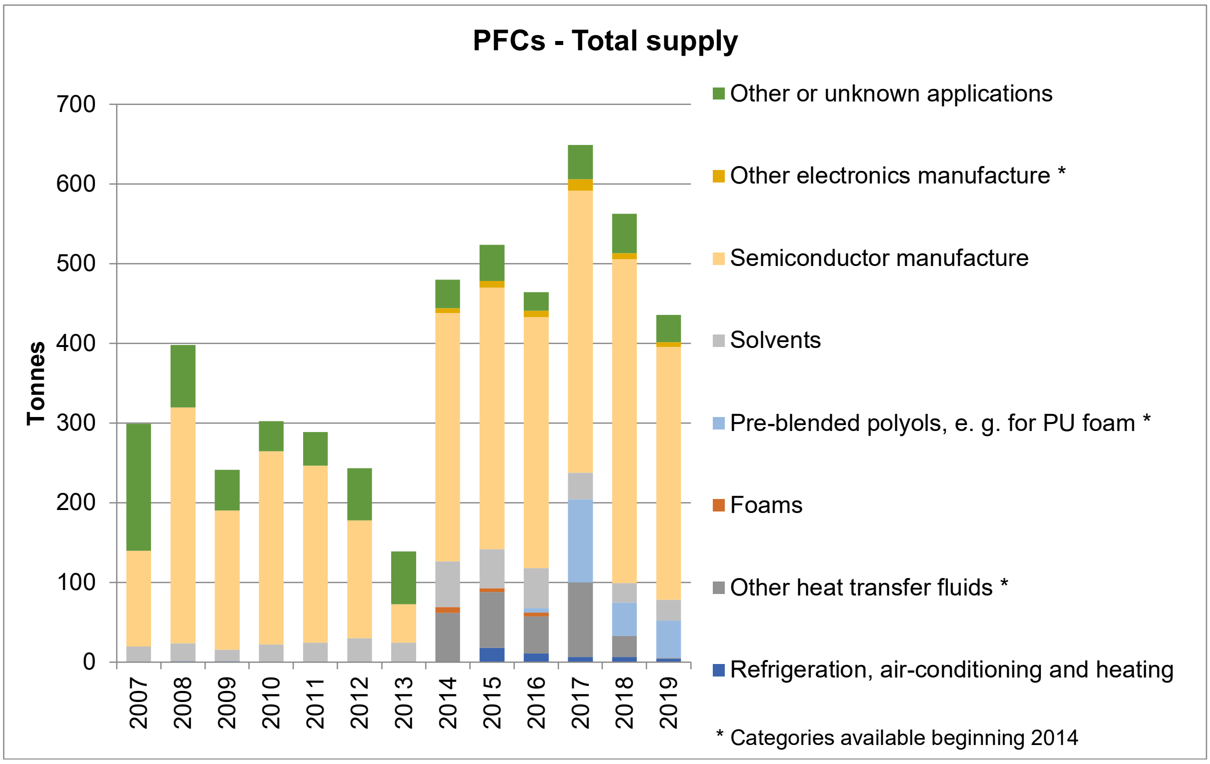
[42] Commission Implementing Regulation (EU) 2019/661 of 25 April 2019 ensuring the smooth functioning of the electronic registry for quotas for placing hydrofluorocarbons on the market, https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32019R0661&from=EN

and regions, although it is noted that the study only focused on 10 importing African countries and only analysed the origin of 61% of imports to these nations, and hence does not comprehensively analyse this risk.

5.1.8.3 *Unintended shift from HFCs to PFCs*

The following section collects evidence whether the HFC phase-down may have triggered an unintended shift from HFCs to PFCs (which generally have even higher GWPs than HFCs) given that PFCs are not controlled under the phase-down unless part of blends that also contain HFCs. Figure 36 presents the EU27+UK PFC supply by intended applications.

Figure 36: EU27+UK PFC supply by intended applications



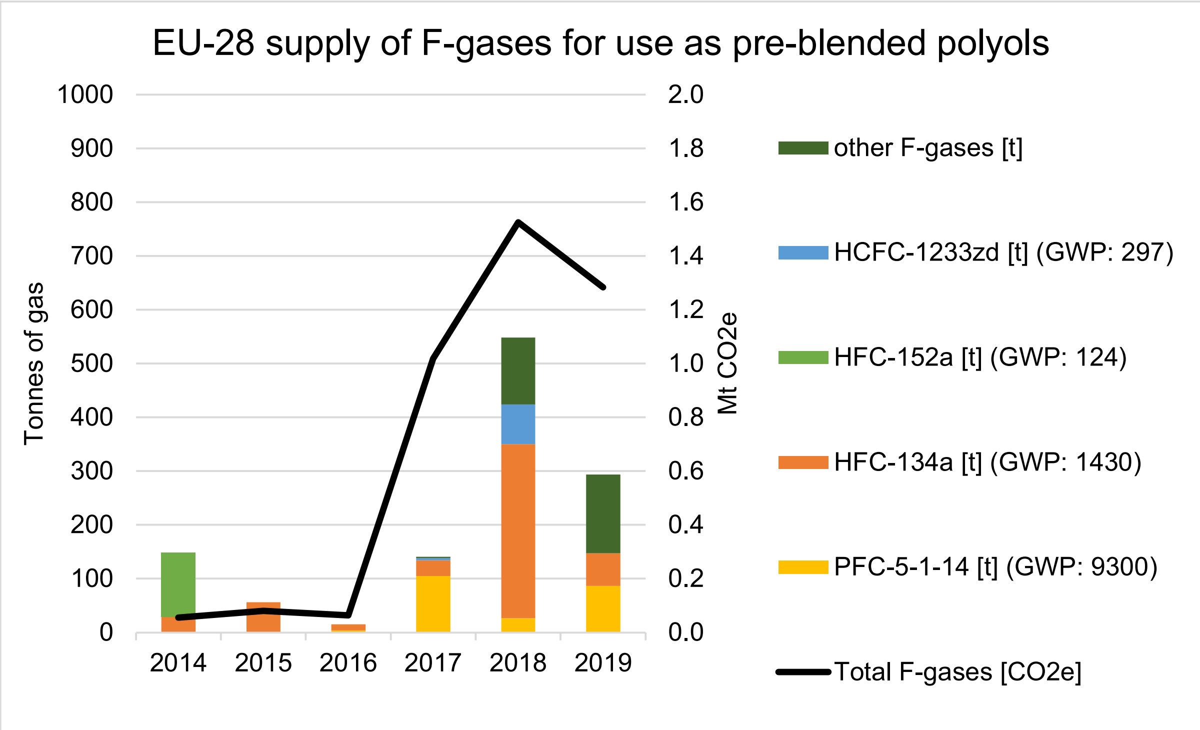
Source: [EEA 2020 confidential dataset], own calculations

The overall size of the EU27+UK PFC market (measured in tonnes) is at only approximately 1 % of the EU HFC market. PFC supply to the EU27+UK has been fluctuating over the complete time series. In particular for the HFC phase-down period beginning 2015 no particular trend is discernible. Only a small share of PFC supply is intended for sectors which are also relevant for HFC supply (refrigeration, foams and solvents): PFCs in the order of magnitude of up to 100 tonnes per year are reported for the intended application as pre-blended polyols (e.g. for polyurethane (PU) foams).

The main use of PFCs continue without a decreasing trend is in semiconductor manufacture. It is noteworthy that these stable amounts are noticeably higher than they were before 2014.

For F-gas use in pre-blended polyols (Figure 37), PFCs started to play a role since 2017 where about 75 % of F-gases reported for pre-blended polyols were PFC-5-1-14 (C_6F_{14}). Given higher amounts of HFC-134a and HCFC-1233zd reported for pre-blended polyols for 2018 and 2019, the share of PFCs declined to about 5 % in 2018 and about 30 % in 2019. It should be noted that the reporting scheme relevant to pre-blended polyols was changed since 2019 (relevant for the reporting on 2018 data). Thus, it is likely that the data reported for up to 2017 for this use type may have been incomplete. Given these uncertainties, a clear trend for a shift from HFCs to PFC cannot be concluded. An expert from the EU association PU Europe confirmed low uptake of PFCs in polyols and insulation boards (flexible laminate) throughout the last decades.

Figure 37: EU27+UK supply of F-gases for the use as pre-blended polyols



Note: Data reported up to 2017 does not include F-gas supply to EU industries for use in exported pre-blended polyols. Data starting 2018 does include such amounts.
Source: [EEA 2020 confidential dataset], own calculations

Taking note of the uncertainties discussed for pre-blended polyols, the analysis of Article 19 reporting data thus does not allow to conclude that the HFC phase-down would have triggered an unintended shift in relevant quantities from HFCs to PFCs.

5.1.8.4 *Cross-media-effects, toxicity*

To review whether the Regulation has introduced other environmental impacts (i.e. cross-media effects) through the elimination of certain F-gases and the consequential introduction of their alternatives, the correlation between the reduction in use of certain F-gases and the changes in the trend of use of possible substitutes was investigated as well as the hazardous properties of such substitutes. A thorough review was conducted and is presented in detail in Annex 8. The following section presents only the conclusions of this review.

From an analysis of market data, the key unsaturated fluorinated substances phased in as HFC substitutes since the revision of Regulation are HFC-1234yf, HFC-1234ze and HCFC-1233zd. Regarding these and other alternatives for HFCs, most substitutes have classifications with relatively low hazard categories, i.e. low potential for severe impacts. Classifications regarding flammability are quite common, due to the pressured gas consistency of the substances. Flammability comprises a physical hazard rather than one related to toxicity. This potential risk is well known and addressed in practice through legislation, the relevant harmonised standards and the design of equipment to reduce related incidents.

In this sense, it is assumed that despite flammability being common, the potential risk does not translate into an actual impact for the most part and does not suggest a reduced effectiveness of the Regulation in that sense. In other words, the trade-off between GWP and the need to redesign equipment to prevent impacts in the case of flammable alternatives is considered acceptable and not a sign of a shortcoming of the FGR. Increased flammability is a characteristic for almost all refrigerants of low GWP, including the natural options (except CO_2).

The main concern for HFC substitutes is in relation to HFC-1234yf (2,3,3,3-tetrafluoroprop-1-ene), which has been included in the community rolling action plan (CORAP) for possible identification as a substance of very high concern (SVHC). Substances that may have serious effects on human health and the environment can be identified as SVHCs under Regulation 1907/2006 (REACH)[43]. In relation to HFC-1234yf, the listing requires the substance to be investigated for mutagenicity and carcinogenicity properties.

Five European States[44] are planning to prepare a joint REACH restriction proposal (EHCA, 2020) to limit the risks to the environment and human health from the manufacture and use of a wide range of per- and polyfluoroalkyl substances (PFAS), referring to 'substances that contain at least one aliphatic -CF2- or -CF3 element' (which are therefore persistent in the environment) as the scope of their investigation and of a possible restriction proposal. This process includes looking into HFC-1234yf and other potential climate-friendly substitutes for HFCs as well as HFCs themselves which are covered by the aforementioned definition. The assessments under REACH are still pending.

For a further discussion of processes under REACH, see the chapter 5.4.1.2 on coherence with EU environmental policies.

HFC-1234yf was found to have a significant contribution to the formation of trifluoroacetyl fluoride (TFF) which in turn reacts with water and forms trifluoroacetate (TFA) in the atmosphere (Behringer et al, 2021). TFA is considered as being highly persistent and highly mobile, meaning that once it is in the environment, it is difficult to reverse the situation. TFA appears to accumulate in surface waters (and groundwater) after being washed out of the atmosphere. By incentivising the use of HFC-1234yf, the F-gas Regulation[45] (and to a larger degree the MAC Directive, outside the scope of this FGR evaluation[46]) have contributed to an increase in the amounts TFA in the environment and possible related impacts.

A further concern regarding this substance is the by-production of HFC-23 (GWP of 12,400) through the production of HCFC-22, a feedstock of HFC-1234yf and some HFCs. Although under various legislative (including the Kigali Amendment) manufacturers are encouraged to collect and destroy this substance, stakeholders have concerns about how far this is being done in producer countries (workshop feedback and feedback received during targeted stakeholder interviews). Furthermore, there is preliminary evidence regarding the decomposition of HFC-1234ze into HFC-23 in the atmosphere (Campbell et al, 2021).

To summarise, the main risks associated to HFC alternatives are the issues explained for unsaturated HFC-1234yf, i.e.:

- the ongoing scrutiny for a potential identification as SVHC under REACH,
- the potential restriction of this substance along with other PFAS in the future,
- the contribution to the formation of persistent TFA in the atmosphere,
- persistency in the environment for many HFCs and HFOs and/or their breakdown substances.

As for hydrofluoroethers (HFEs), which are suited to replace high-GWP PFCs and HFCs, the reported use does not seem to correlate with reductions in supply of HFCs or PFCs. In other words, there is no strong evidence that HFEs actually replaced HFCs or PFCs in response to the Regulation. Related

[43] Regulation (EC) No 1907/2006 of the European Parliament and of the Council on the Registration, Evaluation, Authorisation and Restriction of Chemicals (REACH), https://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2006:396:0001:0849:EN:PDF

[44] Germany, the Netherlands, Norway, Sweden and Denmark

[45] Significant uses of novel refrigerant blends R-448A and R-449A, containing approximately 20 or 25% of HFC-1234yf respectively, have been observed since 2019.

[46] The use of R-1234yf (=100% HFC-1234yf) in AC systems in passenger cars and light duty vehicles (see section 2.2.3 / Figure 1) can be attributed to the MAC Directive.

hazards of such substitutes are detailed in the annex but considered of lower relevance to the evaluation of the current Regulation.

The common perception amongst stakeholders (as presented by the majority - 64 % - of respondents to the OPC) is that they do not believe the Regulation may lead to an increased accumulation of persistent chemicals in the environment. That said, there is a difference of opinion amongst stakeholders. The majority (but not all) of industry adhere to this overall consensus, whereas the majority of NGOs/environmental organisations and industrial stakeholders using natural alternatives noted they were concerned that this could be a detrimental environmental result of the Regulation. Indeed, interviews with some Member State authorities highlighted the large increase in the use of unsaturated HFCs (R1234yf, R1233ze), producing TFA as breakdown product, as a negative environmental cost of the Regulation. NGOs elaborated that that HFC-134 and HFO-1234yf are responsible for the rise of persistent substances such as TFA and PFA and so the Regulation (through this and other aspects) could lead to an increase in these potentially harmful substances. It was noted that there has been an absence of research into the impact of persistent chemicals in the environment produced from HFO/HCFO blends and other alternatives promoted through the Regulation. As such, those stakeholders that were concerned about these effects believe the Regulation should be cautious in promoting alternatives which may have wider negative effects without a full assessment. It should be noted that there was a relatively high number of respondents who were not confident to provide an opinion (34 %) which may reflect the technical understanding required to answer such a question.

5.1.9 Conclusions on effectiveness

To what extent have the objectives of the Regulation been met? To what extent can the observed effects be attributed to the Regulation and its individual elements?

It can be concluded that the Regulation has been effective in meeting its original objectives. The individual measures of the Regulation have worked together in order to meet the objectives and the effectiveness of the Regulation as a whole would have been impacted if one or more of the measures had not been included. The effectiveness of the Regulation in meeting the specific objectives is outlined below.

Objective 1: Discourage the use of F-gases with high GWP in the EU and encourage the use of alternative substances or technologies when they result in lower GHG emissions without compromising safety, functionality and energy efficiency

The HFC phase down and prohibitions have worked together in order to discourage the use of F-gases with high GWP. The supply of HFCs has declined by about 34,000 tonnes from 2015 until 2019 equalling a 37 % reduction (- 47 % GWP of HFCs and unsaturated HFCs and HCFCs).

There has been a shift to F-gas alternatives with lower GWP as well as natural alternatives, as demonstrated by the annual decline in CO_2 eq as of 2016. This has occurred in part due to the introduction of CO_2 (R744) in centralised systems and R290 (propane) in stand-alone system in the commercial refrigeration sector and the switch from R410A (GWP 2088) to R32 (GWP 675) in split air-conditioning systems. For the user, natural refrigerants have the clear advantage in that they are not subject to the Regulations.. The supply of unsaturated HFCs and HCFCs has grown to about 18,000 tonnes in 2019, reflecting the role of these substances as HFC substitutes. The transition is also going on in all other HFC using sectors, although at a (much) slower pace.

While HFCs in imported equipment remained rather constant since 2016 at about 10,000 tonnes, the GWP of those HFCs in equipment dropped by 33 % until 2019, in part as a result of R32 replacing R410A in AC. Quota-exempted amounts under the export exemption have been fluctuating, with the HFCs amounts for MDI use increasing by about 45 % from 2015 to 2019.

By its design, price increases for HFCs with high GWP (which are the main driver for an increased use of more climate-friendly alternatives) were expected as a consequence of the phase down. In practice, prices of high GWP HFC refrigerants have been strongly affected and have risen significantly in mid-2017 and early 2018 until reaching a peak of 6 to 13 times higher than the original price in 2015. The peaking of prices and subsequent decline observed over the past three years can be interpreted as a delayed reaction of the market and an overshoot of prices but could also be related to the increased use of low-GWP alternatives from 2018 onwards. Price of high GWP HFC refrigerants today continue to be several levels higher than the world market and continue to therefore be an incentive for innovation. In contrast, prices of lower GWP alternatives have remained rather stable, and in particular natural alternatives are still available at comparably low cost. However, there are claims that the effectiveness of the phase-down has been affected by the occurrence of illegal trade.

The phase-down has also influenced the reclamation of F-gases in the EU, resulting in a low, but steady increase between 2014 and 2018. Stakeholders agreed that the HFC phase-down has proven to be an effective measure, especially in combination with the prohibitions. Some stakeholders (workshop) suggested that the phase-down has been the most important measure of the Regulation as it provides flexibility and clarity, whilst also driving efficient change.

The POM and control of use prohibitions were implemented successfully and have been observed to have been effective. According to Article 19 F-gas reporting data, supply and/or equipment imports for respective applications have declined reflecting the implementation of these measures. This is partly related to the fact that the prohibitions have been easily understood by industry and end users and thus also contribute to overall awareness-raising. Good compliance with related provisions is found for fire protection and technical aerosols where provision dates already passed. For moveable and split air conditioning as well as foam products, the implementation is found to be on track while the prohibition dates are still in the future.

The successful transition in the face of prohibitions likely reflects that prohibitions were placed in sectors where suitable alternatives are available. This is supported by the fact that no derogations on the basis of 11(2) and 11(3) were made. The prohibitions efficiently avoided the use of HFCs in certain applications while facilitating the availability of HFCs where finding alternatives has been more difficult or costly in the context of reduced HFC quantities due to the HFC phase-down measure. Stakeholders also broadly agreed on the effectiveness of the control of use restrictions in meeting the objectives of the Regulation.

Reporting and verification have been key measures in the success of the Regulation in meeting its objectives. Data reported under the Regulation were mostly found to provide a reliable basis for monitoring how the EU industries react to the intervention, as shown in the completeness check carried out in the study for DG CLIMA. Reporting supports the detection of trends as the consequence of innovation and checking on compliance. The large increase in the number of undertakings reporting under the Regulation indicates the significant role it has played in ensuring that reporting and verification are implemented. The requirements have supported the aim of the phase-down, helping to ensure compliance with the quota system, and supporting consistency across industry. Exceptions relate in particular to reclamation and exports of F-gases in equipment:

However, there are also some gaps. Data collected for reclamation of F-gases was found to be incomplete as reclamation is only subject to mandatory reporting in case the reclamation is performed by undertakings which are also importers of F-gases. A self-standing reporting obligation for reclamation undertakings is missing. The Regulation does not contain mandatory reporting obligations related to exports of F-gases contained in products or equipment. The voluntary reporting option for HFCs supplied to equipment manufacturers for export has hardly been used. Thus, a reliable data base on F-gases exported from the EU insider products and equipment is presently not available. This is explored in more detail in the efficiency section. Furthermore, enforcement of the requirement to submit the equipment verification report has been noted to have been somewhat lacking.

Verification obligations for reporting data to be submitted according to Article 19 are in place, but can also be improved.

A range of additional actions going beyond the requirements of the Regulation have been observed at Member State level covering different measures, although what additional action is taken varies across Member States. Likewise, producer responsibility schemes have been implemented in some, but not all Member States. Where these have been implemented, they are considered to be working well by stakeholders, but direct data on their performance is lacking. A further area of variation between Member States is with respect to penalties. The variation of penalties between Member States is viewed as a challenge by stakeholders. This, in addition to some not being considered dissuasive, are observed to have been a facilitator of the issue of illegal trade. Although some Member States have established equipment registers, data from these systems are not (yet) commonly used for the UNFCCC reporting. However, strengthening the EU wide data on F-gas emissions is necessary to identify potential emissions sources and their significance.

Objective 2: Prevent leakage from equipment and proper end of life treatment of F-gases in applications

Leakage of F-gases from equipment is key to the success of the Regulation as any issues with containment can have a significant environmental impact. The Regulation has continued to address **prevention of leakage from equipment and the provision of proper end-of-life treatment**. Data available from surveys in some EU Member States have shown the importance of leakage regular leakage checks and associated servicing activities, especially in the retail sector. Data has been collected primarily through the use of surveys, national reporting systems (e.g. Slovakia, Poland) and electronic recording systems operated by national association (e.g. in Germany). These case studies can be seen as indicators also for EU-wide trends and impacts of the Regulation (even though the exact effects may differ from country to country) and show a reduction in leakage rates over time. However, enforcement and compliance with containment and leakage checks was raised by stakeholders as an area which required further attention to ensure energy efficiency.

The Regulation prohibits the intentional release of F-gases, obliges operators of equipment to take all technically and economically feasible **precautions to minimise leakages** and to have leaking equipment repaired by certified service technicians without undue delay. However, these requirements only concern F-gases listed in Annex I of the Regulation, while no such requirements apply to other fluorinated gases listed in Annex II, such as unsaturated NF_3, hydro(chloro)fluorocarbons, fluorinated ethers and alcohols and other perfluorinated compounds. Furthermore, the current prevention provisions do only apply to the use of bulk gases, but not to their manufacturing, storage and transport, where leakages can also occur.

In addition to measures to prevent leakages, the availability and uptake of training has further progressed, with a good number of personnel currently trained and the current level of training provided across industry considered to be appropriate to ensuring the safe handling of equipment. There is still further development required, particularly in relation to training on the safe handling of alternatives to F-gases. The availability of technical training could also be improved, with only a little over half of the current training centres able to offer this. There was also some evidence from stakeholders on the current challenges facing training programmes, with a number believing the current availability to be lacking or unevenly spread across Member States.

Objective 3: Facilitate convergence towards a potential future agreement to phase down HFCs under the Montreal Protocol

The Regulation has been successful in meeting its objective to facilitate convergence towards a potential future agreement to phase down HFCs under the Montreal Protocol. Prior to the implementation of the Regulation there was no international agreement in place to tackle F-gas emissions globally. The EU Member States were vocal supporters and advocates of the proposed Kigali Amendment at the Twenty-Eighth Meeting of the Parties (MOP) to the Montreal Protocol on Substances that Deplete the Ozone Layer, on the basis of the Regulation as EU consensus. The EU is considered to have led by example through the adoption of the Regulation. The Regulation enabled a joint European negotiation position and the tabling of an amendment proposal that provided crucial impetus for the negotiations. The Regulation was regarded by others as the ‘gold standard’, prompting action by Japan, Canada, and Australia, and US (at the time), and attracted considerable interest in China and elsewhere. It was therefore an important puzzle piece in driving the negotiations forward.

Objective 4: Enhance sustainable growth, stimulate innovation and develop green technologies by improving market opportunities for alternative technologies and gases with low GWP

With regard to the objective of the Regulation to enhance sustainable growth, stimulate innovation and develop green technologies by improving market opportunities for alternative technologies and gases with low or zero GWP, the Regulation is in line to meet this objective. As evidenced by some of the examples above, the HFC phase-down has been a strong trigger for innovation aided by some prohibitions addressing single substances or specific applications. Dozens of new blends, especially mixtures consisting of HFCs and unsaturated HFCs, have entered the EU market since 2015. Likewise, according to a report (Shecco, 2016), the number of undertakings working with natural refrigerants has increased from 400 to 650 since 2013. Furthermore, the report also found within the commercial refrigeration sector over 80 % of undertakings have increased their levels of investment in research and development within the last five years (2011-2016). It is expected that innovation and development of green technologies will continue to grow as a result of the prohibitions that will be introduced over the coming years, and the need to continue to reduce F-gas use in line with the Kigali Amendment worldwide.

What factors have contributed to or hindered the achievement of the objectives of the Regulation? What have been the unintended/unexpected effects?

Although the Regulation has been found to be successful in meeting its objectives, there certain aspects which were not foreseen to that extent when the Regulation entered into force that have affected the achievement of its objectives.

Illegal trade has emerged as one of the key issues with the potential to impact on the effectiveness of the Regulation and the functioning of the internal market, with some Member States experiencing greater number of cases than others. Illegal trade in F-gases involves activities such as smuggling, false labelling and misreporting of volumes, with non-refillable container use being of significant concern (this is explored further under Coherence). However, this issue is related to a combination of factors, including aspects related to the interaction between the Regulation and customs rules. All Member States have introduced penalties for non-compliance with the Regulation. However, the type and level of penalties vary between the Member States and may be ineffective when the same violation of an EU-wide system can be penalised differently depending on in which Member State it occurs.

A further key challenge are ***technically unjustified barriers in safety codes***, i.e. safety codes being more restrictive than would be needed on safety grounds, which was considered by stakeholders to be the most serious challenge facing the implementation of the Regulation. There are currently recommendations to ensure EU harmony in this respect, with a view that a set of defined standards as an EU baseline will help to support the transition to sustainable technologies.

A **lack of awareness** remains a more minor challenge, and is likely to predominantly relate to the awareness of the availability of alternative technologies, training and safety standards.

On the other side of the coin, as the Regulation has been seen to have had a positive impact on the development of the Kigali Amendment, so too the development of the international framework has been observed to have had a corresponding positive impact on the subsequent implementation of the Regulation. A key benefit to the Regulation from the Kigali Amendment is the creation of a more level playing field internationally.

In addition, the Regulation has had some unexpected effects. While substances replacing HFCs generally have a negligible GWP, and thus contribute to climate change mitigation, for a few of the replacement substances there may be some ***negative environmental effects*** that require further monitoring, such as the formation of persistent and bioaccumulative by-products.

Although the relevant data does not currently exist for 2020, there may be an impact on trade of products and equipment containing F-gases as a result of the ***Covid-19 pandemic***, however the stakeholder consensus on the potential impacts of the pandemic is broadly neutral, perhaps reflecting the uncertainty around the ongoing situation.

5.2 Efficiency

The efficiency criterion seeks to look closely at the costs and benefits of the Regulation. In addition, it aims to understand how these impacts accrue to different stakeholders, identifying what factors are driving these costs/benefits and how these factors relate to the EU intervention. Ultimately efficiency analysis seeks to draw conclusions on whether the total costs of all activities and across all actors under the Regulation are proportionate to the benefits achieved.

EQ3: What have been the benefits of the Regulation?

5.2.1 EQ3a. What environmental benefits has the Regulation delivered?

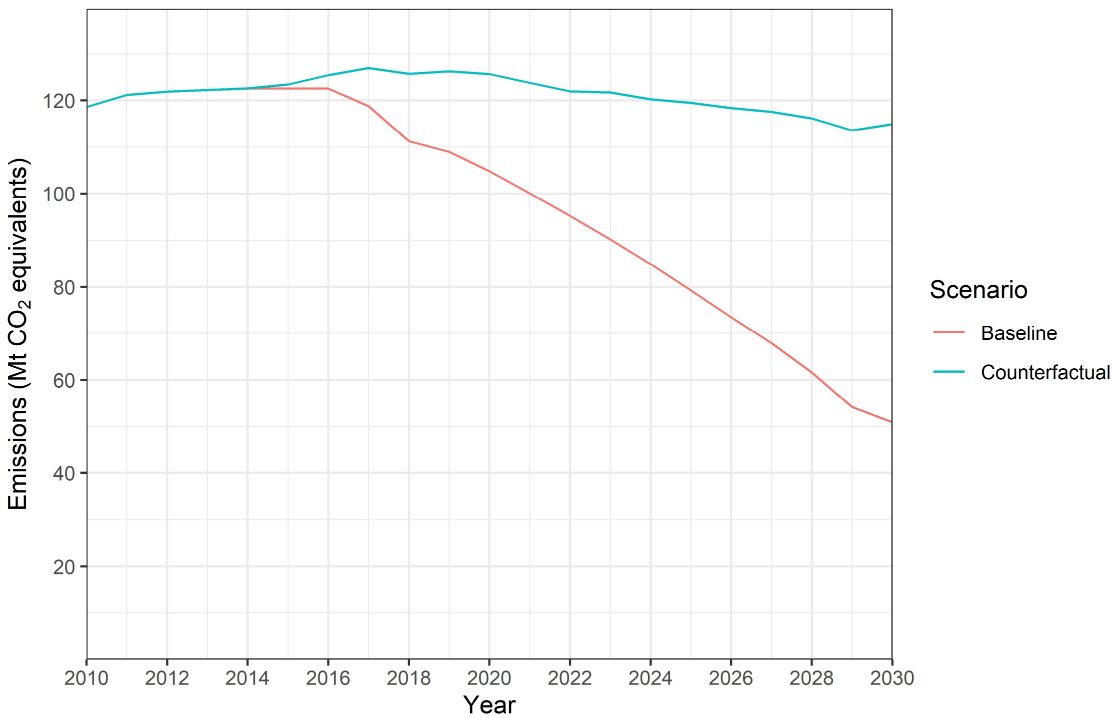
5.2.1.1 *Emissions of F-gases*

The key objective of the Regulation is to ***reduce emissions of F-gases***.

Figure 38 shows the total emissions of F-gases calculated by the AnaFgas model in the period of 2010 to 2030 in the EU27+UK under the baseline and the counterfactual scenario. Under the baseline scenario, the emissions increase until 2012 and then enter a plateau phase until 2016, from when a decrease in emissions can be observed until 2030. In contrast, under the counterfactual scenario, there is no incentive to reduce high-GWP F-gases (except MAC) and consequently, the emissions remain around 120 Mt CO_2 eq until 2030.

Cumulatively, until 2020, the Regulation led to a decrease in emissions of 64 million tonnes of CO_2 eq, or 5 %, in the EU27+UK (Table). Until 2030, the cumulative decrease in emissions in CO_2 eq is expected to amount to 495 Mt CO_2 eq, or 19 %.

Figure 38: **Modelled emissions of F-gases in CO_2 eq in the EU27+UK from 2010 to 2030 under the baseline and the counterfactual scenario**



Source: AnaFgas modelling

Table 37: Modelled emissions of F-gases in the EU27+UK from 2010 to 2030 under the baseline and the counterfactual scenario

Scenario	Unit	2010	2015	2020	2025	2030
Baseline	Mt CO_2 eq	119	123	105	79	51
Counterfactual	Mt CO_2 eq	119	123	126	120	115
Reduction	Mt CO_2 eq	0	<1	21	41	64
Reduction	%	-	<1%	17%	34%	56%
Cumulative reduction	Mt CO_2 eq	0	<1	64	222	495
Cumulative reduction	%	-	<1%	5%	11%	19%

Source: AnaFgas modelling

The positive impact of the Regulation on reducing demand and emissions of F-gases is corroborated by respondents to the OPC. The vast majority of respondents suggested the Regulation has had either a ‘positive’ or ‘very positive’ impact on: contributing to the EU’s climate targets, facilitating agreement to phase down HFCs under the Montreal Protocol, discouraging the use of F-gases with high GWP in the EU, and preventing leakage and ensuring proper end-of-life treatment.

5.2.1.2 *Energy use*

The Regulation can also have an impact on ***energy efficiency and consumption*** as it incentivises the technological change in energy-using equipment, in particular in the RACHP sector.

In the AnaFgas modelling framework, final energy consumption of RAC equipment was calculated both for the counterfactual scenario (assuming the ongoing deployment of traditional HFC-based equipment in new installations) and for the baseline scenario (accounting for the energy efficiency of deployed low-GWP substitution options). The modelling assumes, in line with the design of the policy options for the Regulation (European Commission, 2012) that where replacement occurs, alternatives selected are at least as energy efficient as the equipment they are replacing.

Literature review has been undertaken to explore the strength of this assumption. The overall conclusion of this review is that recent innovation allows lower GWP alternatives to reach at least similar energy efficiency levels to the replaced F-gases. The Shecco EIA report (Shecco, 2019) and the 2015 Gluckman Consulting Fact Sheets to the UNEP Ozone Secretariat suggest that lower GWP alternatives are generally associated with a similar or improved energy efficiency for domestic and commercial refrigeration. An EIA Shecco report from 2018 highlights that a variety of energy-efficient, HFC-free refrigeration technologies are available on the market, and that: *‘Evidence shows that there are energy efficient solutions for any type of application and store format, guaranteeing reliable operation, lower operation costs, and proofing against future regulatory measures.’* This evidence supports the working assumption of the modelling. That said, the literature identifies that in some cases, adaptations may be required to ensure this is the case: for example, insulating foams may require some additional space for hydrocarbons as alternative to HFCs, to achieve the same insulating efficiency. For a detailed documentation of energy efficiency assumptions for the different technology options, please refer to the sector sheets in the Annex.

The modelling concludes on marginal savings of final energy use in the RAC sector in the evaluation period 2015 to 2019 which can be attributed to technological change induced by the 2014 revision of the Regulation (Table). Given the low intensity of energy savings (about 0.1 %), no quantification of linked indirect emission reductions has been attempted.

Stakeholders (workshop feedback) corroborated this calculated energy savings: some highlighted that energy-efficiency of home appliances and HVAC equipment has indeed improved over the implementation period (although this is more attributable to existing synergies with wider EU legalisation – e.g. Ecodesign and Energy Labelling). Others (workshop feedback) also noted that energy efficiency where alternatives are used is at least equivalent or even better than the best HFC systems, e.g. CO_2 systems in centralised refrigeration where these alternatives offer the opportunity to utilize heat recovery or even utilize spare compressor capacity to export heat. In any event, the reduction of direct emissions has not been resulting in a trade-off with energy savings initiatives, and synergies with e.g. eco-design have been exploited.

Table 38: Final energy use savings in the RAC sector

Sector	Final energy savings, 2015-2019 average	Final energy savings, 2015-2019 average
	GWh/a	% of final energy use in counterfactual scenario
Refrigeration	0.3	0.11%
Stationary A/C	0.7	0.17%
Mobile A/C	0.0	0.00%
Total RAC sector	**1.0**	**0.10%**

Source: AnaFgas modelling

Making sure that indirect emissions are further reduced, the Ecodesign Directive is developed in complementarity to the Regulation. Ecodesign regulations setting energy efficiency requirements for commercial refrigeration appliances will apply in all 27 EU Member States from March 2021. In October 2019, the EU Commission adopted Ecodesign implementing regulations for ten product groups including refrigerators with a direct sales function (terminology for commercial refrigeration appliances including fridges in supermarkets, vending machines for cold drinks)[47]. The latter are regulated for the first time and energy efficiency requirements result in a minimum Energy Efficiency Index (EEI) to be met, based on a Standard Annual Energy Consumption. Ecodesign requirements for minimum energy performance apply to air conditioners sold in the EU with a rated capacity of smaller than or equal to 12 kW for cooling[48]. Further Ecodesign rules relate to air heating and cooling products as well as high temperature process chillers. For these product groups they cover depending on the type either energy performance or energy efficiency[49].

5.2.2 EQ3b. What economic benefits has the Regulation delivered?

Evaluation has been undertaken using descriptive analysis, looking at the change of value added for the NACE sector 'Manufacture of non-domestic cooling and ventilation equipment (28.25)'[50] over time. This sector is considered as most representative for the EU industry sectors affected by the Regulation, representing approximately 80 % of the HFC demand.

A counterfactual scenario is constructed by applying three steps: First, for overall economic development by constructing a time series of the coefficient of sector 28.25 in relation to the development observed for total industry[51] was adjusted. Second, the trend for this coefficient prior to the revision of the Regulation is derived by a simple linear trend analysis for the years 2010 to 2014. Finally, the pre-

47 Commission Regulation COMMISSION REGULATION (EU) 2019/2024, 2019, laying down ecodesign requirements for refrigerating appliances with a direct sales function pursuant to Directive 2009/125/EC of the European Parliament and of the Council, https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=uriserv%3AOJ.L_.2019.315.01.0313.01.ENG&toc=OJ%3AL%3A2019%3A315%3ATOC

48 COMMISSION REGULATION (EU) No 206/2012, 2012, implementing Directive 2009/125/EC of the European Parliament and of the Council with regard to ecodesign requirements for air conditioners and comfort fans, EUR-Lex - 32012R0206 - EN - EUR-Lex (europa.eu)

49 COMMISSION REGULATION (EU) 2016/2281, 2018, implementing Directive 2009/125/EC of the European Parliament and of the Council establishing a framework for the setting of ecodesign requirements for energy-related products, with regard to ecodesign requirements for air heating products, cooling products, high temperature process chillers and fan coil unitshttps://eur-lex.europa.eu/legal-content/EN/TXT/?uri=uriserv%3AOJ.L_.2016.346.01.0001.01.ENG&toc=OJ%3AL%3A2016%3A346%3ATOC

50 According to the statistical classification of economic activities in the European Community of the NACE codes (https://ec.europa.eu/eurostat/documents/3859598/5902521/KS-RA-07-015-EN.PDF), this class includes: manufacture of refrigerating or freezing industrial equipment, including assemblies of components; manufacture of air-conditioning machines, including for motor vehicles; manufacture of non-domestic fans; manufacture of heat exchangers; manufacture of machinery for liquefying air or gas; manufacture of attic ventilation fans (gable fans, roof ventilators, etc.). This class excludes: manufacture of domestic refrigerating or freezing equipment, see NACE code 27.51; manufacture of domestic fans, see NACE code 27.51

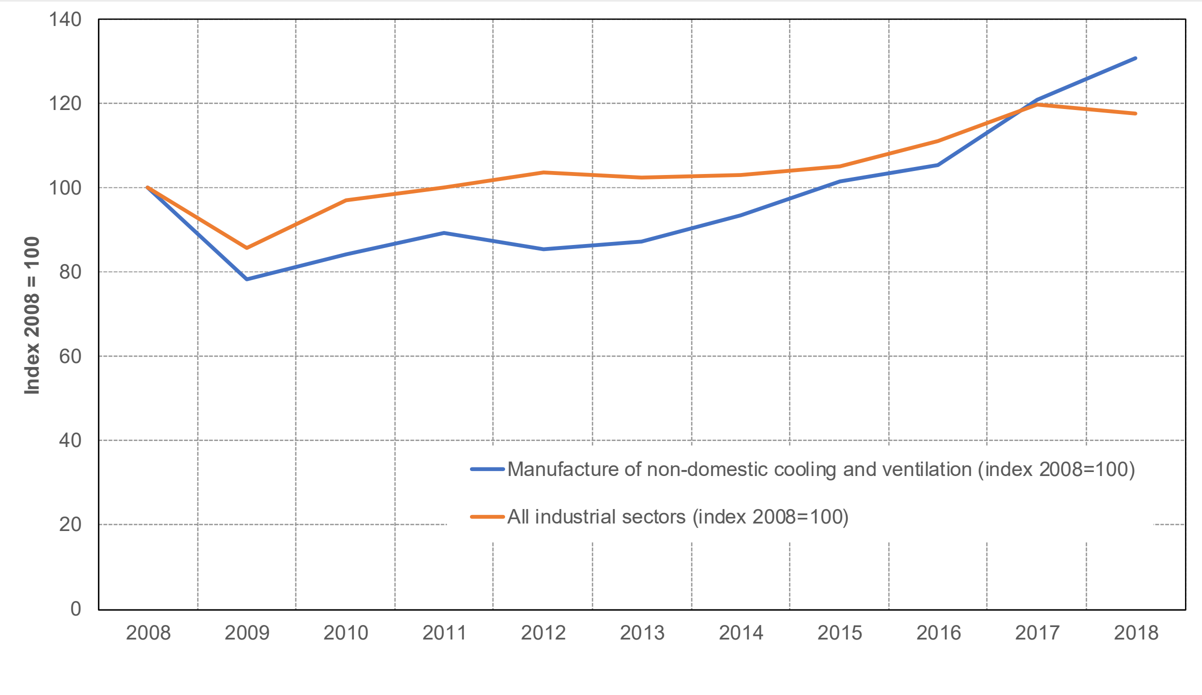
51 Total industry' includes NACE codes B mining and quarrying, C manufacturing, D electricity, gas, steam and air conditioning supply and E water supply; sewerage, waste management and remediation activities.

revision trend is extrapolated into the future to arrive at the counterfactual development for the years 2015 to 2018, with 2018 being the latest year that data is available for.

Figure 39 shows the development of value added for the sectors ‘Manufacture of non-domestic cooling and ventilation equipment’ and for total industry. Value added decreased more strongly during the financial and economic crisis in 2008/2009 in the manufacturing of non-domestic cooling and ventilation equipment and recovered more slowly than total industry. However, it has performed better with higher growth rates since 2014. The need for replacement due to high leakages, and prohibitions under the Regulation may have contributed to additional investment supporting that trend.

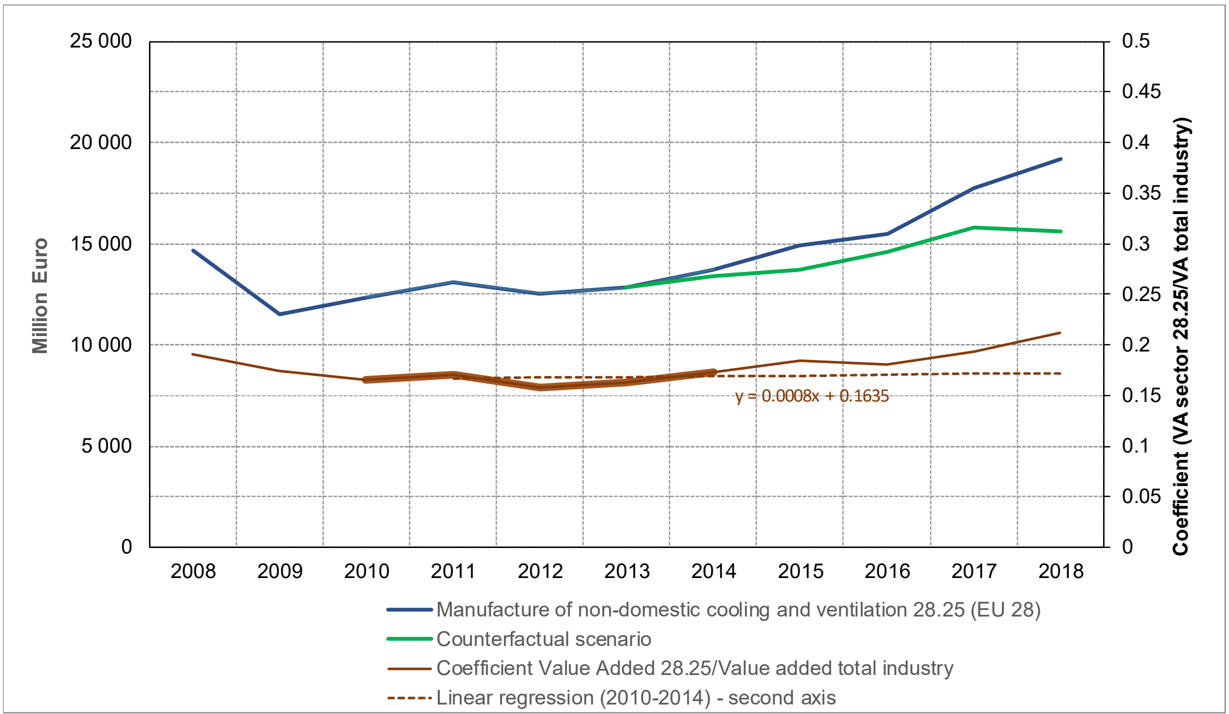
Figure 40 shows value added for the cooling and ventilation equipment sector in absolute values reflecting the indexed values above. To disentangle the development of the cooling and ventilation equipment sector from overall economic effects, the green line in Figure 40 shows how value added for the sector ‘Manufacture of non-domestic cooling and ventilation equipment’ would have developed from 2014 if the revision of the regulation had not taken place. The counterfactual was constructed by adjusting for overall industry development and applying a pre-regulation trend (considering the years 2010 until 2014). The coefficient and its linear trend for the years 2010 to 2014 that are used for the adjustment are also shown in Figure 40. Compared to the counterfactual scenario, actual value added has grown faster in the cooling and ventilation equipment sector since 2014.

Figure 39: Value Added (VA) Manufacturing of non-domestic cooling and ventilation equipment and all industrial sectors (Index 2008 = 100 (EU 28))



Source: Eurostat – own calculation based on annual detailed enterprise statistics for industry (NACE Rev. 2, B-E) [sbs_na_ind_r2]. Value added at factor costs.

Figure 40: Value Added (VA) Manufacturing of non-domestic cooling and ventilation equipment – actual development and counterfactual scenario (EU 28)



Source: Eurostat – own calculation based on annual detailed enterprise statistics for industry (NACE Rev. 2, B-E) [sbs_na_ind_r2], Value added at factor costs.

This analysis suggests that the EU industry, represented by the sector manufacturing cooling and ventilation equipment, may have profited from the revision of the Regulation – i.e. the introduction of the Regulation appears to align with a period of expansion for the sector over and above the trend observed for industry as a whole. In particular, the measure to include imported pre-charged RAC equipment into the HFC phase-down has prevented negative effects for EU industry. However, this result is based on simple descriptive trend analysis and is hence highly uncertain. It is important to note that this simple analysis has not fully accounted for all other variables which have influenced the sector over this period, and hence the trend cannot be disentangled from other influencing factors, such as demand for heat pumps from energy efficiency policy in the buildings sectors, general growth in demand for climate cooling, or other climate change or energy efficiency policies that lead to demand and investment responses. Such changes go hand in hand with the revision of the Regulation. Furthermore, this analysis is representative to the extent that the selected NACE code is representative of all industries influenced by the Regulation.

Further econometric analysis which regressed GVA in this sector against explanatory variables including a dummy for the introduction of the Regulation did not produce statistically conclusive results – i.e. the co-efficient on the Regulation variable was not statistically significant. That said, the co-efficient was positive (suggesting that the introduction had had a positive impact on GVA) and the results suggested that there was a low probability (< 20%) that the Regulation had had a negative effect on the sector. However, again it is important to note that this simplistic modelling has key limitations.

Outside of GVA, the Regulation may also have delivered economic impacts through its influence on investment, in particular in R&D. The impact of the Regulation on innovation and R&D is considered in detail under EQ1e in the effectiveness section. In summary, the market for natural refrigerants has continued to grow following the implementation of the Regulation.

5.2.3 EQ3c. What social benefits has the Regulation delivered?

Impacts on employment have been explored using a methodology analogous to the assessment for value added as described in *EQ3b. What economic benefits has the Regulation delivered?* As above, the change of employment for the NACE sector ‘Manufacture of non-domestic cooling and ventilation equipment (28.25)’ over time has been analysed. Employment in the cooling and ventilation equipment sector shows similar patterns to value added. Figure 41 shows the development of employment for the sectors ‘Manufacture of non-domestic cooling and ventilation equipment’ and for total industry. In line with value added, employment decreased more strongly during the financial and economic crisis in 2008/2009 in the manufacturing of non-domestic cooling and ventilation equipment than total industry. It recovered slowly and has performed better than total industry with higher growth rates since 2014.

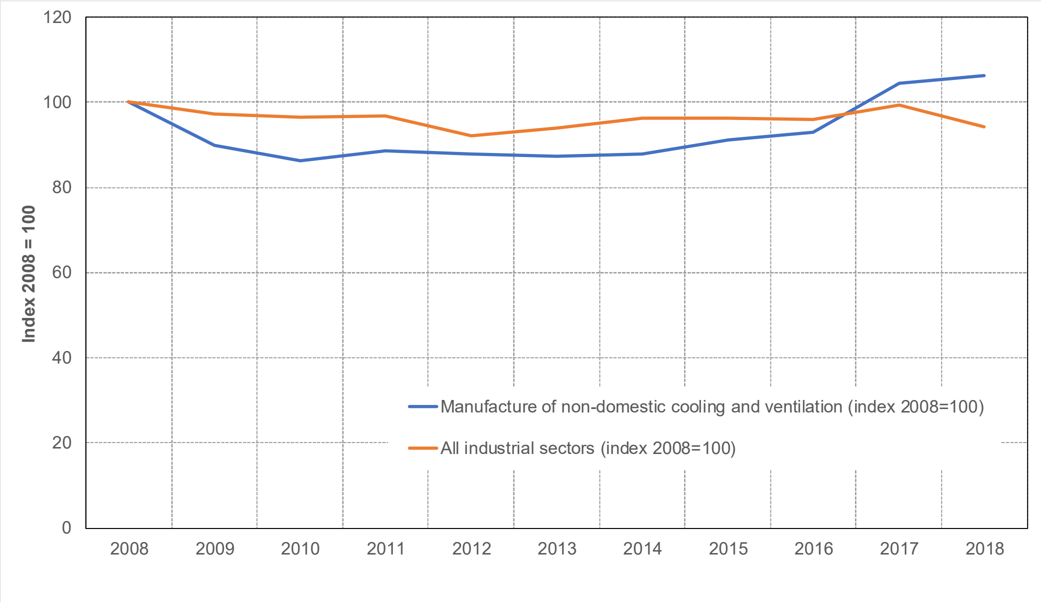
Applying the same methodology as for value added to derive the counterfactual scenario, we observe that employment performed slightly worse than the counterfactual trend scenario in 2014 and picked up thereafter with substantially better performance than the counterfactual scenario in the years 2017 and 2018 (see Figure 42). Although it appears that the Regulation may have had a positive effect on employment, the actual effect is highly uncertain.

Although this simple analysis appears to signal that the Regulation may have had a positive effect on employment, the actual effect is highly uncertain. The quantitative analysis cannot disentangle the effect of the Regulation from other influencing factors, such as the increase in demand for heat pumps driven by energy efficiency policy in the buildings sectors or other climate change policies. Indeed, the Regulation itself does not seek to increase demand for equipment and applications using F-gases but seeks to influence the nature of the refrigerant or substance used in these applications.

Stepping away from this simple analysis, several measures are likely to have directly impacted on employment: the requirement for leak checks to be performed by certified technicians, additional reporting requirements, the replacement of substances or equipment under prohibitions has all created economic activity, which carries with it employment effects. However, it is uncertain to what extent these effects are ‘additional’ – for example in the case of certified technicians, has this created new job roles or would these roles have been performed anyway by the same technicians, just uncertified. In addition, the clear impact of the Regulation on R&D expenditure, innovation and the development of low-GWP alternatives in the EU (see EQ1e) all implies additional employment benefits.

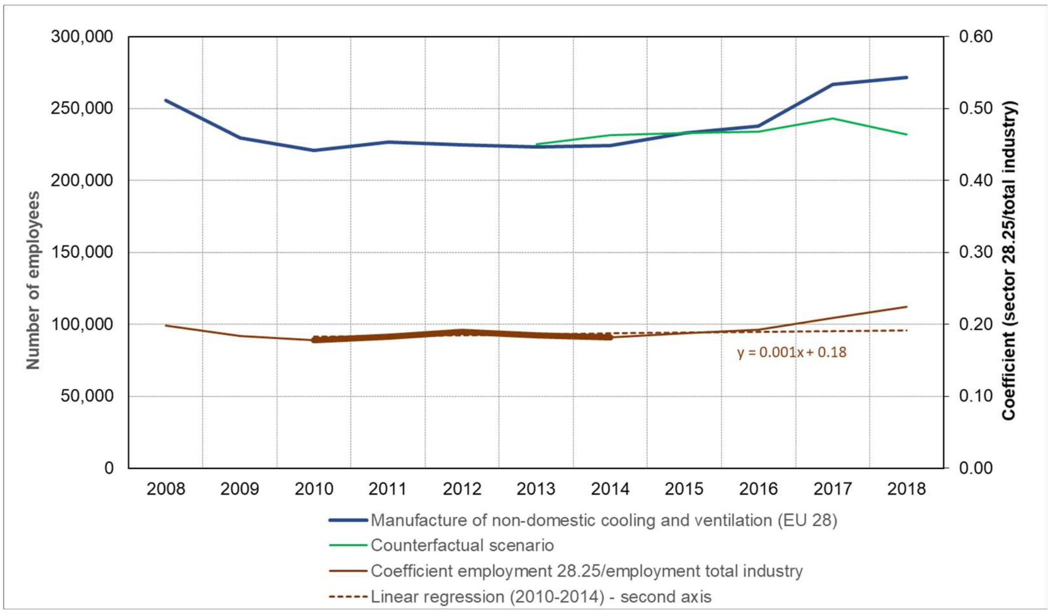
Some insights can be gained from the stakeholder feedback. The majority of stakeholders believed the Regulation has not impacted on the competitiveness of the EU industry. This opinion was common across all stakeholder types. As such, it could be concluded that on the whole the Regulation has not acted as a break on economic activity and employment. That said, in some specific cases stakeholders did highlight particular issues around employment. During the targeted interviews, industry stakeholders such as AREA and APPLiA underlined the general lack of qualified technicians that has been affecting heating and cooling sectors for many years. Out of the F-gas certified personnel, who have been trained in line with the minimum requirements set out by implementing acts, only few technicians are competent and experienced in the use of flammable, toxic and/or high-pressure alternatives.

Figure 41: Employment Manufacturing of non-domestic cooling and ventilation equipment and all industrial sectors (Index 2008 = 100 (EU 28))



Source: Eurostat – own calculation based on annual detailed enterprise statistics for industry (NACE Rev. 2, B-E) [sbs_na_ind_r2]. Value added at factor costs.

Figure 42: Employment - Manufacturing of non-domestic cooling and ventilation equipment – actual development and counterfactual scenario (EU 28)



Source: Eurostat - Annual detailed enterprise statistics for industry (NACE Rev. 2, B-E) [sbs_na_ind_r2]

EQ4. What have been the costs of the Regulation?

5.2.4 EQ4a. What has been the change in operative and other costs to businesses or undertakings? How are these costs split by sector and EU Member State?

Table 39: presents the average annual relative operative compliance cost (i.e. the difference between cost calculated in the baseline and counterfactual scenario) calculated for the evaluation period 2015-2019. That table presents first total equipment operators' compliance cost but also identifies

- the share of equipment operators' compliance cost which are due to the HFC price increase under the HFC phase-down and thus constitute a net profit in the businesses of the HFC supply chain and
- the equipment operators' cost of technological change, equal to the overall net compliance cost of affected EU industry.

Total equipment operators' compliance costs are also expressed as a percentage of equipment operators' total expenditures (totex) calculated for the counterfactual scenario (i.e. percentage of totex without the revision of the Regulation). Data at sub-sector level are given in the Annex to EQ4a (Annex 9).

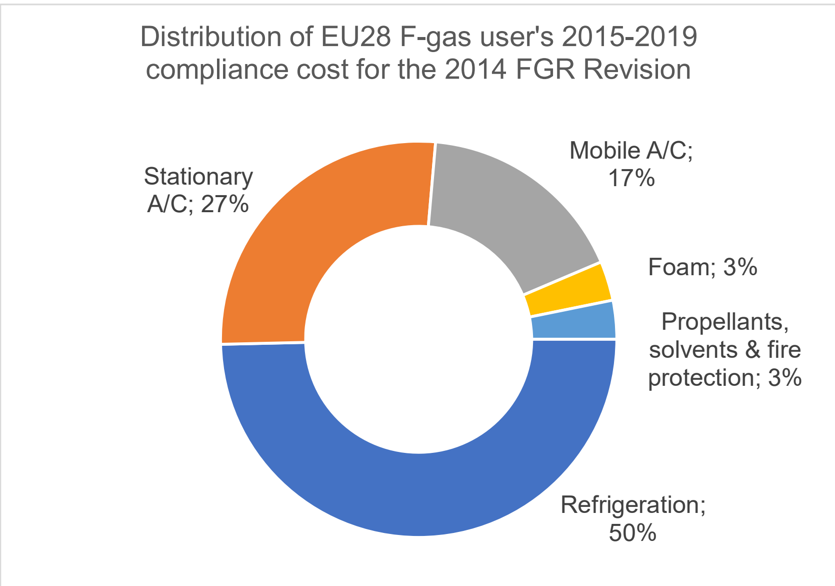
Table 39: Average annual relative operative compliance cost of Regulation to industry 2015-2019 (costs difference between counterfactual and baseline)

	Total equipment operators' compliance cost	thereof: cost of HFC price increase (= cost for equipment operators, =revenue in HFC supply chain)	thereof: Cost of technological change (= net EU industry compliance cost)	Total equipment operators' compliance cost
	Mio € / a	Mio € / a	Mio € / a	% of equipment operators' totex in counterfactual scenario
Refrigeration	1 075	723	352	2.3%
Stationary AC	581	530	50	0.7%
Mobile AC	374	370	4	0.3%
Foam	69	44	25	18.3%
Propellants, Solvents & fire protection	69	40	29	0.01%
Other HFC sectors	-	-	-	NA
SF_6 sectors	-	-	-	NA
Total	**2 169**	**1 707**	**461**	

Source: AnaFgas cost modelling

The total average annual compliance cost of EU F-gas using industries in the 2015-2019 evaluation period are calculated at a level of 2,169 million €/a. The distribution between the key sectors of F-gas use, are visualised in Figure 43.

Figure 43: Distribution of EU27+UK F-gas user's 2015-2019 compliance cost for the 2014 revision



Source: AnaFgas cost modelling

The refrigeration sector covers 50 % of total cost, stationary AC 27 % and mobile AC 17 %. Foam and propellants, solvents and fire protection cover 3 % each.

Table 39: also shows the relation of the calculated total equipment operators' compliance cost to those industries' total expenses related to the investment in and operation of the affected equipment: In the refrigerant and air conditioning sectors, accounting for approximately 94 % of total cost in 2015-2019, the compliance costs are equivalent to about 0.3 % - 2.3 % of total cost. In the foam sector, the cost increase was substantially higher at about 18 %[52]. For the HFC use as propellant, solvent or fire suppression agent, the cost increase is about 0.01 %[53]. Note that the price increases in relative terms are hardly comparable across sectors as the role of HFCs in the respective value chains is very different.

Only about 20 % of total F-gas users' compliance cost is directly due to technological change (see Table 39:), i.e. for industry switching technologies from HFCs to low-GWP substitutes in order to comply with the Regulation's provisions.

About 80 % of EU end users' compliance cost in the 2015-2019 evaluation period was due to HFC price-related cost to those parts of the industry which did not (or not yet) fully switch to low-GWP alternatives. That share was particularly high in the first years of the phase-down, as those years were characterised by still high shares of operated equipment relying on established HFC technologies, and technology change just starting for new equipment. In a sectoral view on EU F-gas end users, the share of HFC-price-based compliance cost in total compliance cost was higher for those sectors which showed less technological change. However, this is the way in which the phase-down was intended to operate: Higher prices will eventually promote the use of alternatives also in these sectors.

As visible in Table 39:, the respective shares of technology change cost and HFC prices vary by sector: the share of HFC prices is highest in the mobile A/C sector and in the refrigeration sector. For the mobile air conditioning sector, it should be noted that a large part of these costs relates to servicing of older passenger cars, whereas newer cars are using a climate friendly refrigerant which is not an HFC and thus not covered by the quota requirements. The shift away from HFCs is a result of the MAC Directive from 2006. For other mobile air conditioning applications, hardly any technological change has yet been triggered by the Regulation. For the refrigeration sector, technological change was cost-effective even without considering higher HFC prices induced by the HFC phase-down, resulting in negative cost for technological change in various subsectors (see Annex to EQ4a (Annex 9)).

The HFC-price related share of the compliance cost at F-gas user level is based on an average 2015-2019 HFC surcharge of 8 €/t CO_2 eq at OEM purchase price level, or 16 €/t CO_2 eq at service company selling level, concluded from the regular EU HFC price monitoring conducted by Öko-Recherche.

For a further discussion of distributional effects between the equipment operators and the businesses of the HFC supply chain, please refer to section 5.2.7.1, under EQ4d. Have there been any other (indirect) economic costs?

5.2.4.1 *Distribution of costs across business size*

Unfortunately, no reliable data is available to quantitatively assess the distribution of compliance cost across business size and possibly identify impacts on small and medium enterprises (SMEs).

[52] Key reasons are high cost for HFOs used as a replacement. It should be noted though, that in the present analysis only a niche-application part of the overall EU foam sector is considered in the AnaFgas model and thus in the present analysis. For full comparability with the data calculated for the RAC sectors, a recalculation of observed cost increases to the complete EU foam sector would need to be undertaken. This would result in far lower percentage than calculated here for the niche application of HFC-based foams.

[53] That low number is due to the consideration of pharmaceutical MDIs where the cost of HFCs is very low in relation to total product cost. As MDIs are exempted from the HFC phase-down no cost increase at all has been calculated for that sub-sector. If MDIs are not considered for the assessment of the propellant, solvent and fire sectors, an average price increase of about 13 % is calculated.

The impact on SMEs among equipment operators can be approximated by the compliance cost expressed in relation to counterfactual totex as given on aggregate level in Table 39: above, and on disaggregated level in the Annex to EQ4a (Annex 9).

A high share of SMEs is likely to be found among equipment importers and service undertakings. For both, however, no particular disadvantage is found: Equipment importers face basically the same surcharges on HFCs in equipment like EU OEMs[54]. Service undertakings do benefit from higher margins on HFC prices. However, they are required to get certifications on trainings for installations including to have skilled personnel to work with HFOs and natural refrigerants.

Stakeholders (workshop feedback) highlighted that the price effects have likely been a strong driver of the way costs have impacted different businesses, Namely, the profits from price rises have benefits HFC producers and quota holders more so than other elements of the supply chain.

5.2.4.2 *Distribution of costs across EU regions*

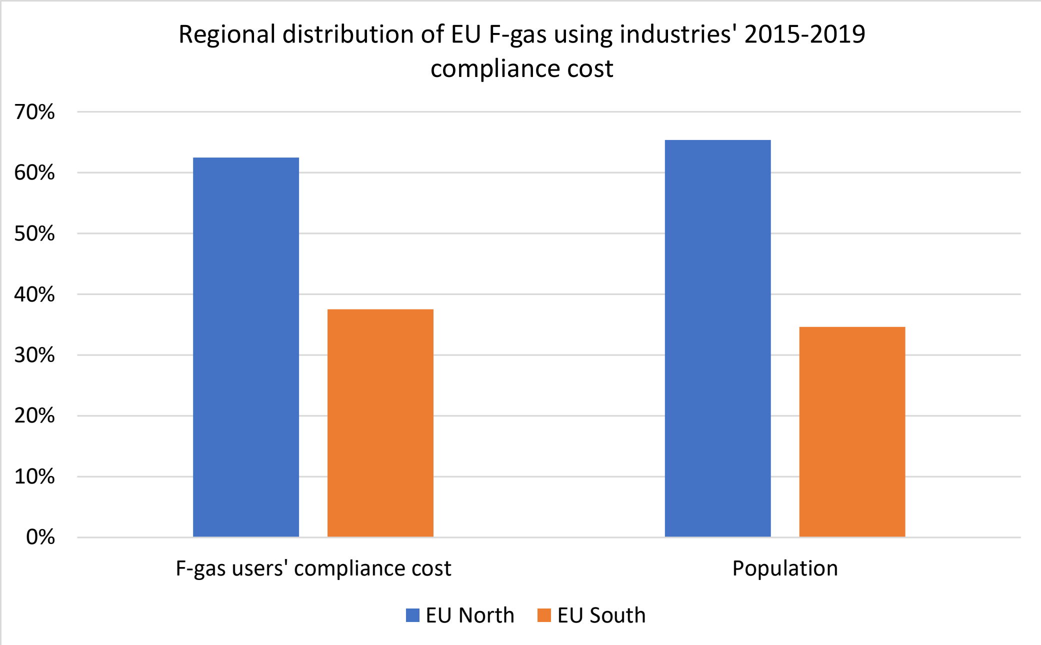
In the sub-sectors of domestic refrigeration, commercial refrigeration, transport refrigeration, mobile AC as well as for aerosols a large number of installations are affected by the 2014 revision and the type of equipment is relatively equally distributed among Member States. Investments in replacement technologies will show some variations: The use of natural refrigerants has been common in Northern European countries for many years, especially CO_2 technology in commercial refrigeration, so that a large number of installations have been running on alternatives for years. Furthermore, the structure of applications differs between Member States especially in the commercial refrigeration sector as small shop formats are more common in Southern Europe requiring different types of refrigeration and air conditioning systems than hypermarkets and large shopping malls.

However, stationary AC units as well as AC systems in buses and trams are more frequently used in warmer Mediterranean climate in southern Member States than in temperate climate in the north. Therefore, for these subsectors higher direct net costs will occur for Southern European countries: On the other hand, heating-only heat pumps are more frequently used in the northern EU region. Other subsectors concern very few installations in few Member States, such as halocarbon production plants and XPS foam blowing installations.

Figure 44 presents the distribution of cost between northern and southern EU Member states, in comparison to the distribution of population, based on sub-sectoral cost data as given in the Annex to EQ4a in Annex 9 and on assumptions on regional distribution of equipment stocks as given in Annex1.

[54] See discussion above in footnote **Fehler! Textmarke nicht definiert.**.

Figure 44: Regional distribution of EU F-gas using industries' 2015-2019 compliance cost



Note: EU South: Bulgaria, Croatia, Cyprus, southern France (25% of FR population), Greece, Italy, Malta, Portugal, Romania, Spain; EU North: other EU27 MS + UK, including 75% of the French population.
Source: AnaFgas cost modelling

The assessment shows that the southern EU region, representing approximately 35% of EU27+UK population has borne about 37.5% of total end-users' compliance cost. The northern EU region, representing about 65% of the EU 28 population, however, has borne only about 62.5% of total cost. Thus, in general, even if some regional effects may have taken place, the overall economic impacts are rather small and will hardly negatively or positively affect certain regions in the EU.

5.2.4.3 *Split of costs by measure*

The type of affected stakeholders are diverse and some measures are only relevant for some uses or sectors. The table below sets out a list of measures from the Regulation that entail costs for undertakings, alongside a description of the cost.

Table 40 – List of measures from the Regulation entailing costs for undertakings

Measure	Description of costs for undertakings
HFC phase-down and quotas (Articles 15 and 16)	Apply for quota Manage use within bounds of quota allocated, including investigation / replacement with alternatives
Article 14	Obtain quota authorisations Manage imports within bounds of authorisations obtained including investigation / replacement with alternatives
Registration (Article 17)	Register in F-gas Portal & HFC Licensing System
Placing on the market (Articles 11 to 13)	Investigate / adopt alternatives to products and equipment subject to prohibition
Containment (Articles 3 to 7)	Prohibit any intentional release of F-gases, that is not technically necessary. Operators of F-gas equipment must be taking all technically and economically feasible precautions to avoid emissions Undertake leak checks to required frequency, using certified personnel Repair leaks without undue delay Maintain a record for each piece of equipment
Recovery (Article 8)	Ensure recovery carried out by certified persons Ensure appropriate treatment of recovered F-gases
Certification and training (Article 10)	Personnel undertake training and undergo certification according to national rules
Labelling (Art 11)	labelling
Reporting (Article 19)	Report data specified in Annex VII on each of those substances for that calendar year Verify reporting (where applicable)

The stakeholder engagement offers some insights to the relative costs imposed by different measures (noting this likely covers all costs to operators, not just capex and opex but also administrative burden also). The table below presents the responses to the OPC where respondents were asked to assign a rating to individual measures according to how high the costs have been for businesses on a scale of 1 to 5 (where 1 is marginal costs and 5 very high costs). The table shows the average score across different business sizes, and for businesses as a whole (relative to all responses). The responses have been filtered to only include those respondees who are affected directly by each measure (to ensure the relevance of opinions).

Table 41 – Costs for businesses of each measure (scoring of OPC responses split by business size)

	Containment	Training and certification	Recovery and producer responsibility schemes	Labelling	Restrictions on use and equipment	HFC quota system	Reporting and verification
Micro (1 to 9 employees)	2.46	3.00	2.85	2.00	3.30	3.39	3.13
Small (10 to 49 employees)	2.71	2.82	3.14	2.08	3.00	3.31	3.17
Medium (50 to 249 employees)	3.00	3.16	2.91	2.18	3.00	3.50	2.86
Large (250 or more)	3.23	2.88	3.00	2.23	3.41	3.82	2.79
All Business	2.91	2.95	2.97	2.15	3.24	3.56	2.92
All	2.91	2.93	2.97	2.18	3.22	3.52	2.89

Notes: Rate from 1 (marginal costs) to 5 (very high costs)

In response to the OPC, respondents suggested:

- '*Restrictions on use and equipment'* and '*HFC quota system'* had presented the highest costs for businesses (with average scores of 3.22 and 3.52 respectively amongst all survey respondents, and 3.24 and 3.56 respectively looking only at responses from businesses.
  This result also holds across 2 of 4 of the business size categories. For 'small' firms, costs for *Recovery and producer responsibility schemes* ranked higher than *restrictions on use and equipment* and for 'medium' firms, *training and certification* ranked higher than prohibitions.

- *Reporting and verification, recovery and producer responsibility schemes*, *training and certification* and *containment* were all moderately scored.
  Reporting and verification was scored as less costly than the other moderate measures by the medium and large firms, but for micro and small business sizes this was the next highest cost measure (and was even the second ranked cost by small firms).
  For medium and large firms, *containment* was the next most costly measure after prohibitions and the phase down. Whereas for micro and small firms, *containment* was ranked as the second lowest cost measure.

- *Labelling* received the lowest score, with an average score of 2.18 across all respondents, and 2.15 across all business respondents. This result also holds across all business sizes.

This analysis suggests that all measures are likely to have inferred some costs to undertakings. Some measures are likely to have placed greater costs (i.e. phase-down and prohibitions), whereas some have placed lower costs on undertakings (i.e. labelling). However, the more costly measures are also those that are most effective in saving emissions. For some measures, it appears that the cost placed can vary by business size – for example reporting and verification costs were perceived to be more impactful for micro and smaller businesses (potentially as these imply the same requirements as for larger firms, but the costs for which can be spread across fewer activities), relative to containment which was more significant for larger firms (potentially as these costs vary with scale and larger firms undertake more of these activities/are affected by those). It is important to note again that the analysis above does not differ clearly between compliance and administrative costs. The average ratings also suggest that the costs were not perceived as exceedingly high (i.e. receiving either a score of 4 or 5 in the OPC) by most. This is in line with stakeholder responses that the costs of measures in general were justified by their benefits.

5.2.5 EQ4b. Which administrative costs have been incurred by undertakings?

Alongside the operative costs associated with compliance, such as investment in new equipment, the Regulation has also placed administrative burdens on several actors. This includes all actions associated with compliance that have an associated 'time cost', but not necessarily a direct financial outlay. These have been assessed through application of the standard cost model.

5.2.5.1 *Administrative costs incurred by industry*

Categories of administrative costs to industry resulting from the Regulation are outlined in Annex 9. The costs have been mapped to the actions required by industry due to the measures and requirements outlined in the Regulation under each Article. The OPC, targeted interviews and a written administrative cost questionnaire that was sent to the targeted interview respondents have been used to explore the level of administrative costs to business operators. Following the stakeholder workshop additional information on administrative costs was collected from a number of industry stakeholders.

The stakeholder consultation focussed primarily upon interviews and feedback from large business organisations, and it was therefore considered that the average costs collected would be representative of the costs borne by large companies. For some measures, the costs for large companies were expected to be equivalent to the costs borne by small and medium companies. In these instances, the costs collected through stakeholder engagement have been applied to the total estimated number of companies irrespective of size. For a number of other measures, the costs are expected to vary dependent based upon the level of activity of the firm, and the costs have therefore been adjusted accordingly. For these measures, firms have been grouped by size based upon ratio of different sized companies in the EEA reporting database. The approaches to determining the number of companies impacted by each measure has typically relied upon expert understanding of the sector, data collected through the BDR reporting database, and desk based research. An in-depth explanation of the overall approach taken, as well as a measure-by-measure explanation, is provided in the Annex to EQ4b.

The annual costs incurred by each firm have been based initially upon the feedback obtained through stakeholder engagement, which as noted has been associated with the costs for a large firm. Although these costs have provided the basis for the estimated cost for each measure, they have also been adjusted based upon expert understanding of the sector and the requirements of the measure. The final number of estimated working days was then calculated based upon the aggregated working days for each company. A cost of EUR 230 per day (based on an assumed average annual salary of around EUR 50,000, and annual days worked around 230) was then applied to calculate a total estimated cost. A summary of the evidence used in the calculations, and the results, is presented in the table below. The costs have been determined through a combination of stakeholder feedback and adjustments based upon expert knowledge of the sector. A more detailed table of the costs and approach taken is presented in Table 60 of the Annex.

Table 42 – Administrative burden split by measure

Measure	No. companies impacted	Calculated cost per firm affected* (€pa)			Total administrative burden (m€ pa)
		S	M	L	
Record Keeping (Article 6)	25,800	115	115	115	3
Training and Certification (Article 10)	9,400	230	230	230	2.2
Labelling and product and equipment information (Article 12)	4,700	58	115	230	0.3
Documenting compliance for pre-charged equipment with HFCs (Art 14)	2,900	1,552	3,105	6,210	4.8
Complying with the HFC phase-down and quota system and registration in the HFC Registry	1,700	856	1,712	3,424	1.5
Reporting and verification (Art 19)	3,000	757	1,514	3,028	2.4
Total		**3,600**	**6,800**	**13,200**	**14.1***

Notes: *No total is provided for cost per firm as not all firms are affected by all measures. Costs have excluded outliers reported by stakeholders. S/M/L = small / medium / large.

*Aggregate cost appears as

The average working days as captured through stakeholder feedback has been extrapolated to estimate the overall impact upon industry. The average total yearly working days required for industry was estimated to be approximately 61,400 (around 270 FTEs on the basis of 230 working days pa) across all of the relevant measures identified. Taking into account an estimated rate of €230 per day, this will result in a total administrative burden of €14.1m. A detailed breakdown of the costs per each measure assessed is available in Annex 9, alongside an explanation of the approach used.

5.2.5.2 *Administrative costs incurred by public bodies*

EU Commission

Detailed data on the administrative costs incurred by the EU Commission have been provided by DG CLIMA. When providing the costs, EU Commission services noted that this was the current situation and that initially costs had been around 3.5 full time equivalents (FTEs[55]), increasing to 5 FTEs by

[55] One Full Time Equivalent (FTE)) assumed to be equivalent to one employee working 230 days annually

2019. The most significant number of working days has been associated with IT related aspects of the HFC Registry, as well as providing information on the implementation of the Regulation (including compliance) to stakeholders. The total number of working days required per annum has been estimated at 1100, with an additional 330 working days for IT support and a smaller number of working days provided as external support. This is a minimum cost, not counting costs by other DGs, e.g. TAXUD and OLAF on cross-cutting issues such as illegal trade. A detailed breakdown of the costs is available in Table 62 of the Annex.

European Environment Agency (EEA)

The data provided from the EEA are based on actual EEA time recording and invoice information from EEA's contractors. Based on the profile of days committed per annum for the separate actions and requirements of the EEA, the annual average administrative burden for the EEA would equate to approximately 330 working days. Table 63 in the Annex details the specific costs provided by the EEA for the time period 2012 – 2020.

Member States competent authorities and customs authorities

For Member State competent authorities, a good base of data was collected on which an estimate of administrative costs could be made. In total 13 Member States provided information on administrative burdens, with six noting upfront costs. In order to extrapolate the figures to account for all EU Member States, the number of reporting companies in each Member State was determined using data collected from the 2020 EEA report[56]. The costs for the Member States which had not reported were then determined based upon the data collected relative to the proportion of reporting companies based in the Member State.

Using this approach, the total yearly costs across all Member State competent authorities and across all measures is estimated to be 8.8 million € (based on financial costs provided), or 58,300 working days (based on time effort provided) to ensure compliance with the Regulation (including small costs associated with guidance and awareness raising). The two separate costs have been based upon different sets of data collected through the engagement process.

In addition, a number of one-off costs were stated by Member States. The costs reported by Member States for several measures were initially reported as ongoing annual costs. However, upon review of the measures it has been determined that the costs to the competent authorities would more likely be borne as an initial cost, rather than an ongoing annual cost. The analysis found that:

- Member States explicitly reported a total of approximately **€1m upfront costs** (reported by seven Member States). This figure excludes the costs provided by Italy and has not been extrapolated to all MS.
- Alternatively, Member States expended an **estimated 20,100 working days initially** as a result of the measures. This figure reallocates some of the costs reported as ongoing, and has been extrapolated following the methodology applied to ongoing costs.

Annex to EQ4b contains a detailed breakdown of the measures which have been determined to incur an initial cost, as well as the range of costs provided by Member States through the consultation process.

It should be noted that the above costs have been estimated based upon all measures for which Member State authorities indicated they incurred administrative costs. However, there are a number of measures for which it is expected that there would be either: a) a proportion of cost already incurred under the 2006 Regulation; b) the costs are not wholly attributable to the F-gas Regulation or c) the costs stated include enforcement or implementation costs. As such, the estimate above is likely over-

[56] Fluorinated greenhouse gases: Data reported by companies on the production, import, export and destruction of fluorinated greenhouse gases in the European Union, 2007-2019, 2020, 2020, EEA

stated estimate of the true cost associated with the 2014 Regulation. Based on the data available, it is not possible to make an accurate estimation of the additional costs.

5.2.6 EQ4c. What have the environmental costs of the Regulation been?

Although the primary objective of Regulation is to reduce emissions and provide an environmental benefit, there is the potential that actions in response to the Regulation could have a negative environmental impact. A detailed discussion on potential cross-media effects and toxicity of F-gases, substitutes and their atmospheric decomposition products is captured in section 5.1.8.4 under EQ2b. Have there been any unintended/unexpected effects of the intervention, including on trade of F-gases? This section concludes that for a few of the replacement substances there may be some environmental effects that require further monitoring.

In addition, one stakeholder representing national cross-sectoral Craft and SME federation (workshop) highlighted a potential negative impact on volumes of waste as a consequence of the incentives provided by the Regulation. Specifically, equipment within which F-gases are used may have a lifetime of 20 years, as such at the end of life this may not necessarily be the best available technique but if maintained well can be used until end of useful life, maximising resource efficiency. However, where there is an incentive to replace equipment before end of useful life, modern equipment does not last as long, increasing volumes of waste. That said, the stakeholder did not provide any evidence how significant this issue had been over the appraisal period.

5.2.7 EQ4d. Have there been any other (indirect) economic costs?

5.2.7.1 *Distributional effects between equipment operators and undertaking of the HFC supply chain*

As discussed in section 5.2.4, the cost to F-gas using industries (equipment operators) due to HFC price increases are reflected as revenues without associated cost in the HFC supply chain.

An increase in HFC prices is the essential mechanism of the HFC phase-down in order to efficiently incentivise EU end-users / equipment operators to switch from high-GWP HFC-based installations to alternative installations based on low-GWP alternatives as soon as cost-efficient alternatives are available in the respective sectors. Thus, the gas producers and gas importers, i.e. the undertakings which place the HFCs on the EU market and get allocated the limited amounts of required quota under the HFC phase-down, increase their selling prices and thus issue a price signal to downstream actors in the HFC supply chain, and subsequently to equipment operators, reflecting the scarcity of HFCs, measured in CO_2 eq, imposed by the HFC phase-down. Where not restricted by long-term contracts, both gas distributors and, further downstream, service undertakings apply surcharges on their respective purchasing prices when selling to their respective customers. The price signal reflecting scarcity, finally visible to the equipment operators, i.e. those undertakings making the investment decisions on future use of HFCs or low-GWP substitutes, is thus higher (in terms of €/kg or €/t CO_2 eq) than in the selling prices of producers/importers placing the HFC on the EU market[57].

In the AnaFgas modelling framework it was calculated how those additional revenues in the HFC supply chain were split between HFC producers and importers and HFC distributors on one hand, and service undertakings on the other hand (Table).

About 60 % of the HFC-price increase related cost to EU F-gas using industries 2015-2019 reflected as additional revenues for further upstream actors in the HFC supply chain, i.e. producers and importers

[57] For equipment pre-charged by OEMs (original equipment manufacturers) and then directly sold to customers (e.g. hermetic refrigeration equipment, movable AC units or vehicles containing an AC unit), the step of service undertakings is omitted in the supply chain at least for the first fill of such equipment.

of HFCs and the gas distributors. About 40 % of the equipment operators' cost due to HFC price increases is generated further downstream in the HFC supply chain by service undertakings providing a re-fill to compensate for leakages or, in some sub-sectors, the first fill[58].

Table 43: Average annual 2015-2019 additional revenues in the HFC supply chain

Total equipment operators' cost due to HFC price increase	thereof: additional revenue for producers, importers and distributors of bulk HFCs	thereof: additional revenue for HFC service undertakings
Mio € / year	**Mio € / year**	**Mio € / year**
1 707	**1005**	**703**

Source: AnaFgas cost modelling

The allocation of quota under the HFC phase-down is for free based on a grandfathering approach, complemented with a reserve for new entrants to be distributed evenly among all applicants. Unlike the EU ETS, where emission certificates are being auctioned, EU governments thus do not claim a fee which could possibly be re-distributed into the affected sectors with the aim to support the Regulation's objectives.

However, where the HFC-price related additional revenues end up with actual gas producers, this may possibly in return provide an opportunity to finance the development of new low GWP alternatives / refrigerant gases. However, such revenues incurred in the HFC supply chain are not likely to contribute to financing the development of equipment operating based on low-GWP alternatives or increasing the use of non-synthetic alternatives.

5.2.7.2 *Price effects*

Effects on consumer prices depend on the extent that the operators of F-gas using equipment pass through any additional costs they may experience. In few sub-sectors the equipment operators mostly coincide with private consumers (e.g. domestic refrigeration, moveable AC units, mobile AC in passenger cars). In most sub-sectors, however, the operators of equipment are undertakings which use such equipment in order to provide other goods or services to consumers, e.g. refrigerated products, air-conditioned office space or transport or IT services relying on fire-protected server farms.

Potential effects on consumer prices can be assessed based on equipment operators' relative compliance cost (i.e. the difference between cost calculated in the baseline and counterfactual scenario, see section 5.2.4, Table 39:, or the Annex to EQ4a (Annex 9) on more disaggregated level). Those relative compliance cost give an indication how much the usual operative cost of the respective equipment changed due to the FGR Revision. For those sector that exhibit negative relative compliance costs no effects, or even positive effects on consumer prices through reduced prices can be assumed. This is the case for domestic refrigeration and hermetic units in commercial refrigeration (see the Annex to EQ4a, Annex 9).

Effects on consumer prices in sub-sectors facing low but positive relative compliance costs will likely be comparable to those that are caused by volatile input prices anyway (e.g. for HFC-gases). With prices for HFC fluctuating strongly in the past, equipment operators continuously needed to adapt their cost calculation and decision on cost pass-through. The same rationale can be assumed to hold for low additional costs due in response to the revision of the Regulation. For the majority of sub-sectors, the calculated relative compliance cost was below 1 % (see the Annex to EQ4a, Annex 9).

For sub-sectors with higher relative compliance costs, the situation may differ. In order to recover their additional costs, affected entities may need to adjust consumer prices. However, such an adjustment process (i.e. the actual pass-through rate) depends on a variety of economic factors, such as the position in the market, competitiveness, profit margins. Moreover, the additional costs that are passed

[58] In sub-sectors where the first-fill is not provided by original equipment manufacturers (OEMs), the first fill of (tailor-made) equipment is provided by service undertakings.

through to consumers may represent only a very small cost share in overall production costs. For example, additional costs for refrigeration or air conditioning on ships are small compared to other operative costs for such vessels. Likewise, additional costs for large scale commercial refrigeration in supermarkets may be distributed among a large range of products and services and thus be negligible. Therefore, the overall/average cost effect per sector may be balanced and no cost pass-through initiated.

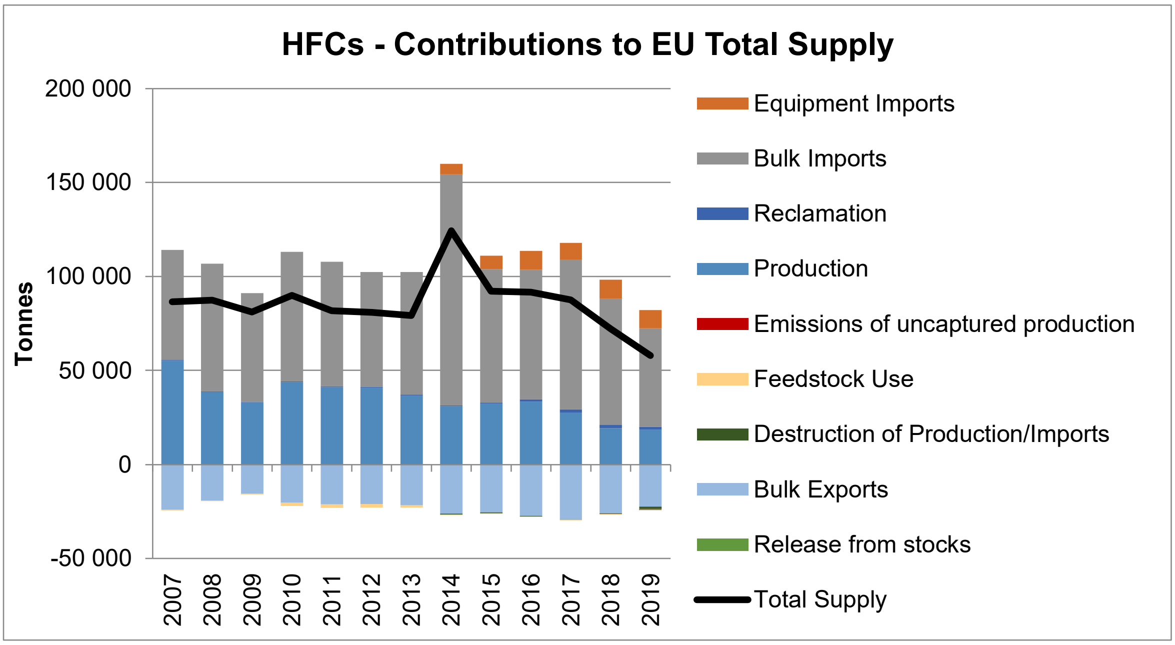
The relative compliance costs are highest in the foam and fire protection sub-sectors. Here, it should be noted that in both cases not the complete EU sectors were covered in the analysis but rather only those niche applications of the overall EU foam and fire protection sectors which used to rely on fluorinated gases as blowing agent or suppression agent. For the fire-protection sector, for example, HFC-based installations are usually used to protect particularly sensitive goods and high values.

In summary, due to the fact that: i) most sub-sectors have negative or very low relative compliance costs, that ii) compliance costs can be balanced within sectors (or applications) that iii) equipment operators have always had to cope with highly fluctuating input costs and that iv) cost of the F-gas using equipment often constitutes only a marginal share of overall system cost of the users, it can be concluded that the overall effect of the revised Regulation on consumer prices was not significant.

5.2.7.3 *External market effects*

The development of trade patterns for the F-gases most affected by the revision of the Regulation, namely HFCs (subject to multiple types of restrictions) and unsaturated HFCs and HCFCs (getting established as HFC replacements) can be analysed from Article 19 reporting data and from AnaFgas modelling results: Figure 45 presents the development of EU27+UK HFC supply since 2007 and identifies the contributions of different types of transactions (like production, imports, exports etc) which are added or subtracted for the calculation of EU supply as defined[59] in the EEA F-gas reports (EEA, 2020).

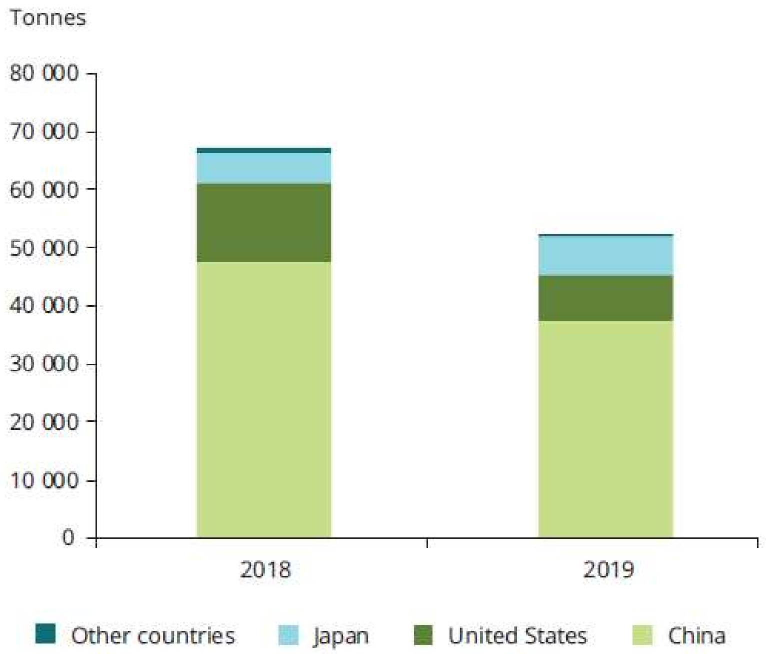
Figure 45: EU27+UK HFC supply by contributions of reportable transactions



Source: [EEA 2020 confidential dataset], own calculations

[59] Supply of fluorinated greenhouse gases (F-gases) is a metric used by the EEA that provides information on the actual use of F-gases by EU industries. It is calculated primarily from reported production, imports and exports. For a detailed documentation of the calculation of supply, please refer to Annex 4 of the 2020 EEA F-gas report [EEA 2020 public report].

Figure 46: Origin of EU bulk HFC imports (tonnes)



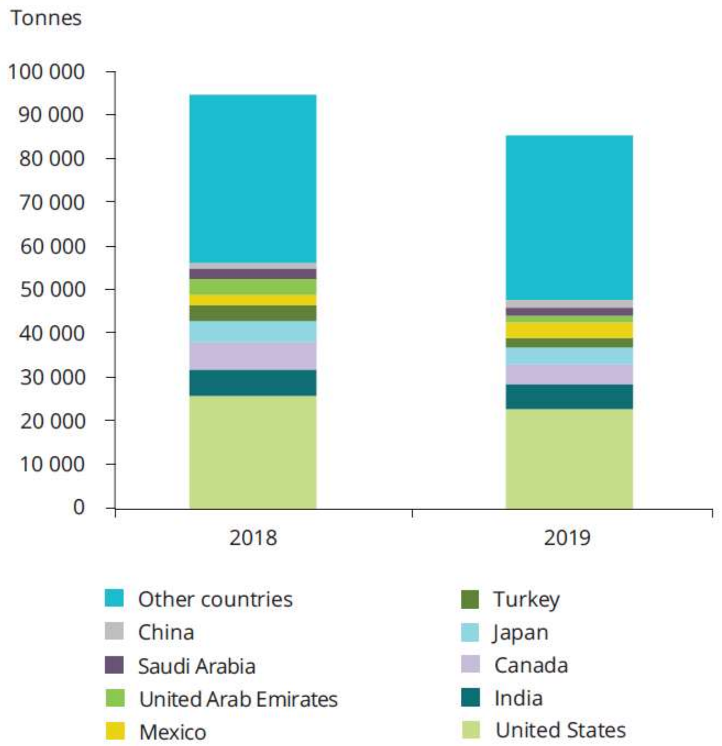
Source: [(EEA, 2020)]

As shown in Figure 45, the decline of EU HFC supply after 2015 was realised primarily by a decline of EU HFC production for domestic use, and after 2017 also by a decline of bulk HFC imports. Imports of HFCs in equipment (measured in tonnes of gas) have been stable since 2016, the increase observed for the 2014 to 2016 period was due to incomplete reporting before 2016. About 70% of HFC imports into the EU come from China, about 30 % from Japan and the United States, other countries of origin do not play a quantitative role (Figure 46).

However, total bulk EU HFC exports remained relatively stable (see Figure 47). The ratio of bulk HFC exports to HFC productions has been moving from about 50 % in the years before 2014 to more than 100 % in 2018 and 2019. Bulk EU HFC exports are mainly sourced from EU HFC production and from HFC imports for inward processing (e.g. blending of mixtures) and re-export. Those export-related trade patterns are hardly affected by the Regulation.

About one quarter of HFC exports from the EU go to the United States, another quarter is supplied to a set of eight more destination countries as displayed in Figure 47 while about one half of EU HFC exports is spread world-wide on a wide range of countries.

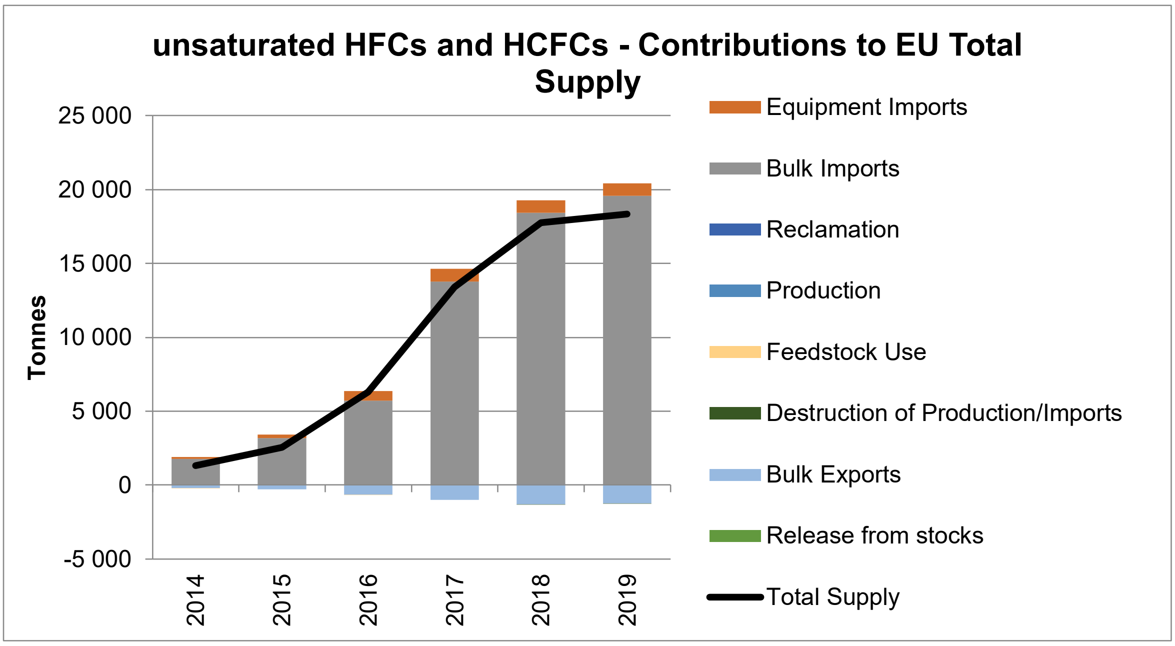
Figure 47: Destination of EU bulk HFC exports (tonnes)



Source: [(EEA, 2020)]

Figure 48 presents the EU27+UK supply of unsaturated HFCs and HCFCs since 2014 in the same format as Figure 45 does for HFCs: EU27+UK supply for these HFC replacements is fully dependent on imports. It should be noted that size of 2019 imports of unsaturated H(C)FCs (~ 20 000 tonnes, Figure 48) roughly equals the decline in bulk HFC imports (Figure 45) observed between 2015 and 2019.

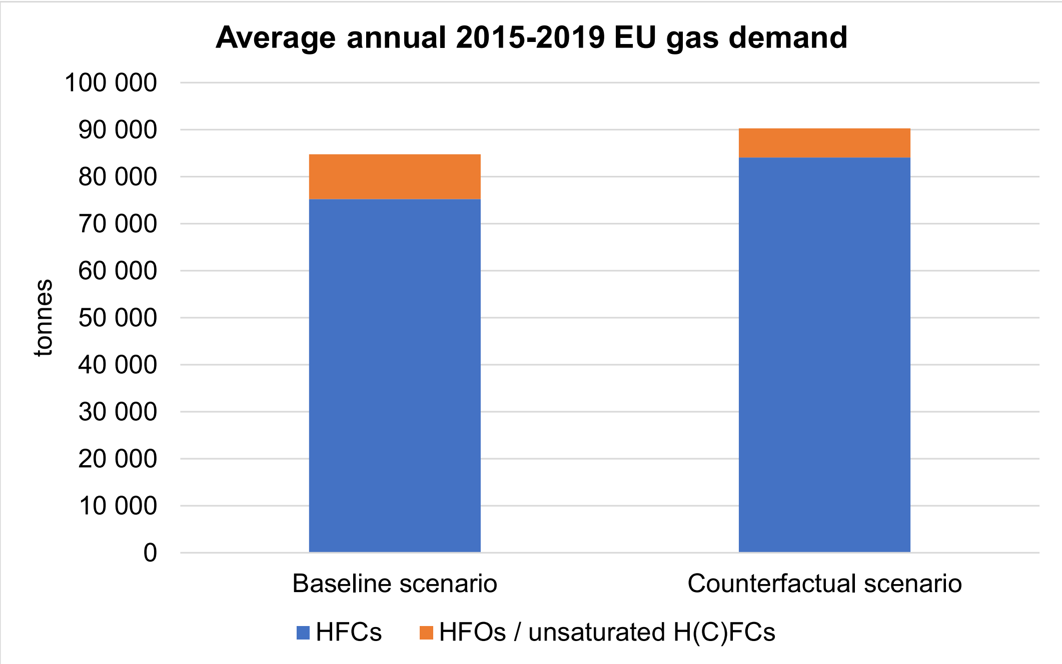
Figure 48: EU27+UK supply of unsaturated HFCs and HCFCs by contributions of reportable transactions (in tonnes)



Source: [EEA 2020 confidential dataset], own calculations

For an assessment of the impact of the 2014 FGR Revision on trade patterns the EU demand for HFCs and unsaturated HCF(C)s in the baseline and counterfactual scenarios are summarised in Figure 49.

Figure 49: Modelled EU27+UK demand for HFCs and HFOs in the baseline and counterfactual scenarios (in tonnes)



Source: AnaFgas

The average annual EU HFC demand 2015-2019 in the baseline scenario is about 9 000 tonnes or 11 % below the counterfactual, while for HFOs the average EU demand was about 3 500 tonnes or 55 % higher than the counterfactual.

The world-wide HFC market in the past years has been characterised by a tremendous growth of production capacities in China along with an expiration of patents accompanying HFC production. Chinese production capacities were reported not to be fully used (cf. e.g. (J.J. Zhang, 2017)). For a counterfactual scenario on EU HFC production, exports and imports, it can thus be assumed that the observed decline of EU HFC production (see Figure 45) was not solely a consequence of the 2014 FGR revision. Likewise, EU bulk exports in the counterfactual scenario are assumed to match the observed exports. The higher HFC demand in the counterfactual scenario would thus have been supplied by respectively higher HFC imports from China.

For HFOs, the EU supply is fully dependent on imports (see Figure 48). In the counterfactual scenario, the smaller HFO demand is thus reflected by less HFO imports than actually observed for the period 2015 to 2019. For natural refrigerants, data on external trade are not available.

In the overall balance of the EU's external HFC and HFO trade, the annual EU HFC imports in the period 2015 to 2019 evaluation period would have averaged about 9 000 tonnes higher without the Regulation, while EU HFO imports would have averaged 3 500 tonnes lower. In terms of mass of refrigerant, the additional EU HFO imports due to the Regulation account for about 40 % of the avoided HFC imports. In sum, the observed 2015 to 2019 EU imports of HFCs and HFOs were about 6 % (in tonnes of gas) lower than in the counterfactual scenario without the Regulation.

In monetary units however, the balance is reverse as HFOs are priced highly: The ratio of prices at distributor sales level per kg of gas, for the counterfactual scenario adjusted for EU-internal HFC surcharges due to the HFC phase-down, is roughly around 6:1 to 12:1. Based on these assumptions, the value of imported HFCs and HFOs 2015-2019 was approximately 15 % (90 Mio €/year) higher than it would have been without the revision of the Regulation. Those additional costs are covered in the cost of technological change as discussed above in the section on cost (EQ4a).

The conclusion that the Regulation has had at most a limited impact on trade is somewhat corroborated by stakeholders (OPC), who consider the Regulation to have had a neutral impact on competitiveness and at most, a slightly negative impact on trade with third countries (although the majority of stakeholders were unable to provide insight on the latter impact).

5.2.7.4 *Competitiveness*

The impacts of the Regulation on competitiveness can be discussed at several levels:

1) Competitiveness of producers of gases where the demand is affected by the revision of the Regulation, in particular HFCs and HFOs.

As discussed in section 5.2.7.3 on external trade, the FGR Revision did not significantly impact the production of F-gases. The remaining HFC production is mostly limited to specialty gases. It should be noted that EU HFC producers are also large-scale importers and quota holders, benefitting from the Regulation by profits due to risen HFC process as discussed above under EQ4a. Neither the export of gases was affected. Thus, no negative effect on competitiveness can be concluded.

2) Competitiveness of businesses active in the manufacture and maintenance of equipment that operates based on F-gases or low-GWP alternatives

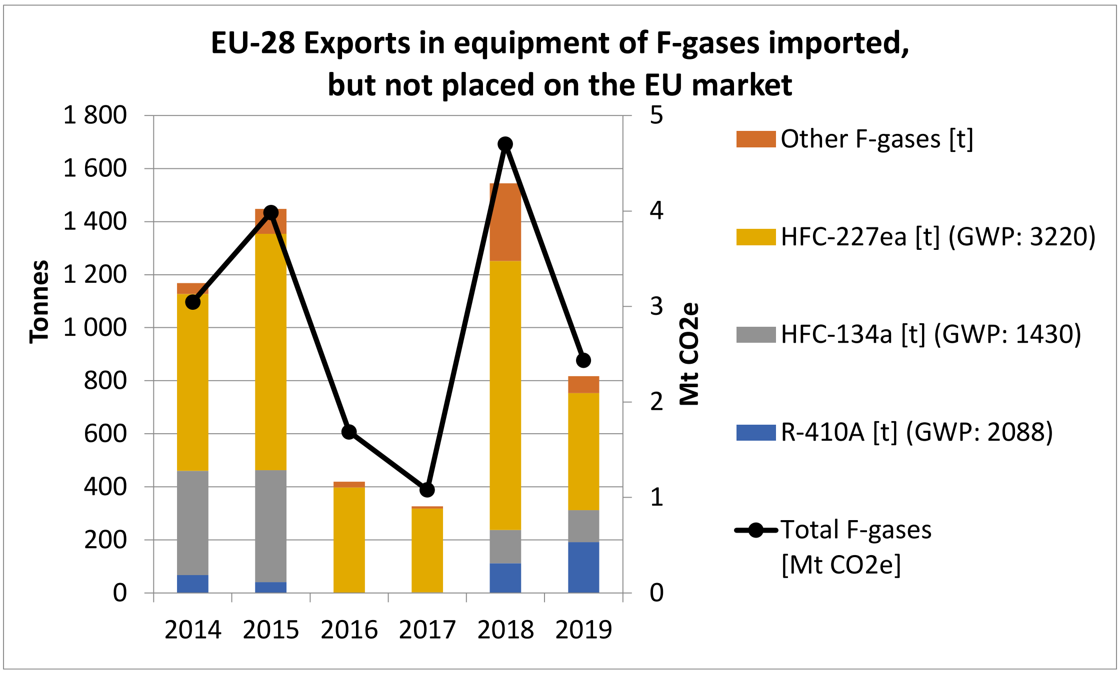
As discussed in section 5.2.2 on economic benefits, the trends observed for value added in the EU sector under NACE Code 28.25 'Manufacture of non-domestic cooling and ventilation equipment' do not give any indication that that the Revision had a negative effect. The Regulation has incentivised R&D and innovation related to equipment operating with low-GWP alternatives. This is likely to increase export opportunities, in particular, considering the Kigali Amendment to the Montreal Protocol, which will lead to a world-wide increase in demand in such technologies, however in a scheduled delayed to the EU HFC phase-down. For those undertakings in the EU equipment manufacturing sector which do manufacture pre-charged refrigeration, air-conditioning and heat pump (RAC) equipment a level playing field in relation to non-EU competitors was effectively provided under the Regulation by means of the inclusion imports of such equipment in the HFC phase-down under Article 14. Equipment not covered by Article 14 is hardly traded, as confirmed by the reporting data collected under Article 19. All of this points toward positive effects for competitiveness of EU manufacturers.

However, the competitiveness of export-oriented EU businesses could possibly have been negatively affected in cases where EU manufactures rely on HFCs to be charged into products or equipment to be exported: In case such EU manufacturers rely on HFCs which were placed on the EU market and are thus subject to the quota limitation and rising HFC prices, which could imply a competitive disadvantage on the non-EU markets in comparison to non-EU competitors with access to lower-priced HFCs.

However, first the disadvantage will depend on the how big a share the HFC costs are in terms of overall manufacturing costs, in general the share is not very high, see Table 39: (Annex to EQ4a in Annex 9 on sub-sector level). Second, in case the costs are relatively high the EU company may import HFCs under the inward processing customs procedure, charge those HFCs into the products or equipment and subsequently export those products or equipment without ever having placed the contained HFCs on the EU market. Thus, such imported HFCs would not require quota and thus would also not be subject to higher costs[60].

Figure 50: EU27+UK F-gas exports in equipment of F-gases imported, but not placed on the EU market

[60] However, moving to the inward processing procedure may limit the exporters' eligibility for special trade arrangements with third countries.



Note: Data relate to reporting category 2B: Amount imported into the Union by the reporting undertaking, not released for free circulation, and re-exported by the reporting undertaking contained in products or equipment (not in bulk).
Source: [EEA 2020 confidential dataset], own calculations

Reported amounts have been fluctuating since reporting started for 2014 at levels of approximately 0.5 % – 2 % of overall EU HFC supply, the key reported gas was HFC-227ea as part of exported fire suppression systems.

In addition, it is noted that the voluntary reporting option on gases supplied to equipment manufacturers for subsequent exports has not been used by EU undertakings except for two single reports on 2014 and 2015 on marginal volumes of gas. Thus, no statistical information on the extent of such export volumes is available. The voluntary reporting option[61] had been established in Commission Implementing Regulation (EU) No 1191/2014 determining the reporting format along with the clarification that the quota-exemption for exports according to Article 15(2)c of the Regulation applied to bulk exports only.

3) Competitiveness of businesses relying on services provided by F-gas-using equipment

As discussed in section 5.2.7.2 on price effects the Regulation is not likely to have any significant impacts on consumer prices. It can thus be concluded that EU undertakings relying e.g. on refrigeration or air-conditioning services in their respective businesses did not suffer a significant competitive disadvantage in comparison to non-EU competitors.

4) Innovation and first mover advantage

The higher price on HFCs has made climate friendly products more competitive in the EU and enabled undertakings, in particular in the refrigeration and air conditioning equipment manufacturing sector, to invest in innovation. These investments translate in to improved competitiveness for these undertakings.

5) Competition within the EU market

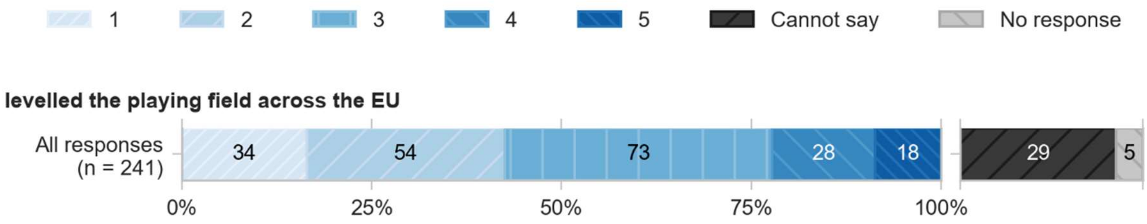
The EU HFC phase-down at EU level, implemented by a quota allocation system, not only increases the environmental benefit and reduces costs by setting an EU-wide cap, but also provides certainty on the allowed maximum quota quantity, creating a level playing field for market players operating in a

[61] BDR reporting section 5C_voluntary

single, integrated EU market. Likewise, the use of EU-wide placing on the market and use restrictions, and requirements for labelling and containment also contribute to this level playing field for the F-gas using industry and end-users.

This is corroborated by OPC respondents, who provided a broadly neutral response as to whether the EU had impacted 'EU competitiveness' (i.e. it had not had a positive or negative impact) and a slight bias in response in favour of agreeing with the statement that the Regulation had created a level playing field across the EU (public authorities, NGOs and EU citizens were more inclined to agree with this statement, whereas business associations were more neutral in response). Member States competent authorities also agreed through interview that the Regulation had avoided creating an imbalance in the internal market.

Figure 51: Survey response to the question: Has the Regulation levelled the playing field across the EU?



It can be thus concluded that generally the Regulation did not significantly impact the competitiveness of EU businesses in a negative way and may have improved the competitiveness of innovators.

5.2.8 EQ4e. What have the social costs of the Regulation been?

Alongside operational, administrative, economic and environmental costs, the Regulation could also deliver 'social' impacts, which are considered as part of this question. Changes in employment were considered under EQ 3c (section 5.2.3).

5.2.9 EQ5. To what extent have the costs been proportionate to the benefits?

In order to judge whether the Regulation has delivered value-for-money, it is important to compare the costs to the benefits – i.e. to what extent have the costs incurred been proportionate to the benefits achieved.

Table summarises the observed annual data on emission reduction and compliance cost on sectoral level as taken over from data presented in EQ3 and EQ4a. As discussed above a direct ratio calculated between cost and emission reductions shown in Table should not be considered 'emission reduction cost'. Table covers the respective amounts recalculated into comparable life-time averages according to the methodology discussed above and the thereof calculated emission reduction cost for the 2015 – 2019 evaluation period, as emission reduction cost for technological change.

Table 44: Observed average 2015-2019 annual emission reductions and operative cost increase

	Observed average annual emission reduction 2015-2019 compared to counterfactual scenario	Total equipment operators' compliance cost	*thereof:* cost of HFC price increase (= cost for equipment operators, =revenue in HFC supply chain)	*thereof:* Cost of technological change (= net EU industry compliance cost)
	Mt CO_2 eq / a	Mio € / a	Mio € / a	Mio € / a
Refrigeration	6.8	1 075	723	352
Stationary AC	0.8	581	503	50
Mobile AC *	0.0	374	370	4
Foam	0.6	69	44	25
Propellants, Solvents & fire protection	1.7	69	40	29
Other HFC sectors	-	-	-	-
SF_6 sectors	-	-	-	-
Total	**10.0**	**2 169**	**1 707**	**461**

Note: Mobile AC: Emission reductions due to the declining trend of the use of HFC-134a in AC units of passenger cars are assigned to the MAC Directive and are thus not accounted for the evaluation of the Regulation. Thus, the costs of low-GWP AC systems are not covered in the amounts given for cost of technological change. However, increased refill cost for users of old cars with HFC-134a based AC units are shown here as cost due to the HFC price increase.

Source: AnaFgas cost modelling

As discussed above, a meaningful comparison of cost to industry and emission reductions is restricted to the cost for technological change: The average ratio of the annualised technological cost relative to annual implied emissions savings is 6.4 €/t CO_2 eq (Table

Table). As suggested in the Better Regulation Guidelines, a discount factor of 4 % has been used.

Table also presents data at sectoral level. For the stationary A/C sector, average technology-related emission reduction cost is slightly negative. This means that based on observed trends for technology development investment in low-GWP alternatives for new equipment is in average less costly[62] than the traditional HFC-based options. For refrigeration, average emission reduction costs were at 10 €/ t CO_2 eq. For mobile AC, the calculated average emission reduction cost is very high at 94 € /t CO_2 eq.

[62] Given the calculation methodology the increased HFC prices under the HFC phase-down are not considered for that comparison: In the equipment operator's perspective, an investment into technological change / emission abatement is profitable if the reduction cost (defined as demand reduction cost are below the HFC price increase.

Table 45: Average emission reduction cost 2015-2019

	Implied lifetime-integrated emission reductions of new equipment installed in 2015-2019 average	Cost of technological change of lifetime-integrated emission reductions of new equipment installed in 2015-2019 average	Calculated emission reduction cost for technological change
	Mt CO_2 eq	Mio €	€ / t CO2 eq
Refrigeration	13.0	125	10
Stationary AC	5.5	-25	-5
Mobile AC	0.1	12	94
Foam	0.0	0	8
Propellants, Solvents & fire protection	2.5	24	10
Other HFC sectors	-	-	NA
SF_6 sectors	-	-	NA
Total	**21.2**	**137**	**6.4**

Note: Data on subsector level are presented in the Annex to EQ5 in Annex 9.
Source: AnaFgas cost modelling

Due to high costs and technical challenges, in that sector very little technological change and hence little emission savings were observed so far, mostly for AC systems for trucks and buses[63]. For the foam and propellant / solvents / fire protection sectors, technological emission reduction costs are calculated as 8 and 10 €/ t CO_2 eq, respectively, thus at levels close to the refrigeration sector.

Data for the calculation of emission reduction cost at sub-sector level are presented in Annex to EQ5 in Annex 9). For those sub-sectors where no emission reductions at all compared to the counterfactual scenario have been observed, a calculation of emission reduction cost is not possible.

The calculated emission reduction cost as presented in Table

[63] Note that the declining trend of the use of HFC-134a in AC units of passenger cars cannot be attributed to the FGR Revision but rather to the MAC Directive.

Table (and on sub-sector level in the Annex to EQ5 in Annex 9) are methodologically comparable to the threshold of 50 €/t CO_2 eq as considered in the 2012 impact assessment (European Commission, 2012) for the 2014 Regulation. The average the emission reduction cost of abatement measures taken in the 2015-2019 evaluation period (6.4 €/t CO_2 eq, Table) was far below that threshold. In the 2012 impact assessment, an average of 16 €/t CO_2 eq had been calculated as average emission abatement costs for the phase-down option, however based on calculations for the 2030 time horizon.

The cost-effectiveness of the Regulation is corroborated by the respondents to the OPC, who across the measures under the Regulation generally agreed that the benefits had outweighed the costs. The OPC is also able to provide insights into this trade-off for the individual measures, which is not possible from the modelling (and furthermore in theory presents a picture which includes all costs relative to benefits, not just capex and opex). From the OPC:

- For the key components of the Regulation, there was agreement that the benefits had outweighed the costs: almost 50 % of respondents suggested that the benefits outweighed (or significantly outweighed) the costs for the HFC quota system and for restrictions on use and equipment, and this proportion was greater than 50 % for containment
- For other measures, there was an even stronger response that the benefits outweighed the costs: training and certification, recovery and producer responsibility schemes, and labelling
- For the remaining measures, the predominant response was also positive: reporting and verification (24 % neutral, 36 % benefits outweigh costs), collecting emissions data (22 % neutral, 31 % benefits outweigh costs), national enforcement actions (21 % neutral, 27 % benefits outweigh costs).

5.2.10 EQ6. Are there any unnecessarily complicated or burdensome aspects and areas of excessive costs? What are the reasons and magnitude of any identified inefficiencies?

Although the Regulation appears to have delivered value-for-money, that does not mean that further improvement would not be possible, in particular to the cost burden. This question explores whether there are excessive costs which can be removed, but importantly without undermining the effectiveness of the Regulation. Broadly, very few areas of the Regulation were highlighted as overly burdensome and stakeholders (OPC) considered that the benefits of the different measures under the Regulation had outweighed the costs. The small number of specific elements that were highlighted are as follows.

As discussed in the effectiveness sections, the obligations for importers and producers to have their annual reports verified by an independent auditor do not appear balanced between HFC producers and importers of bulk HFCs on one hand and importers of equipment pre-charged with HFCs on the other hand. For equipment importers, the threshold for obligatory verification is 100 t CO_2 eq per year, equivalent for example to approximately 70 kg of refrigerant HFC-134a (GWP 1430). For bulk importers and producers, the threshold is 100 times higher, at 10,000 t CO_2 eq per year. Equipment imports, however, represent approximately 10 % of the total market.

In addition, other issues have been identified around reporting and verification that could signal administrative burdens are higher than they are needed to be. These are discussed further under EA1d above, but in summary:

- The lack of obligation for all registered undertakings to submit a 'NIL'[64] report leads to administrative burden for competent authorities when checking the reports which would be avoidable.
- Reporting and quota authorisation thresholds for placing pre-charged products and equipment on the market vary.

[64] A nil report is a notification by a company that it considers itself not obliged to report under the Regulation.

- Uploading of verification reports is not mandatory, this means an additional step is required for the competent authorities when checking compliance.
- For the BDR system, it was indicated that it is not very user-friendly and as English is the only user language available, this caused problems for some undertakings (especially smaller ones).
- The verification requirements were said to be difficult to understand in part, especially for smaller undertakings, but also verification undertakings. Although this reportedly results in lower quality of reports, more so than higher costs.

Average amounts of HFCs placed on the market per equipment importing company declined from 32 kt CO_2 eq in 2015 to 12 kt CO_2 eq in 2019 (see EQ2b for further discussion). For HFC producers and bulk importers those averages have been far higher: In 2015 the average was at 519 kt CO_2 eq per company, declining to 45 kt CO_2 eq per company in 2019. That decline was due to the increasing number of new entrant undertakings acting as HFC importers in relatively low volumes each. Due to the same trend, however, the 10,000 t CO_2 eq threshold since 2019 proved to be too high to ensure a nearly complete coverage of reported HFC placed on the market (POM) by verification: 8 % of POM supplied by 86 % of importers was below that threshold in 2019 (see analysis in effectiveness chapter).

Equipment importers and endusers raised the issue that they were asked to pay the bill while profits are made by gas importers and service companies. This is discussed under distributional effects above.

Several issues have also been identified related to the internal coherence of the Regulation (see EQ10 below) which could in theory lead to higher administrative cost. However no evidence has been found as to whether this has been the case in practice, and if so, how significant this excessive burden may be.

5.2.11 Conclusions on efficiency

The Regulation has delivered a range of benefits since its revision in 2014. First, until 2019, there has been a ***decrease in F-Gas emissions*** of 44, 43 or 51 million tonnes of CO_2 eq when using the GWPs from the 4th, 5th and 6th assessment report, respectively. Second, based on the substitution of alternatives forced by the Regulation, the modelling shows that ***energy efficiency was not compromised*** and small savings (<0.1%) may have been made (and review of the literature appears to support this assumption).

In terms of wider economic effects, the Regulation has not had any negative effects on production of F-gases in the EU, EU exports, GVA and employment and may even have led to an ***increase in GVA and employment*** from affected sectors, although the contribution of other factors is not clear. However, the FGR Revision did reduce the imports of fluorinated gases into the EU, as desired. Reacting to the switch from HFCs to HFOs and natural refrigerants, imports of HFCs and HFOs in tonnes of gas were about 6 % lower than they would have been without the Revision. Given the higher cost for HFOs, however, the value of HFC and HFO imports was about 15 % higher. What is certain is that industry has ***increased R&D investment*** and the wide range of new alternatives is representative of the ***high levels of innovation*** driven by the Regulation.

In order to produce these benefits, a number of costs are associated with the Regulation. The ***average annual compliance cost of EU F-gas using industries in the 2015-2019 evaluation period are calculated at a level of approximately 2,200 million €/a***. This is comprised of: the cost of technological change and the cost related to HFC price increases induced by the HFC phase-down instrument chosen in the Regulation (the latter costs are meant to stimulate innovation and can be avoided by turning to alternatives). As the 2015-2019 evaluation period is characterised by still high shares of operated equipment relying on established HFC technologies, and technology change just starting for new equipment, we see a ***high share of HFC price-related compliance cost*** (€ 1,707m pa) ***relative to the costs of technological change*** (€ 461m pa), in particular in those F-gas using sectors with rather slow technological change. However, the HFC ***price related compliance costs are equally***

offset by benefits to actors in the HFC supply chain. Hence although higher HFC prices, due to the phase-down, implied higher gas cost to end-users that were still using HFCs. These costs were on the other hand offset by equivalent benefits to undertakings in the HFC supply chain.

A complete analysis of how these costs fall across the industry was not possible, but some conclusions can be drawn around potential distributional patterns. About 94% of compliance cost relate to the refrigeration and air conditioning sectors. In those sectors, the compliance cost are equivalent to about 1 % of the total expenditures related to the investment in, and operation of, related equipment. Furthermore, as HFC quota under HFC phase-down are allocated for free, the additional profits remain with HFC producers and bulk HFC importers.

A regional analysis on cost distribution shows that the southern EU region, representing about 35% of the EU27+UK population was exposed to compliance cost slightly above proportion at about 37.5%.

Some measures ***place an administrative burden on different actors*** (industry, Member State Competent Authorities, the EC and EEA). That said, the total admin costs are much smaller than the cost of technological change. The annual average administrative burden calculated for the implementation period are m€19.2pa.

In terms of overall value-for-money, the calculated averaged ratio of the technological cost relative to emissions savings is about 6 €/t CO_2 eq. Emission reduction cost observed for the first years of the phase-down are thus below the average of 16 €/t CO_2 eq calculated for the 2030 time horizon in the 2012 impact assessment for the 2014 Regulation As such, it is concluded that ***the Regulation has resulted in significant emission savings at very low abatement costs linked to technological change****.* That said, the cost of action seems to vary significantly across sectors. However, the phase-down gives more time for the difficult sectors to switch, while the easy ones go early. As a result, there are little emission savings for some difficult sectors so far. The *cost-effectiveness of the Regulation is underlined by stakeholder feedback*, where OPC respondents did not signal that for any of the individual components the costs outweighed the benefits.

Finally, very few areas of the Regulation were found to be unnecessarily burdensome. An issue where improvements can be made to lower the burden while maintaining better control is in adjusting reporting and verification obligations between bulk HFC producers and importers and importers of equipment pre-charged with HFCs.

5.3 Relevance

This section seeks to examine whether the above-mentioned objectives of the Regulation are still relevant, i.e. meet the problems and needs of society with regard to climate change – both as identified at the time of its adoption and considering how they have evolved over time. If the Regulation no longer addresses these needs (or these needs have changed in the meantime or even ceased to exist) then it is no longer an appropriate intervention and policy makers may need to decide future actions based on whether to continue with it as it is, change certain aspects or to stop the intervention completely.

EQ7. To what extent do the objectives of the Regulation continue to reflect and respond to the needs of the EU?

5.3.1 EQ7a. Does the problem persist?

This question aims to examine whether F-gases continue to be emitted in the EU, resulting in a relevant impact to climate change. Two key data sources were used in the assessment of this question, namely data collected on the basis of the reporting obligations by undertakings under the EU Regulation as analysed in the annual EEA report (EEA, 2019), and by Member States under the EU Monitoring Mechanism Regulation (MMR)[65] as reported to the UNFCCC were taken into account.

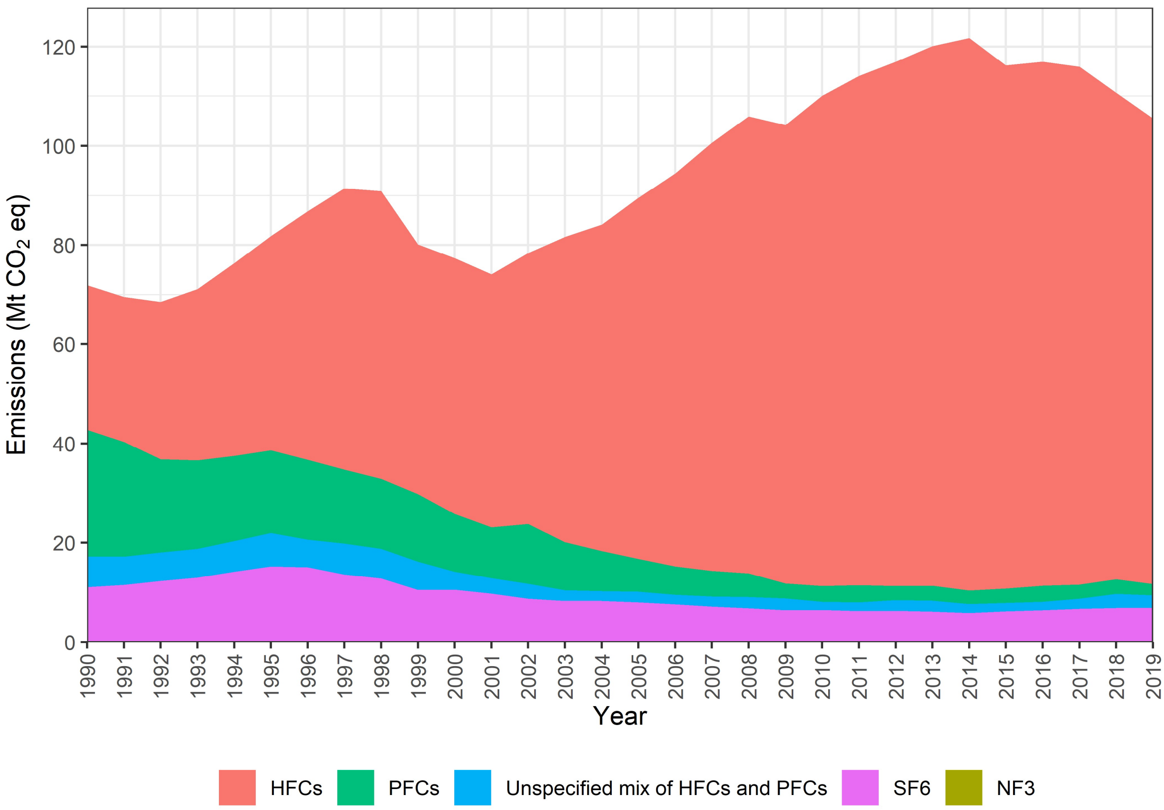
5.3.1.1 *F-gas emissions in the EU*

Although the Regulation has already shown initial effects in terms of reducing F-gas emissions in the EU, the emission level is still high and F-gas emissions continue as F-gases are still used in many applications, but primarily in the RACHP sector as also highlighted in section 3.1 of this report.

Figure 52 shows the development of emissions of HFCs, PFCs, SF_6 and NF_3. Emissions are represented as Mt CO_2 eq using the GWP values of the Fourth Assessment Report (AR4) of the Intergovernmental Panel on Climate Change (IPCC). The group of HFCs is still the most important among the F-gases, both in terms of quantity in tonnes and CO_2 eq, as EEA data show. F-gas emissions increased steadily since the 1990s. In 2014, a turning point was reached and emissions have been slowly decreasing since then.

[65] REGULATION (EU) No 525/2013 OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 21 May 2013 on a mechanism for monitoring and reporting greenhouse gas emissions and for reporting other information at national and Union level relevant to climate change and repealing Decision No 280/2004/EC

Figure 52: F-gas emissions in the EU27+UK from 1990 to 2019



Source: (UCFCCC, 2021)

The current Regulation sets the goal to reduce the total emissions of F-gases by 60 %, which means a reduction to 35 Mt CO_2 eq by 2030. Here it needs to be noted that this emission quantity applies to the EU27 plus the United Kingdom. The model output underlines that F-gas emissions have decreased overall in recent years, but that relevant emission volumes will continue to occur in the coming decades.

5.3.1.2 *F-gas supply*

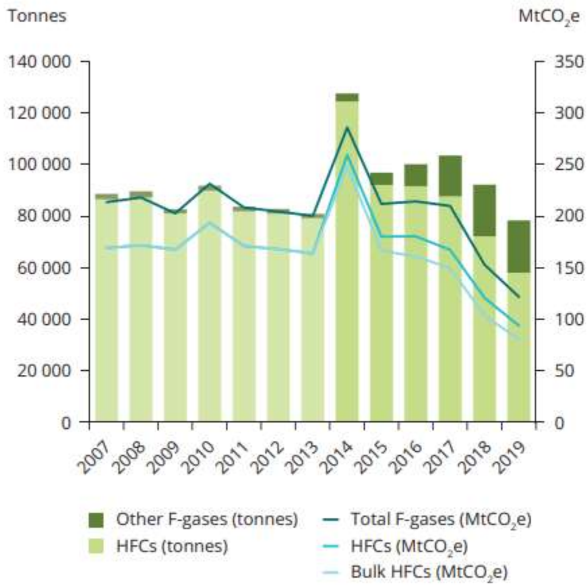
'EU total supply' as used as metric in the annual EEA F-gas reports is the sum of 'EU bulk supply' and 'EU supply in products/equipment' and provides information on the actual use of F-gases by EU industries. The EU total supply considers reported production, reclamation, bulk imports, imports in products and equipment, bulk exports, destruction, feedstock use and EU-based stocks from own production or import.

The 2020 EEA report reveals that there is still a significant supply of F-gases to the EU market, and thus the potential for future emissions. The supply of F-gases to the EU was relatively stable from 2007 until the peak in 2014, prior to the HFC phase-down came into effect. This was again followed by relative stability in the years 2015 to 2017, after which the supply of total F-gases has declined. When compared to 2015, the EU total supply of F-gases decreased by 19 % in tonnes and 43 % in CO_2 eq until 2019.

The supply of F-gases is dominated by HFCs, which accounted for 74 % in tonnes (with 61 % delivered in bulk and about 13 % delivered in products and equipment) and 77 % in CO_2 eq of the total in 2019. When measured in tonnes, unsaturated HFCs/HCFCs made up 23 % of supply, while only approximately 0.1 % in CO_2 eq. PFCs and SF_6 both accounted for about 1 % of the total in tonnes and for 4 % and 14 %, respectively, in CO_2 eq. Due to its high GWP, SF_6 is the most relevant species in climate terms after the HFCs.

The proportion of equipment imports in the total F-gas supply has increased over time and reached a level of 14 % in 2019 (or 11 % in CO_2 eq). Due to data confidentiality reasons, the share of unsaturated HFCs/HCFCs delivered in bulk and products and equipment is not published. PFCs, SF_6 and other gases are supplied almost exclusively in bulk. Therefore, the continued supply and use of F-gases in the EU not only contributes to today's emission release but also adds to the existing 'bank' of gases that will lead to emissions in the future.

Figure 53: EU supply of F-gases (EEA, 2020)



Due to the success of the Regulation in encouraging the use of lower GWP alternatives which have increasingly replaced conventional high GWP F-gases in various applications such as refrigeration and air conditioning, the average GWP of the EU F-gas supply could be reduced from 2187 in 2015 to 1552 in 2019, which presents a reduction of around 30 %. However, F-gases with high GWP are still widely in use and to meet the Regulation's reduction targets, including the HFC phase-down schedule, it is indispensable that the average GWP further declines.

5.3.2 EQ7b. Does the Regulation cover all relevant F-gases, sectors and sub-sectors that use F-gases, as well as all actors in the F-gas supply and use chain?

5.3.2.1 *F-gases covered by the Regulation*

In Annex I, the Regulation currently covers 19 HFCs, seven PFCs and SF_6. These gases are subject to the phase-down (HFCs only), placing on the market and use prohibitions, containment, labelling, reporting and certification requirements.

In addition, the Regulation covers other fluorinated greenhouse gases in Annex II that are to be reported according to Article 19 of the Regulation but are not subject to further emission reduction or containment measures. The listed gases include five unsaturated hydrofluorocarbons HFCs and HCFCs, 33 hydrofluoroethers (HFEs) and fluorinated alcohols and four other perfluorinated compounds, including nitrogen trifluoride (NF_3). The inclusion in Annex II ensures that these substances are annually reported and monitored.

Based on the literature review and stakeholder feedback from the targeted interviews and the OPC, additional substances currently not covered by the Regulation were identified (see following table) that have become relevant on the EU market or have started to be commercialised. While for some identified substances the areas of use are already known, for others this is not the case.

Table 46: Identified substances that are not yet covered by the Regulation

Identified substances	Comment
Perfluorodecalin ($C_{10}F_{18}$; GWP >7.500 (AR4))	PFC used in cosmetic and medical applications
Long-chain PFCs - C_5F_{12} - C_6F_{12} pp1c - 1,1,1,2,3,4,5,5,5(or1,1,1,3,4,4,5,5,5)-nonafluoro-4(or2)-(trifluoromethyl)pent-2-ene (C_6F_{12}) - C_6F_{14} - C_7F_{14} - C_7F_{16} - C_8F_{16} - C_9F_{16}pp3 - C_9F_{18} - C_9F_{20} - $C_{10}F_{18}$ pfd - $C_{10}F_{20}$ - $C_{11}F_{20}$ - $C_{13}F_{22}$ - $C_{12}F_{24}$ - $C_{14}F_{24}$ pp11 - $C_{16}F_{26}$ - $C_{17}F_{30}$	PFCs used or potentially to be used in various applications including electronics and semiconductor manufacture, as heat transfer fluids, for direct contact cooling, in medical research, insulation, tagging and tracing, as blowing agent for PU foams (C_6F_{12}) etc.
Sevoflurane (HFE-347mnz1, GWP 216 (AR5))	Inhalation anaesthetic
Enflurane (HCFE-235ca2, GWP 583 (AR5))	Inhalation anaesthetic
Cis-1-chloro-2,3,3,3-tetrafluoroprop-1-ene (HCFO-1224yd (Z))	Alternative to HFCs to be used as refrigerant in centrifugal chillers, binary cycle generators and waste heat recovery heat pumps, but also as blowing agent, aerosol solvent, and cleaning solvent (AGC Chemicals, 2016).
New unsaturated HFCs: such as isomers of difluoroethylene: - HFO1132(E) - HFO1132(Z) - R1132a	Unsaturated HFC used e.g. in electric vehicles
2,3,3,3-tetrafluoro-2-(trifluoromethyl)propanenitrile (C_4F_7N)	Alternative to SF_6 in electrical equipment (to be used in mixture with CO_2).
Perfluorinated polyethers (PFPE)	Working fluids in ORC installations, heat transfer fluids, vapour-phase reflow soldering in electrics and electronics manufacture, solvents. GWP: > 10,000 (Umweltbundesamt, 2021).
Perfluorotripropylamine ($C_9F_{21}N$)	Used as heat transfer fluid in the semiconductor industry. GWP: 8690 (Umweltbundesamt, 2021).
Perfluoro-N-methylmorpholine ($C_5F_{11}NO$)	Used as heat transfer fluid. GWP: 9500.
Perfluorotributylamine (PFTBA, FC43, $C_{12}F_{27}N$)	Used in electronics industry, for medical and analytical purposes. GWP: 7100.
Sulfuryl fluoride (SO_2F_2, GWP 4732 (AR5))	This substance is used to fumigate hardwood and softwood in containers destined for export. This is done to eliminate pests such as bark beetles. Despite its high GWP and increasing use, sulphuryl fluoride has not been regulated or monitored and is also not covered by any reporting requirements under the UNFCCC. The German Member State competent authority raised the issue of increasing use of sulfuryl fluoride in the targeted interviews, while mentioning that Germany will abolish the existing exemption for sulfuryl

	fluoride with regard to the use of exhaust gas purification devices, in the course of amending its national legislation on clear air.
Fluorinated ethers and alcohols: HFE-7300 (3M, 2009) (GWP 200); HFE-7100 (3M, 2009) ($C_4F_9OCH_3$; GWP 320), HFE-7200 (3M, 2009) ($C_4F_9OC_2H_5$; GWP: 55)	Used as heat transfer fluids, cleaning and rinsing agents for industry applications, carrier for lubricants and other specialized industry applications.
Fluorinated ketones and fluoronitrile blends: - Iso-C3F7CN (GWP 2100)	Alternatives to SF_6 in electrical equipment

Due to the lack of mandatory reporting, the extent of use of these substances and their emissions is not yet known. Substances covered by each measure

Stakeholders including the gas producers proposed to move HFOs from Annex II to a new section in Annex I, which would imply that personnel dealing with HFOs would e.g. need to have certification or that emissions should be avoided (Art. 3). In addition, for nitrogen trifluoride (NF_3) and perfluoro-cyclopropane ($c\text{-}C_3F_6$) labelling rules would be useful as these gases are covered by Regulation (EU) No 525/2013 and the UNFCCC reporting obligations, which would make their use more evident.

The Member State competent authority raised that sulphuryl difluoride (SO_2F_2, GWP 4780 based on scientific literature) should be addressed by the Regulation. The use of this gas as a fumigant was recently discussed in Germany as it increases the product carbon footprint. It has also been noted by a Member State authority that currently there are no reduction targets for F-gases other than HFCs, such as SF_6, PFCs or other perfluorinated compounds, and that it would recommend for the EU Commission to therefore explore whether additional measures are necessary for these other F-gases.

With regard to electrical switchgear, one industry stakeholder raised that all alternatives to SF_6 with a GWP > 1 should be subject to reporting obligations. This would be relevant for fluoroketones and fluoronitriles that are suggested by some manufacturers as SF_6 alternatives in medium and high voltage applications. Furthermore, a switchgear industry stakeholder highlighted that varieties of SF_6-free switchgears (capsulated air-insulated switchgears) are already in use at some medium voltage primary substations, if the necessary economical and technical requirements are fulfilled (e.g. availability of sufficient space). That said, stakeholders also highlighted that sufficient time is needed to allow an orderly transition. With regard to SF_6, it has also been noted that there is currently no competency requirements for leak testing of SF_6 containing switchgear, i.e. it would be useful to add leak prevention and control to the list of obligatory knowledge and skills to be covered.

Some Annex II gases are used in applications where non-fluorinated technical options exist so that emissions could be avoided both during operation and at end-of product life. An example for such applications is membrane pressure expansion vessels (diaphragm tanks) used in heating and refuelling systems that are filled with R1234ze (sometimes blended with R134a). Alternatives established on the market include nitrogen and hydrocarbon blends. Through consultation (workshop), some stakeholders highlighted that the focus of reclamation was too narrow and could be expanded to other pollutants. Furthermore, some also highlighted that certification and training requirements could be extended to all refrigerants (Workshop, feedback to workshop).

5.3.2.2 *Actors covered by the Regulation*

The Regulation covers different actors along the supply and use chain, which are affected by different provisions. Review of the coverage of the legislation has identified several potential gaps:

- Current requirements for service technicians only cover F-gas related activities. But due to the increasing use of F-gas alternatives and safety issues such as flammability, toxicity and high pressure, additional requirements for service technicians working with unsaturated H(C)FCs and natural refrigerants such as CO_2, ammonia and propane are becoming increasingly important. Training and certification programmes for F-gas service technicians as set out in Article

10 of the Regulation are required to only include information on alternative technologies and their handling, but practical training is not obligatory. In order to remove barriers for the use of lower GWP alternatives, the training and certification programmes for service technicians should be extended accordingly.

- Under the Regulation, recycling and reclamation undertakings do not face any reporting obligations, unless they are also HFC bulk producers or importers or a destruction company. Hence, data collected for the recycling and reclamation of F-gases was found to be incomplete. However, in view of the increasing relevance of recycling and reclamation for the HFC market, full overview is needed.

- Recipients of HFCs exempted from the phase-down regime are not subject to reporting which could be used as a loophole for illegal imports of HFCs that are labelled as an exempted category according to Article 12 and 15. Currently exempted categories which are not affected by reporting obligations are HFCs for use in military equipment, for the etching of semiconductor material or the cleaning of chemical vapour deposition chambers within the semiconductor manufacturing and for the production of MDIs, as well as recycled and reclaimed HFCs.

- The Regulation does not yet impose any obligations on distributors of F-gases. While Article 11 (4) of the Regulation stipulates that F-gases shall only be sold to and purchased by undertakings that hold relevant certificates or attestations, there is no such obligation for distributors. Reporting or certification obligations could support market surveillance and hence avoid illegal trade.

5.3.2.3 *Sectors and subsectors covered by the Regulation*

In certain applications that were not addressed by prohibitions under the existing Regulation, alternatives have been introduced to the market in recent years. This relates to:

- **Stationary refrigeration equipment:** Alternatives with lower GWP than the conventional HFC-based options are common in all applications including refrigeration equipment with a charge size below 40 tonnes of CO_2 eq and for the temperature range below -50°C but not all niche applications appear to be covered.

- **Stationary air conditioning:** Alternatives to conventional HFCs (i.e. typically R410A) are available for many applications including small single split air conditioning systems and also increasingly larger single split, multi split and VRF systems as well as chillers.

- **Mobile air conditioning:** Under the MAC Directive, only passenger cars and very small trucks are covered. Alternatives to conventional HFC-134a are available in many cases in the case of larger trailers, trains, ships and public transportation.

- **Transport refrigeration:** It relates to refrigeration systems in vans, trucks and trailers as well as reefer containers. Leakage rates tend to be higher in transport refrigeration as compared to stationary applications due to the increased level of vibration in motion. These sectors escape the leak checking rules.

- **Heat pumps:** Alternatives to conventional HFCs (i.e. R410A, R407C) have been commercialized by several manufacturers for residential, commercial and industrial heat pumps, which become enormously important given the significant expected growth rates for this sector to avoid an increase of direct emissions through the growth of this sector.

- **Electrical switchgear:** Alternatives to SF_6 are being developed and placed on the market or intensively researched (medium voltage switchgear, high voltage switchgear) (European Commission, 2020).

Some of the applications currently not addressed by specific provisions are so far subject to exemptions (military uses; possibly also uses required for safety reasons). Furthermore, the use of SF_6 as insulation medium in particle accelerators might represent a niche, which, however, is becoming increasingly common in research (e.g. for medical purposes such as cancer therapy and for surface treatments in industrial applications).

To prevent emissions of HFEs, SageTech recently undertook a pilot study for F-gas capture at a UK hospital trust which demonstrated the ability of a capture medium that has a high binding affinity for Isoflurane, Sevoflurane and Desflurane, to remove all F-gases and 99.9% of the waste drugs from the waste stream (SageTech, 2021).

The high amounts of SF_6 emissions estimated from 'other', diverse uses is not addressed by the uses regulated today. Some of the applications might have emerged in recent years and/or which might have been below the threshold for reporting by individual users or might be included in an unspecified way in the F-gas reporting of 'other or unknown uses' to the EEA (41 tonnes of PFCs, 169 tonnes of SF_6 in 2019).

In addition to the OPC, some stakeholders indicated for a range of areas a lack of coverage, including: medical applications such as anaesthetic gases/medical cabinets, military applications, transport including maritime, trains, airplanes, lorries, trailers and vehicles < 3.5 tonnes, switchgear and electrical equipment based on SF_6 as well as electronic applications. However, stakeholder were not specific regarding what measures were lacking for each area identified. Single indications were made for areas like agrochemical gases, cable productions, semiconductor fabrication, plastic fabrication and glass fibre production.

Regarding fire extinguishers, an industry trade association noted that, where not already forbidden, the use of HFCs in fire protection had decreased strongly nevertheless due to alternatives offering the same performance in an environmentally friendly way, in particular noting that fluoroketones can be considered as a complete substitute of HFC-227ea, HFC-125, and HFC-23. As such, the stakeholder highlighted that ambition could go further for fire extinguishers (e.g. limiting agents to <50 t CO_2 eq).

Table 47: Uses of F-gases not addressed by specific provisions for which further information from the UNFCCC emission reporting is available (Source: EU NIR, 2020 submission)

Use type	Description	Data source	Emissions (2018)
Military uses	Use of F-gases (HFCs, PFCs, SF_6) in various equipment as refrigerants, fire extinguishing agents; use of SF_6 as insulation medium in AWACS	EU 2020 submission to UNFCCC: CRF table, category 2.G.2	SF_6: 5.18 t
Accelerators	Use of SF_6 as an insulating gas	EU 2020 submission to UNFCCC: CRF table, category 2.G.2	SF_6: 10.71 t
Other	**Research:** Use of F-gases as tracer gases and analytical use; **Personal products:** use of fluorinated liquids in creams and mousses; **Medical applications:** Eye surgery, inhalation anaesthetics; optical fibre production; possibly further uses	EU 2020 submission to UNFCCC: CRF table, category 2.G.2; 2.G.4; 2.H.3	CF_4: 12.12 t C_2F_6: 8.72 t C_3F_8: 0.44 t c-C_4F_8: 0.01 t SF_6: 10.38 t Unspecified mix of PFCs: 531 378.53 t HFC-4310mee: 2.78 t HFC-134a: 0.14 t HFC-245fa: 9.66 t HFC-365mfc: 1.43 t Unspecified mix of HFCs: 1866.41 t Unspecified mix of PFCs: 917.97 t Unspecified mix of HFCs and PFCs: 134 007.85 t SF_6: 0.31 t

5.3.3 EQ7c. Does the Regulation continue to sufficiently contribute to EU climate change goals (also with view to the ambition raising as part of the EU Green Deal)?

F-gas emissions are included in the EU's current legislated climate targets to cut CO_2 emissions by 55 % by 2030 (European Commission). The long-term climate target is to become climate neutral by 2050 (European Commission).

The EU climate objectives have evolved since the time of the last impact assessment (2012) and demands significantly more action in all sectors to reduce emissions. The Paris Agreement from 2015 urges countries to make the necessary contributions so that global warming can be limited to below 2 (and possibly 1.5) degrees, which requires much swifter and wide-ranging changes globally. The EU recently agreed on an EU Climate Law by, which it is committing to reaching carbon neutrality by 2050 and at least a 55 % emission reduction by 2030 compared to 1990. This is a significant increase compared to the existing target of at least 40 %. Conversely, the Regulation was designed to meet the climate goals set forward in the 2011 Roadmap[66], which were less ambitious.

Some stakeholders, e.g. environmental NGOs, have expressed agreement that more ambition is now required to meet the ambitious demands of the Green Deal (workshop). Indeed, looking ahead, given

[66] COMMUNICATION FROM THE COMMISSION TO THE EUROPEAN PARLIAMENT, THE COUNCIL, THE EUROPEAN ECONOMIC AND SOCIAL COMMITTEE AND THE COMMITTEE OF THE REGIONS, 2011, EUR-Lex - 52011DC0112 - EN - EUR-Lex (europa.eu)

the embedded nature of F-gas emissions, reaching climate neutrality in 2050 also underlines the need for additional effort now.

As outlined in Section 3.1, relevant amounts of F-gases are still being placed on the market despite compliance with the overall HFC phase-down scheme.

F-gas emissions have increased in the EU from 1990 to 2018 in contrast to emissions of all other greenhouse gases, as shown in Table Table . In 2018, F-gas emissions amounted to 111 million tonnes CO_2 eq which was 52 % above 1990 levels. The increase of F-gas emissions compared to 1990 levels is due to the phase-out of ozone depleting substances in the EU since the 1990s as well as to growth of relevant application sectors, especially in refrigeration and air conditioning. The data show a de-crease of HFC emissions since 2014 which indicate not only the results of the previous Regulation but also rapid impact of the 2014 provisions. In this way, the FGR has significantly contributed to the "pre-vious" EU climate goals but not enough. This is also underlined in the data on F-gas supply and use (Section 3).

Given the more ambitious climate targets, the Regulation must be playing a more prominent role in order to contribute to the higher emission reductions needed.

Table 48: Overview of EU-KP GHG emissions and removals from 1990 to 2018 in million tonnes CO_2 eq (UNFCCC, 2020)

GREENHOUSE GAS EMISSIONS	1990	1995	2000	2005	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Net CO_2 emissions/removals	4 203	3 920	3 854	3 985	3 487	3 610	3 467	3 406	3 315	3 162	3 208	3 195	3 241	3 151
CO_2 emissions (without LULUCF)	4 475	4 221	4 186	4 322	3 840	3 960	3 812	3 754	3 663	3 489	3 526	3 508	3 521	3 440
CH_4	741	679	619	558	512	501	491	488	477	469	469	464	465	456
N_2O	397	360	320	302	265	255	251	249	249	252	253	253	257	252
HFCs	29	44	55	78	98	105	106	109	112	114	111	108	106	99
PFCs	26	17	12	7	4	4	4	4	4	3	4	4	4	4
Unspecified mix of HFCs and PFCs	6	6	2	1	1	1	0	1	1	1	1	1	1	2
SF_6	11	15	11	8	6	6	6	6	6	6	6	6	7	7
NF_3	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total (with net CO_2 emissions/removals)	**5 413**	**5 042**	**4 873**	**4 939**	**4 374**	**4 482**	**4 326**	**4 262**	**4 163**	**4 008**	**4 051**	**4 031**	**4 080**	**3 970**
Total (without CO2 from LULUCF)	**5 685**	**5 343**	**5 205**	**5 276**	**4 727**	**4 831**	**4 671**	**4 610**	**4 511**	**4 335**	**4 369**	**4 344**	**4 360**	**4 259**
Total (without LULUCF)	**5 659**	**5 315**	**5 178**	**5 250**	**4 702**	**4 807**	**4 646**	**4 584**	**4 487**	**4 310**	**4 345**	**4 318**	**4 333**	**4 234**

Based on the AnaFgas baseline modelling, by 2030, the existing Regulation ("baseline") is expected to cut the EU27+UK's F-gas emissions by 59 % compared with 2014 levels. By 2050, the emission will be cut by 76 %, compared to 2014. The expected cumulative emission savings from 2014 are 495 Mt CO_2 eq by 2030 and 2 282 Mt CO_2 eq by 2050.

In the Regulation, the emission reduction goal is defined as a 60 % cut in 2030, compared with 2005 levels of ca. 90 Mt CO_2 eq[67]. This translates into emissions in 2030 of ca. 35 Mt CO_2 eq. Based on the AnaFgas modelling, this goal will not be reached and emissions will amount to ca. 51 Mt CO_2 eq in 2030, only reducing emissions by 43 %, compared to 2005 levels. In 2050, emissions will drop to 29 Mt CO_2 eq, a reduction of 68 %. However, the EU climate objective is now to become climate neutral in 2050[68]. This highlights the necessity for further ambitious action to reduce F-gas emissions.

Stakeholders also generally agreed that further ambition was needed to meet the demands of new EU objectives. The majority (43%) of stakeholders suggested the Regulation would only make 'some con-tribution' to the European Green Deal (although a sizeable minority suggested it would make a 'strong contribution' (41%). Perhaps more telling was that a large majority of stakeholders agreed that 'raising ambition in light of the Green Deal and technological progress' was a key objective of the review. This

67 This holds true using the most current UNFCCC data. Total emissions of F-gases in the EU27+UK in 2005 are reported with 89 548 kt CO2 eq (https://www.eea.europa.eu/data-and-maps/data/data-viewers/greenhouse-gases-viewer).
68 COMMUNICATION FROM THE COMMISSION TO THE EUROPEAN PARLIAMENT, THE EUROPEAN COUNCIL, THE COUNCIL, THE EUROPEAN ECONOMIC AND SOCIAL COMMITTEE AND THE COMMITTEE OF THE REGIONS, 2019, https://ec.europa.eu/info/sites/default/files/european-green-deal-communication_en.pdf

agreement was strongest amongst NGOs and Member States, but weaker amongst EU citizens and industry stakeholders (albeit maintaining an overall agreement with the sentiment).

5.3.4 EQ7d. Does the Regulation sufficiently safeguard compliance with international commitments related to the Montreal Protocol (Kigali Amendment)?

In October 2016, in Kigali, Rwanda, the Montreal Protocol was amended to regulate HFCs (the Kigali Amendment). Both developed and developing countries have taken on mandatory commitments on reducing the production and consumption of HFCs in the next three decades. The EU's adoption of the Kigali Amendment carries three areas of compliance: HFC phase-down, reporting and licensing.

5.3.4.1 *HFC phase-down*

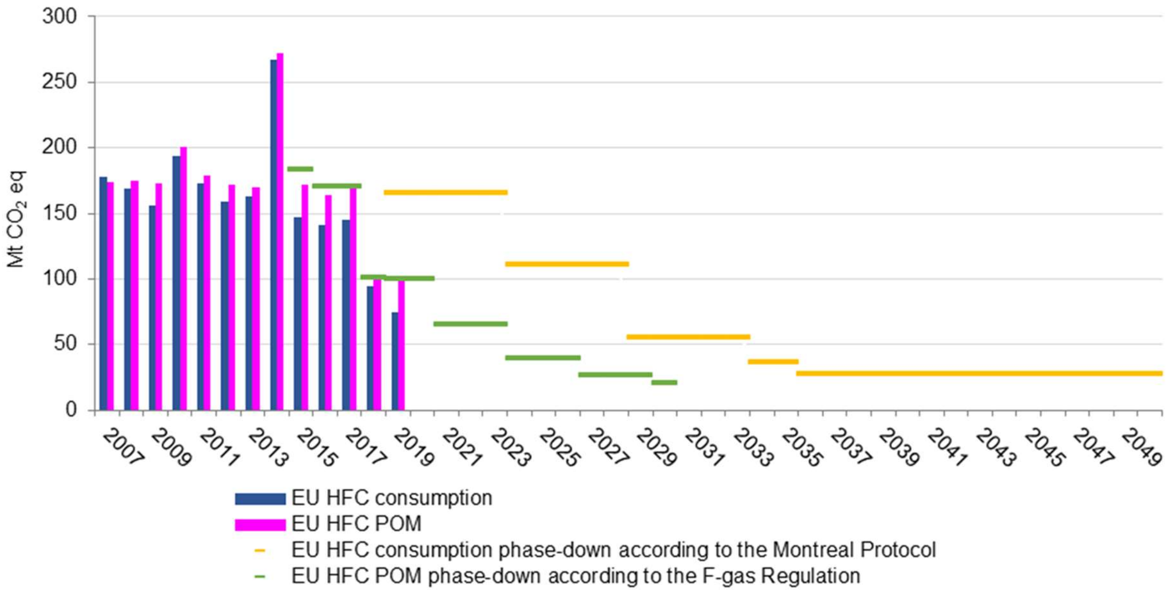
The Montreal Protocol commits the EU to reduce its HFC production/consumption by 10 % for the first time in 2019 and to then gradually phase-down HFCs by 85 % until 2036. From then on, the HFC production/consumption must remain at a constant and low level ('plateau' or 'tail'). In contrast, the reduction of the EU HFC POM started with a freeze (= 100 %) of the baseline in 2015, with further reductions to be made until 21 % of the benchmark level is reached in 2030. Hence there is a difference in the HFC phase-down steps implied by the Regulation and Montreal, as displayed in the following table.

Table 49: EU HFC phase-down schedule according to the Montreal Protocol and the Regulation

Year	Reduction of HFC production/consumption compared to the baseline set out by the Montreal Protocol	Year	Reduction of HFC placed on the market (POM) compared to the baseline set out by the Regulation
		2015	Freeze
		2016 – 2017	- 7 %
2019 – 2023	- 10 %	**2018 – 2020**	- 37 %
2024 – 2028	- 45 %	**2021 – 2023**	- 55 %
2029 – 2033	- 70 %	**2024 – 2026**	- 69 %
2034 – 2035	- 80 %	**2027 – 2029**	- 76 %
As of 2036	- 85 % ('plateau‘ or 'tail‘)	**2030**	- 79 %

The HFC phase-down schedules imply that the vast majority of HFCs will be reduced in earlier years, while the HFC consumption will remain at a low and steady level after reaching the final plateau. As shown in the figure below, the EU HFC phase-down implemented under the Regulation (green line) is more ambitious than the EU phase-down schedule under the Montreal Protocol (yellow line), as the former started four years earlier and thus the reductions will be achieved earlier. Moreover, when looking at first HFC reduction in 2019, it can be clearly seen that the EU HFC consumption in 2019 (blue bar) was well below the HFC consumption actually allowed under the Montreal Protocol.

Figure 54: Approaching the Montreal Protocol HFC phase-down (based on (EEA, 2020)



That said, there are a number of key differences and accountancy rules. One important difference is that under the Montreal Protocol there are reduction obligation on HFC production and consumption beyond 2030, while the EU phase-down ends with 2030 – hence, the EU needs to define further reduction steps to ensure future coherence and compliance with the Montreal Protocol. Other differences between the Montreal Protocol and the Regulation are:

- **Different baseline periods and compositions of the baselines:** The baseline of the Kigali Amendment for the EU, which needs to follow the obligations for A2 or developed countries, is the sum of the average HFC production/consumption in the period 2011 to 2013 and 15 % of the HCFC baseline in 1989. The HCFC baseline also includes 2.8 % of the CFC production/consumption of that year. The reason behind the inclusion of HCFCs in baseline calculations is that HFCs are widely used as substitutes for HCFCs, which still need to be phased out. The 2011-2013 average EU HFC consumption, according to reporting under the Regulation (EU, 2014b), was 165.2 Mt CO_2 eq. The hydrochlorofluorocarbon (HCFC)/CFC part of the EU baseline was calculated as 19.0 Mt CO_2 eq. In total, the EU baseline under the Montreal Protocol HFC phase-down is estimated at 184.2 Mt CO_2 eq.

  The calculation of the baseline used for the EU HFC phase-down and the allocation of quotas stipulated in the Regulation is based on the average HFC quantities placed on the EU market (POM) in the period 2009 to 2011.

Table 50: EU baseline according to the Montreal Protocol and the Regulation

Montreal Protocol **A2 (or developed) countries** **(Article 2F (1); 2J (1), (3))**	**Regulation** **(Article 15 (1), Annex V)**
Average HFC production/ consumption 2011 – 2013 plus 15 % HCFC baseline (HCFC consumption 1989 + 2.8 % of CFC consumption 1989)	Average HFC placed on the market (POM) 2009 – 2012

- **Different coverage/accountancy rules :**
  - HFC 'consumption' used as a metric in the Montreal Protocol is similar but not identical to HFC 'placing on the market' (POM) used in the Regulation (see Table). Moreover, the Montreal Protocol does not only consider HFC consumption (production + imports – exports) but also HFC production specifically which also must be phased down from 2011-2013 average while the EU phase-down only concerns POM. It is thus currently not possible to ensure directly that the reduction in the EU HFC production actually meets the obligations required by the Montreal Protocol in the long run.
  - There are some discrepancies between definitions used by the Regulation and Montreal Protocol. For example, according to the Montreal Protocol, pre-blended polyols containing HFCs are products, whereas they are treated as mixtures by the Regulation.
  - HFCs covered under the Montreal Protocol include all HFCs covered under the Regulation, except HFC-161 (fluoroethane (ethyl fluoride)).
  - HFCs pre-charged in imported RACHP products and equipment have been included in the EU HFC phase-down since 2017 and equipment importers need to hold quota authorisations to prove that the imported products and equipment are covered by quota. In contrast, the phase-down under the Montreal Protocol only applies to bulk HFCs. However, the EU has included pre-charged products and equipment to ensure the environmental integrity of the EU phase-down given that the EU is so far ahead of all other countries in reducing HFCs.
  - Article 15 of the Regulation contains exemptions for specific categories of HFCs that are not foreseen by the Montreal Protocol and thus lead to a lack of coherence. These include exemptions for HFC supplied for the use in military equipment (Article 15 (2)(d)), etching of semiconductor material or cleaning of chemicals vapour deposition chambers within the semiconductor manufacturing sector (Article 15 (2)(e)) and metered dose inhalers (Article 15 (2)(f)).
  - The Regulation also introduced a de minimis threshold for placing HFCs on the EU market below which HFCs are not covered by HFC phase-down. According to Article 15 (2) of the Regulation, this limit is 100 tonnes of CO_2 eq for producers or importers that place HFCs on the market[69]. Such a threshold is not foreseen in the Montreal Protocol and leads to a clear inconsistency.

As shown in the following table, the most important (quantitatively) differences are presently the inclusion of HFCs pre-charged in imported RAC products and equipment in the EU HFC phase-down and the above-mentioned exemptions for military equipment, semiconductors and metered dose inhalers granted by the Regulation. The following table compares the different calculation approaches used under the Regulation and the Montreal Protocol.

[69] For example, this would relate to a quantity of 69.93 kg of R134a or 148.15 kg of R32.

Table 51: HFC POM (Regulation) vs. HFC consumption (Montreal Protocol) (EEA, 2020)

			Supply	POM, relevant to compliance with the EU HFC phase-down	Consumption, relevant to compliance with the MP HFC phase-down
		Covered gases	Applicable to total F-gases and single gases/gas groups (e.g. HFCs)	HFCs of Annex I of EU F-gas Regulation No 517/2014, including HFC shares and non-HFC shares of HFC-containing mixtures	HFCs of Annex I of EU F-gas Regulation No 517/2014 except HFC-161, including HFC shares of HFC-containing mixtures
		Units used	Both physical tonnes and tCO_2e (GWP: AR4)	tCO_2e (GWP: AR4)	tCO_2e (GWP: AR4)
Transactions covered		**Type of contribution**			
Exports in products and equipment	Pre-blended polyols	Minus	No	Yes	No
	Other products and equipment	Minus	No	Subtracted in case the contained gases had never been placed on the market after bulk import (re-export, reported in section 2B)	No
Destruction	of EU production, destroyed before POM and imports for destruction	Minus	Yes	Yes (exemption Art. 15(2)a)	Yes
	of used gases recovered within the EU	Minus	No	No	Yes
Feedstock use		Minus	Yes	Yes (exemption Art. 15(2)b)	Yes (HFC production for feedstock use in the EU and HFC import for feedstock use)
Supplies to military uses		Minus	No	Yes (exemption Art. 15(2)d)	No
Supplies to semiconductor industry		Minus	No	Yes (exemption Art. 15(2)e)	No
Supplies to pharmaceutical MDIs		Minus	No	Not considered 2015-2017, considered 2018 onwards (exemption Art. 15(2)f)	No
1 January stocks		Plus	Full EU-based stocks from own production or own import considered, stocks under customs warehousing not considered, stocks from EU purchases not considered	Only those EU-based stocks from own production or own import considered that have not yet been placed on the market, stocks under customs warehousing not considered, stocks from EU purchases and stocks from own imports/ own production already placed on the market not considered	No
31 December stocks		Minus			
HFC quota authorisations issued by producers/importers		Plus	No	Yes	No

Exports in products and equipment	Pre-blended polyols	Minus	No	Yes	No
	Other products and equipment	Minus	No	Subtracted in case the contained gases had never been placed on the market after bulk import (re-export, reported in section 2B)	No
Destruction	of EU production, destroyed before POM and imports for destruction	Minus	Yes	Yes (exemption Art. 15(2)a)	Yes
	of used gases recovered within the EU	Minus	No	No	Yes
Feedstock use		Minus	Yes	Yes (exemption Art. 15(2)b)	Yes (HFC production for feedstock use in the EU and HFC import for feedstock use)
Supplies to military uses		Minus	No	Yes (exemption Art. 15(2)d)	No
Supplies to semiconductor industry		Minus	No	Yes (exemption Art. 15(2)e)	No
Supplies to pharmaceutical MDIs		Minus	No	Not considered 2015-2017, considered 2018 onwards (exemption Art. 15(2)f)	No
1 January stocks		Plus	Full EU-based stocks from own production or own import considered, stocks under customs warehousing not considered, stocks from EU purchases not considered	Only those EU-based stocks from own production or own import considered that have not yet been placed on the market, stocks under customs warehousing not considered, stocks from EU purchases and stocks from own imports/ own production already placed on the market not considered	No
31 December stocks		Minus			
HFC quota authorisations issued by producers/importers		Plus	No	Yes	No

Note: AR4, Fourth Assessment Report of the Intergovernmental Panel on Climate Change; GWP, global warming potential; MDI, metered dose inhaler; POM, placing on the market; RACHP, refrigeration, air conditioning and heat pump.

In summary, the use of different baseline years and metrics (consumption vs. POM) adds complexity, but the EU's HFC consumption is compliant with the reduction steps required by the Montreal Protocol for the moment, i.e. the Regulation safeguards compliance with the Montreal Protocol at least for the short term. However, there are areas where the EU Regulation may not be sufficient to ensure compliance with the Kigali Amendment in the long run. The quantitatively most important transactions being accounted for differently for POM and consumption are the following: Counted as consumption, but not POM, are quota-exempted supplies for the production of pharmaceutical MDIs and bulk imports under the inwards processing customs procedure that are re-exported after being charged into products or equipment. Counted as POM, but not as consumption, are quota authorisations issued to RAC equipment importers. Similarly subtracted from consumption, but not from POM, are bulk exports for which no quota exemption was claimed, and destruction of HFCs recovered downstream within the EU. The areas where incoherence poses a risk are described in detail under EQ9 (external coherence).

5.3.4.2 *Licensing system and other requirements*

The Montreal Protocol requires a licensing system for import and export of controlled substances. Without licensing, the trade in such substances would be considered illegal. This licensing system must cover bulk HFCs, including mixtures as well as used, recycled and reclaimed substances. It should support the collection of sufficient information to facilitate compliance with relevant reporting requirements and assist in the prevention of illegal trade in controlled substances through cross-checking of reporting between exporting and importing countries.

The Kigali Amendment extends the Montreal Protocol licensing requirements to the import and export of controlled HFCs and required the EU to adopt an HFC licensing system by the 1 January 2019.

The EU F-gas Portal, which encompass the HFC Registry and the Business Data Repository (BDR), is an electronic tool for quota allocation, management of quota authorisations and reporting. It was introduced in its current form in 2015 in order to manage the HFC phase-down. The system requires undertakings to register in the system and to assign a unique registration ID before being able to apply for quota, manage authorisations for quota use and to report relevant activities. Undertakings also need to specify a business profile, i.e. as importer of bulk HFCs, exporter of bulk HFCs, etc. Customs authorities can currently check if importers of bulk gases and pre-charged products and equipment are registered in the HFC Registry and have a quota or quota authorisation. Hence the **EU F-gas Portal ensures compliance with that requirement of the Montreal Protocol** by requiring that all importers and exporters must be registered before undertaking import or export activities [70].

While a licensing system compliant with the Montreal Protocol is in place, the fact that the relevant obligations for importers and exporter is inter alia found in this implementing act, does not increase the visibility of this measure and the clarity of the Regulation.

In addition to the licencing requirements, Article 4 under the Montreal Protocol related to non-Party trade rules prohibits trade with Parties have not ratified the Kigali Amendment. Such restrictions do not currently exist under the Regulation.

5.3.5 EQ8. Has the Regulation been flexible enough to respond to new or emerging issues, such as technological or scientific advances or other changes?

Since the entry into force of the EU Regulation several new and emerging issues became relevant including:

- Changes in relevant safety standards
- New international situation: The Kigali Amendment was adopted in 2016 and Paris Agreement;
- New EU climate targets of 55% CO_2 emission reductions.
- Gas unavailability and illegal trade which occurred to some extent in past years and were partly addressed by means of Implementing Acts (e.g. Commission Implementing Regulation 2019/661, see footnote).

5.3.5.1 *Safety standards*

The Regulation intended a shift of technologies towards alternatives to conventional F-gases. In this context, safety standards for different products and applications are relevant as they were found to pose barriers for the uptake of climate-friendly alternatives to HFCs, especially flammable refrigerants (European Commission, 2016) (the interactions with health and safety standards are considered further in the Coherence section).

As explained in further detail in section 5.1.7.1, the Commission issued, at the end of 2017, a mandate request (M/555)[71] to the standardization organizations in order to have a European standardisation deliverable on the use of flammable refrigerants, in particular those classified as A3, in refrigeration, air conditioning and heat pump equipment by February 2021. The work has been completed and final

[70] Commission Implementing Regulation (EU) 2019/661 of 25 April 2019 ensuring the smooth functioning of the electronic registry for quotas for placing hydrofluorocarbons on the market (Text with EEA relevance.) https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=uriserv:OJ.L_.2019.112.01.0011.01.ENG&toc=OJ:L:2019:112:TOC

[71] COMMISSION IMPLEMENTING DECISION C(2017) 7284 of 14.11.2017 on a standardisation request to the European Committee for Standardisation and to the European Committee for Electrotechnical Standardisation as regards use of flammable refrigerants in refrigeration, air conditioning and heat pump equipment. https://ec.europa.eu/growth/tools-databases/mandates/index.cfm?fuseaction=search.detail&id=578

technical specifications were issued in March 2021, which however were perceived by experts and stakeholders to not contribute sufficiently to updates of existing standards to promote the use of alternatives to F-gases.

Work is currently being undertaken on the product standard IEC 60335-2-40 relating to electrical heat pumps, air conditioners and dehumidifiers, to expand the potential scope of applications within a boundary limit-value of 1 kg for R290. A final draft will be voted on in spring 2022 and publication is expected in June 2022.

As mentioned in section 5.1.7.1, the product standard IEC 60335-2-89 relating to commercial refrigeration has been updated. The charge limit for flammable refrigerants in **self-contained commercial refrigeration appliances** have increased from 150 g to 500 g for A3 refrigerants. For mildly flammable alternatives (A2 and A2L), the limit has increased from 150 g to 1.2 kg. Further changes relate to commercial ice makers which are now covered by the scope of the standard. This standard has been adopted as EN 60335-2-89 and has become a harmonized standard through the EU Machine Directive (MD; Annex ZZB).

Further updates are also being discussed in working group 12 of standard EN 378. Different precautionary measures will be required depending on charge and room size. Alongside, the EU-funded project LIFE FRONT provided, *inter alia*, relevant data such as a leak size/concentration database to support evidence-based risk assessment for the use of flammable refrigerants (LifeFront, n.d.). Most recently, the project has released a report with recommendations on how to safely raise the charge limits of A3 refrigerants (LifeFront, 2020).

The implementation of the Regulation has been impacted by certain standards as well as national safety regulations in certain cases as they prevented the introduction of some alternatives to F-gases (i.e. flammable or toxic or high-pressure alternatives). Updates of standards were only initiated after the entry into force of the 2014 Regulation and take a long time. These processes are carried out by standardisation organisations and are going on in parallel to the implementation of the Regulation. significant improvements for the market penetration of alternatives are expected once more standards are revised.

A more detailed discussion regarding the interaction of the Regulation and national safety codes is included in EQ2a.

5.3.5.2 *Kigali Amendment*

As discussed under EQ7d, the emergence of the Kigali Amendment has posed a question for the Regulation as to whether it is sufficient to achieve compliance.

5.3.5.3 *EU climate targets*

As discussed under EQ7d, proposal for new, more ambitious GHG reduction targets at EU level has posed a question for the Regulation as to whether it is ambitious enough.

5.3.5.4 *Availability of gases and illegal trade*

The HFC phase down and quota allocation mechanism represent a market-based instrument. Price increases for high-GWP gases are intended by gradually limiting the HFC supply on the EU market. In 2017, the raid price for HFCs increase took many companies by surprise and resulted in different reactions: Some companies quickly started stocking HFCs in large volumes, others were not aware of the changing market situation. Furthermore, stockpiled quantities from 2014 (i.e. from before the FGR entered into force) kept prices low during 2015 and 2016 but were running out in 2017. Thus, limited availability of certain high-GWP gases was observed in some Member States during the second half of the year 2017. The most affected gases were R404A (now discontinued by some suppliers due to the relatively high GWP), R134a (widely used in the car air conditioning servicing market) and R410A (mainly used for first fill and refill of air conditioning equipment). At that time, a lack of options to react was observed on Commission side.

A 2020 Commission Report on the HFC availability[72] concluded that close monitoring of the market and the gas prices will continue to be relevant to identify emerging shortages and price issues. Furthermore, effective prevention of illegal activities should be undertaken. The EU Customs Single Window Certificate Exchange project was expected to also support these efforts.

The issue of illegal trade, its drivers and the lack of options to effectively respond to this issue are discussed in detail under EQ2a.

5.3.6 Conclusions on relevance

The high-level objectives of the Regulation continue to reflect and respond to the fundamental need of the EU to reduce demand and emission of F-gases. However, developments over the period of implementation, specifically the European Green Deal and a changed international policy environment (Paris Agreement, Kigali Amendment), pose a challenge to the Regulation in its current form, and require more emission reductions:

- It can be concluded that **the problem still persists, and is evolving**. The Regulation has changed an increasing trend to a decreasing trend (since 2015) of F-gas emissions in the EU and the average GWP value of total F-gas supply (- 31% in 2019 compared to 2014). Reported data show that the supply of F-gases in the EU[73] decreased by 19 % in tonnes and 43 % in CO_2 eq from 2015 to 2019, after peaking in 2014 before the HFC phase-down came into effect. However, emission levels are still high as F-gases are still used in many applications, primarily in the RACHP sector. Furthermore, the continued supply contributes to a ‘bank’ of potential emissions for future periods.

- It has been determined that hydrofluorocarbons (HFCs) are still the most important group of F-gases, both in terms of quantity in metric tonnes and CO_2 eq. The Regulation continues to capture the most important F-gases however the Regulation has some **potential gaps with regard to the substances covered**. F-gases that are not currently covered by either Annex I nor Annex II of the Regulation but are relevant on the EU market or starting to become commercialised include: Sevoflurane (HFE-347mnz1, GWP 216 (AR5[74])); enflurane (HCFE-235ca2, GWP 583 (AR5)); sulfuryl difluoride (SO_2F_2, GWP 4732 (AR5)); a number of long-chain PFCs, PFPEs, fluorinated ethers and alcohols and other unsaturated H(C)FCs and further substances used as F-gas alternatives . There may also be scope to revisit some of the requirements for gases where those do not yet exist (e.g. switchgear use of SF_6).

- In addition, the Regulation **covers diverse actors along the F-gas supply and use chain** (producers, importers, exporters, manufacturers and importers of products and equipment, operators of equipment, service technicians, feedstock users, reclamation and destructions facilities) and foresees requirements for training providers, certification bodies and EU Member State authorities. Current requirements also cover only F-gas related activities: due to the increasing use of F-gas alternatives, additional requirements for service technicians may be useful.

- The scope of the Regulation was significantly extended compared to the previous Regulation (EU) No 842/2006, inter alia, to include far-reaching reduction measures like the phase-down of HFCs and an additional set of placing on the market and use prohibitions. **However, some gaps with respect to sectors have been identified which may need further consideration (or re-consideration).** While reduction measures of the current Regulation address mainly HFC applications, PFCs and SF_6 (as well as Annex II gases) are not covered by the HFC phase-

[72] https://ec.europa.eu/clima/sites/default/files/f-gas/docs/20201216_c_2020_8842_en.pdf
[73] Supply of fluorinated greenhouse gases (F-gases) is a metric used by the EEA that provides information on the actual use of F-gases by EU industries. It is calculated primarily from reported production, imports and exports.
[74] 5th Assessment Report (AR5) of the Intergovernmental Panel on Climate Change (IPCC)

down and their use is only restricted for certain smaller applications. For example, sulphur hexafluoride (SF_6, GWP 22,800), perfluorocarbons (PFCs, GWP 7,400 – 12,200) and nitrogen trifluoride (NF_3, GWP 17,200). Although these gases accounted for only 2 % in tonnes in 2019, they presented 23 % of the EU F-gas supply in terms of in CO_2 eq. but are not currently covered by strong reduction measures such as prohibitions. Also, research on alternatives for the more complex uses of F-gases shows that certain alternatives are technically feasible for certain applications and can be implemented in the near future, the scope of reduction measures could be extended (e.g. heat pumps, chillers, mobile AC in vehicles other than passenger cars).

- The EU Climate objectives have evolved since the time of the last impact assessment (2012). The EU Green Deal aims at raising the EU's 2030 GHG emission reduction target, including emissions and removals, to at least 55 % compared to 1990, and reaching GHG neutrality by 2050. These targets are in an order of magnitude that **demands significantly more action in all sectors to reduce emissions** and requires strong political and effective policies in place. As regards F-gas emissions, despite large emission reductions especially in the refrigeration sector, they still contribute to 2.5% to the EU's total GHG emissions in 2018 and continued supply and use of F-gases will continue to result in a 'bank' of potential emissions for the future. Due to its target to reduce F-gas emissions by up to two thirds by 2030 compared to 2010 levels in a cost-effective way, the objectives of the Regulation remain relevant for meeting the EU's climate targets but further tightening is required to increase its contribution.

- The Regulation is the primary means through which **compliance with international commitments related to the Montreal Protocol are safeguarded**. With the exception of 2014 (when consumption was probably inflated as a result of the upcoming phase-down mandated under the EU Regulation, but not yet mandated under the Montreal Protocol), HFC consumption has exhibited a downward trend. In 2018, HFC consumption dropped by 38 % compared with 2017, in line with the 41 % drop in the maximum HFC quantity under the EU HFC phase-down and corresponding to the 32 % drop in HFC supply. Compliance over the appraisal period has been met, but in order to ensure long-term compliance, there is a need to adjust the phase-down and reporting measures (set out in further detail in Coherence section).

Regarding the flexibility of the Regulation to respond to new or emerging issues, such as technological or scientific advances or other changes (EQ8), the Regulation has been flexible to respond to some external challenges, but not others:

- There has been an emergence and a shift to the use of both natural refrigerants and alternatives with a lower GWP. The Regulation was flexible to facilitate this and has also actively encouraged this trend.

- The Regulation itself does not have the in-built flexibility to automatically align with Kigali,

- The Regulation itself does **not have the in-built flexibility to address serious issues linked to the phase-down, such as market supply or similar.**

5.4 Coherence

The assessment of coherence looks at how well the Regulation works individually, and alongside other EU interventions. It thus points to synergies as well as areas where there are potentially contradictory objectives or approaches that may cause inefficiency.

5.4.1 EQ9: To what extent is the Regulation externally consistent and coherent, i.e. with other interventions which have similar objectives?

This section considers the extent to which the Regulation and its accompanying implementing acts are consistent and coherent with other relevant EU and international legislation. The following section is broken into four parts:

- **Analysis of the Regulation coherence with international environmental and climate policies**
  - Montreal Protocol on Substances that Deplete the Ozone Layer
  - Paris Climate Agreement
- **Analysis of the Regulation coherence with EU environmental policies**
  - Regulation (EC) No 1005/2009 ('Ozone Regulation')
  - Directive 2006/40/EC ('MAC Directive')
  - Regulation (EU) No 2017/1369 ('Energy Labelling Regulation')
  - Directive 2010/31/EU ('Energy Performance of Buildings Directive')
  - Directive (EU) 2018/2001 ('Renewable Energy Directive')
  - Directive 2009/125/EC ('Ecodesign Directive')
  - Directive 2008/98/EC on waste ('Waste Framework Directive', WFD)
  - Directive 2012/19/EU ('Waste Electrical and Electronic Equipment Directive', WEEE)
  - Directive 2010/75/EU ('Industrial Emissions Directive', IED)
  - European Pollutant Release and Transfer Register (EPRTR)
  - Regulation (EC) No 1907/2006 ('Registration, Evaluation, Authorisation and Restriction of Chemicals', REACH)
- **Analysis of the Regulation coherence with EU policies on customs and market surveillance**
  - Regulation (EU) 2019/1020 ('Market Surveillance Regulation')
  - Regulation (EU) No 952/2013 ('Union Customs Code')
  - Directive 2008/99/EC ('Environmental Crime Directive')
- **Analysis of the Regulation coherence with safety standards and building codes.**

5.4.1.1 *Coherence with international environmental and climate policies*

Montreal Protocol and its Kigali Amendment

In 2015, the Regulation introduced a phase-down of HFCs placed on the market. The implementation of the HFC phase-down is crucial for the EU's compliance with its obligations under the Kigali Amendment that entered into force on 1 January 2019. The Kigali Amendment implemented a global HFC phase-down of both production and consumption by more than 85 % over the next 30 years. Hence harmony with the Kigali Amendment is critical, as it is also a question of compliance.

The differences between the EU Regulation and Kigali Amendment are considered in further detail under EQ7d. In summary, there are several differences between the phase down schedules under the EU Regulation and Kigali. Some (e.g. use of different baseline years and metrics (consumption vs. POM)) add complexity, but do not necessarily create a risk of incompliance as long as the EU's HFC consumption is compliant with the reduction steps required by the Montreal Protocol. However, there are areas where the Regulation may not be sufficient to ensure compliance with the Kigali Amendment. The areas where incoherence poses a risk are:

- the requirements for continuing the EU **HFC phase-down after 2030;**
- the Montreal Protocol considers both HFC consumption (production + imports – exports) and **production** which both must be phased down, while the EU Regulation does not. The EU must rely on individual Member States to ensure that production phase-down targets under the Montreal Protocol are being met, hence it is not possible to ensure through the Regulation these obligations are met. The lack of a common EU production phase-down is also likely to give undertakings less flexibility as to where they reduce production, which may result in unnecessary inefficiencies;
- the **exemptions** that are granted by the Regulation but not by the Montreal Protocol. Article 15 of the Regulation contains exemptions for specific categories of HFCs that are not foreseen by the Montreal Protocol and thus lead to a lack of coherence. These include exemptions for HFC supplied for the use in military equipment (Article 15 (2)(d)), etching of semiconductor material or cleaning of chemicals vapour deposition chambers within the semiconductor manufacturing sector (Article 15 (2)(e)) and metered dose inhalers (Article 15 (2)(f));
- a **de minimis threshold for placing HFCs on the EU market** below which HFCs are not covered by HFC phase-down. According to Article 15 (2) of the Regulation, this limit is 100 tonnes of CO_2 eq for producers or importers that place HFCs on the market[75]. Such a threshold is not foreseen in the Montreal Protocol and leads to a clear inconsistency;
- **thresholds for reporting** on production, import, export of bulk gases, feedstock use and destruction of F-gases (Annex I) and other fluorinated greenhouse gases (Annex II) exist in the Regulation below which reporting is not required (Article 19 (1)-(3)). Such reporting thresholds are not included in the Montreal Protocol and thus provide an area of incoherence;
- trade with Parties have not ratified the Kigali Amendment not prohibited. For alignment with the Montreal Protocol (Article 4 on non-Party trade rules) **trade restrictions** would need to be put in place – such restrictions do not currently exist.

The Montreal Protocol requires a **licensing system** for import and export of controlled substances. This licensing system covers bulk gases not equipment, and must include mixtures as well as used, recycled and reclaimed substances. The Montreal Protocol does not require a specific design of the licencing system. A detailed discussion of this system is captured in EQ7d. In summary, Article 17 of the Regulation sets out the requirement that all F-gas importers and exporters must be registered prior to such activities in the HFC Registry which is part of the EU F-gas Portal. This licence constitutes a general licence to import and export HFCs. In this way it ensures compliance with the HFC licencing requirement of the Montreal Protocol.

Stakeholders agreed (workshop) that further action is required to ensure compliance with the Montreal Protocol, in particular post 2030.

Paris Climate Agreement / UNFCCC

Prior to the Regulation being adopted in 2014, the EU had previously committed to reduce GHGs by 20% by 2020 (including F-gases). It has since made further commitments, e.g. to reduce domestic emissions by 40% compared with 1990 levels under the Paris Agreement . More recently, the EU has submitted an update of its Nationally Determined Contribution in 2020 including a target for a net reduction from base year emissions of at least 55% GHG reduction. In this context, it is apparent that the original objectives (from 2011) are no longer ambitious enough, and that the Regulation should look to

[75] For example, this would relate to a quantity of 69.93 kg of R134a or 148.15 kg of R32.

re-examine its targets. This is particularly true as the EU has begun to set broader, more ambitious climate targets, in order to achieve carbon neutrality in 2050 and a 55% reduction by 2030 (this is discussed in further detail under EQ7c).

There are reporting requirements around F-gases in both the Regulation and under the United Nations Framework Convention on Climate Change (UNFCCC), which requires Parties to report their annual national **F-gas emissions**. In the EU, Regulation (EU) No 525/2013 ('MMR Regulation') in conjunction with Regulation (EU) 749/2014 defines the mechanism and requirements for reporting GHG emissions.

There are several differences in the required reporting:

- Data reported under the Regulation relate to F-gas activities. Under Article 20, Member States must establish reporting systems to acquire, to the extent possible, emissions data. F-gas emissions reported to the UNFCCC are mainly calculated based on estimates than on actual emissions and are derived by the MMR.
- Regarding the geographical scope, F-gas data is aggregated at EU level according to the Regulation, while for the UNFCCC reporting, national data are summarised for the EU submission to the UNFCCC.

In addition, stakeholders (interview with company) highlighted a potential bias in the calculation methods used for reporting. Namely, that the Regulation, IPCC reporting and Montreal Protocol use default values for the calculation of leakage rates from heat pumps (50 % of the F-gas used). However, from practical experience, the stakeholder noted that these values are a lot lower (probability levels lower than 1 %), over the entire product life cycle.

5.4.1.2 *Coherence with EU environmental policies*

Ozone Regulation

The Regulation is similar to the requirements for ozone-depleting substances (ODS) under Article 23 of Regulation (EC) No 1005/2009 ('Ozone Regulation'). In various areas including RAC&HP applications, foam blowing and fire protection system, ODS have been widely replaced by F-gases, particularly HFCs. Since the current Ozone Regulation is older than the current F-gas Regulation, which has only entered into force in 2014, some provisions are not wholly aligned. Particularly, the Ozone Regulation is currently not requiring proofs of destruction or recovery for subsequent use of quantities of the highly potent greenhouse gas HFC-23 that are by-produced during production of other ODS. These areas of inconsistency are being considered and taken further as part of the ongoing review of the Ozone Regulation.

Industry stakeholders highlighted in the interviews the importance of ongoing and improving consistency with the Ozone Regulation, this also related to the changes being considered to that legislation in terms of coverage of substances. In particular, it is considered essential that fluorinated gases that are also ozone-depleting substances (e.g. HCFO-1233zd(E) and isoflurane (HCFE-235da2)) continue to be reported/controlled under the F-gas Regulation and that duplications are avoided. Another area where alignment is sought by stakeholders is in the approach to custom controls and rules under both Regulations.

MAC Directive

Directive 2006/40/EC ('MAC Directive') relating to emissions from air-conditioning systems in passenger cars, complements the Regulation by introducing a prohibition on mobile air conditioning containing F-gases from 2017 for new passenger cars. The other obligations of the Regulation such as containment measures continue to apply for this sector, in analogy to all other sectors that are affected by both the phase-down and prohibitions, as well as containment measures. Generally, there is a consensus amongst stakeholders that coherence between the Regulation and MAC Directive is high.

Energy efficiency and ecodesign legislation

The HFC phase-down aims to drive the transition from high to low GWP refrigerants in existing (where existing is replaced with new equipment) and new RACHP applications which can have an indirect impact on energy consumption depending on the efficiency of the new equipment. The Regulation also seeks to improve energy efficiency through better control, monitoring and maintenance of existing RACHP equipment, to avoid the loss of refrigerant and thus prevent efficiency losses, including leakage checks and repairs, leakage detection systems, and training and certification of technicians.

There are a number of different regulations which interact with the Regulation as they also seek to influence the energy use or increase the energy efficiency of RACHP systems simultaneously:

- Directive 2010/31/EU on the energy performance of buildings states that regular assessments of the efficiency of air-conditioning systems with an effective rated output greater than 70 kW must be conducted and compared with the building's cooling requirements (Article 15).
- Directive (EU) 2018/2001 on the promotion of the use of energy from renewable sources requires that Member States assess their potential of energy from renewable sources and the innovative use of waste heat and cold in the heating and cooling sector.
- The Energy Labelling Regulation (EU) No 2017/1369 introduced mandatory labelling requirements in order to showcase the energy efficiency of a product, using a scale (A to G, green to red, without A+ to A+++). It is supplemented by product-specific regulations, e.g. Commission Delegated Regulation (EU) 2019/2018 with regard to energy labelling of refrigerating appliances with a direct sales function.
- The Ecodesign Directive 2009/125/EC provides consistent EU-wide rules for improving the environmental performance of products, including mandatory requirements regarding energy efficiency, durability, reparability, upgradability, recyclability, and the content of recycled materials. The Ecodesign Directive is implemented through product-specific regulations, some of which have set minimum requirements for energy efficiency for refrigerants with GWP > 150 and refrigerants with GWP ≤ 150, such as Commission Regulation (EU) No 206/2012 (ecodesign requirements for air conditioners and comfort fans).

Generally, new RACHP products are more energy efficient as technology improves. Lower GWP alternatives often present an opportunity to further improve the energy efficiency. Furthermore, Article 11 (2) of the Regulation allows an exemption from the placing on the market bans set out in Annex III if the equipment with HFCs (taking into account leakage and recovery rates) would achieve lower overall GHG emissions during its life cycle than the same equipment without HFCs. This exemption provides coherence between the F-gas Regulation and Ecodesign Directive in areas of potential conflict. Notably, there has to date been no record of a need to use that exemption.

Despite this alignment, there is a perception amongst a number of stakeholders (OPC, interviews with MS and industry) that a lack of coherence with the Ecodesign Directive exists. Some highlighted that there are examples where there is trade-off relationship between GWP and energy efficiency, e.g. in the category of R410A alternatives (OPC), and that there may be a lack of energy efficiency in equipment using lower GWP alternatives. However, only limited examples were identified of where such trade-offs could have happened (e.g. in the category of R410A alternatives (OPC)). It may also signal a lack of awareness of Article 11(2) and the recommended course of action in these cases. This perception might also be being driven by the interaction with safety legislation: for example, Ecodesign requirements have an impact on the charge amount needed, with higher efficiencies typically needing more refrigerant. Since A3 refrigerants are more limited in potential refrigerant charge size by existing standards, their scope regarding energy efficiency improvements continues to be more limited unless existing barriers are addressed (European Commission, 2020).

Furthermore, it is not just with respect to energy efficiency that there may be incoherence. One stakeholder (interview with industry) highlighted that whilst the Regulation pushed to reduce the HFC charge size of heat pumps, the Ecodesign Directive pushed for lower sound power level. The latter is generally achieved by increasing the evaporator size and as a consequence the refrigerant charge size. No further detail was provided on the size of the potential issue, but again highlights an area where trade-offs are being made in the marketplace.

Waste legislation

Recovered F-gases might be classified differently under the Regulation: 1) reused on the site where they were recovered; 2) reused for servicing of other systems after having passed a recycling process; 3) returned to the distributor for reclamation; 4) refrigerants which have been reclaimed are no longer treated as waste; and 5) disposed of by incineration.

Article 8 of the Regulation requires the operators of stationary equipment or refrigeration units of refrigerated trucks and trailers that contain F-gases (not in foams) to ensure the recovery of those gases is carried out by certified professionals in order to ensure that those gases are recycled, reclaimed or destroyed[76]. It is also the responsibility of the undertaking that has used an F-gas container to ensure the recovery of residual gases immediately prior to the disposal of the container to make sure they are recycled, reclaimed or destroyed.

Article 3 (1) of the Waste Framework Directive 2008/98/EC (WFD) defines 'waste' as any substance or object which the holder discards or intends or is required to discard. If an F-gas is recovered from an end-of-life container, product or piece of equipment and it is not recycled or reclaimed then it would meet the definition of waste under the WFD. In contrast, this definition should not apply for F-gases subject to recycling and reclamation. Furthermore, used HFCs (as well as CFCs and HCFCs), despite possible recycling or reclamation activities, are included as a hazardous waste in the European List of Wastes (bulk waste code 14 06 01, waste code for discarded equipment containing HFCs 16 02 11)[77].

Under EU legislation, the waste status of a substance can be complex and depends on a number of factors. To navigate the different routes for recovered F-gases requires a sound understanding of both the Regulation and the Waste Framework Directive, including the administrative consequences.

In the targeted interviews, Member State competent authorities noted it is difficult to understand when different Regulations apply in different circumstances and hence to determine the classification of a substance. This leads to disagreement in the market as to when F-gas is classified and should be treated as 'waste' or not. For example, some stakeholders believe that all recovered F-gases are generally treated as 'waste' under the WFD. Furthermore, this confusion may lead to artificial barriers being put in place for some of the activities being encouraged under the Regulation: for example, competent authorities highlighted in the interviews that in some cases an environmental permit may be required to carry out recycling as recovered refrigerants may be considered 'waste', which places a barrier on these activities. Hence the recovery, recycling and reclamation of F-gases is not comprehensively fostered by the WFD.

Stakeholder engagement highlighted several opportunities to improve coherence between the Regulation and WFD:

- There is a need for greater harmony in the end-of-life standards of waste. Some definitions differ between the legislation, particularly the definition of 'recovery', and the Regulation defini-

[76] This requirement applies to: cooling circuits of stationary RACHP equipment; cooling circuits of refrigeration units of refrigerated trucks and trailers; stationary equipment that contains F-gas-based solvents; stationary fire protection equipment; and stationary electrical switchgear.
[77] COMMISSION DECISION of 18 December 2014 amending Decision 2000/532/EC on the list of waste pursuant to Directive 2008/98/EC of the European Parliament and of the Council, https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32014D0955&from=EN

tion for ‘reclamation’ is closer to that of ‘recovery’ under the Waste Framework Directive. Indeed, the difference in terminology drives a perception amongst stakeholders (interviews with industry and MS) that better harmonisation is needed to facilitate more reclamation, and the WFD currently does not ‘prioritise’ reclamation specifically.

- Article 9 could be better aligned with the WFD, and the activities to be included within the scope of the producer responsibility. The WFD has been amended to set minimum requirements for Extended Producer Responsibility schemes, establishing a common policy approach (EIA, 2020).

Recovery activities also need to consider the Shipments of Waste Regulation (EC) No 1013/2006, as in some cases, recovered refrigerants being transported to another location are considered to be hazardous waste and require specific permits for transport and storage which are issued and controlled by the local environment agency. These become particularly relevant in case EU Member States without reclamation and destruction facilities intend to export used F-gases for reclamation and/or destruction purposes to other Member States. This issue was also expressed by stakeholders (targeted interviews with industry and Member State competent authorities) who noted shipment of waste regulations as a barrier to effective end-of-life F-gas treatment and currently transport of waste across EU national boundaries requires significant quantities of documentation for each shipment. However, not all stakeholders agreed this was a significant issue and some stakeholders (targeted interviews with industry) also warned that should transborder shipments become too simple, this may open the market for actors with lower standards or expertise in handling hazardous waste.

The Waste Electrical and Electronic Equipment Directive 2012/19/EU (‘WEEE Directive’) covers equipment containing gases which have a GWP >15, which applies with few exceptions to all gases covered by the Regulation. The electrical and electronic equipment containing HFCs which is in the scope of the WEEE Directive includes: large household appliances (large cooling appliances, refrigerators, freezers, clothes dryers, air conditioners), medical devices (freezers), automatic dispensers for cold bottles or cans. The WEEE complements the Regulation in that it sets out requirements for Member States to: minimise disposal of WEEE in unsorted municipal waste to ensure correct treatment (and noting as a priority fluorinated GHGs (Article 5(1)); prohibit disposal of separately collected WEEE that has not undergone ‘Proper Treatment’ (Article 6(1)); and ensure collection and transport of WEEE is done in a way that optimises conditions for preparing for re-use, recycling and confinement of hazardous waste (Article 6(2)). In addition, the costs of such actions are covered by producer responsibility schemes.

The Regulation complements the recovery requirements under the WEEE Directive by requiring certification of personnel. The WEEE Directive goes beyond the provisions of the Regulation through requiring the extraction and treatment gases with a GWP > 15 from foams and refrigeration circuits, such as those used as insulation in domestic and small commercial refrigeration appliances (although foams do not require recovery under Article 8 of the Regulation, Article 12 does require their presence being noted on the label, enabling treatment under the WEEE Directive).

In terms of ‘proper treatment’, the WEEE contains (Annex VII) specific directions for the treatment of equipment containing gases of GWP above 15 that these gases must be properly extracted and treated. It should be noted that it is stated in WEEE that ozone-depleting gases must be treated in accordance with the Ozone Regulation, but no mention is made of the F-gas Regulation in this context. This perhaps misses an opportunity to reinforce the link to the Regulation and the objectives around recovery.

Although not an incoherence, stakeholders have identified (interviews with undertakings) that WEEE schemes in Member States need to be improved to better facilitate the recovery, recycling and reclamation of refrigerants.

REACH Regulation

The REACH Regulation (EC) No 1907/2006 contains several components that have the potential to interact with the Regulation.

First, Annex XIV of REACH lists substances prohibited from being placed on the market and used, unless an **authorisation** is granted or the use is exempt from authorisation. The authorisation list however does not apply to imported articles. From a review of the substances in Annex XIV, none are known substitutes to F-gases hence although there is a risk of incoherence, there is no mismatch in practice.

There is an obligation to **register** substances placed on the market above a certain amount (typically around 1 tonne per annum in total – not per operator). This requirement also applies to imported substances. A registration dossier includes various detail about the substances, its properties, testing data and risks of emissions. This needs to be prepared by the various economic operators placing the substance on the market. Individual substances are required to be registered under REACH, meaning that components of blended refrigerants have to be registered. However, a blended refrigerant is considered as a 'preparation' and hence does not need to be registered. REACH exempts the requirements for registration of substances which have been recovered in the Community, provided that:

- The recovered substance is already registered;
- The registered substance has the same chemical identity and properties as the recovered substance;
- The legal entity who recovered the substance have access to a safety data sheet; the registration number; and risk management information (EFCTC , 2008).

Third, suppliers of articles are obligated to **pass on information** to recipients and, upon request, to consumers, in accordance with Article 33. This article applies also to imported articles. Information is to be provided on the contents of substances of very high concern (SVHC) when these are contained in a concentration of more than 0.1% weight by weight. For a discussion of specific SVHC investigations related to gases addressed under the FGR, please refer to section 5.1.8.4 on cross-media effects and toxicity.

Although the general perception amongst in the market is that coherence with REACH is high and there are only few 'minor touch points', engagement with stakeholders raised a number of issues for consideration. First, they would like REACH registration for importers to be better enforced since current perceived lack of enforcement creates a disadvantage for EU based F-gas businesses (interview with industry). Second, there is a slight variation in the definition of 'placing on the market', with the Regulation going further to specify this only applies 'for the first time' (interview with industry), and; third between the Regulation and REACH there has been a failure to systematically identify and manage the potentially harmful effects of F-gas alternatives (interview with industry noted that there is currently a REACH PFAS restriction proposal being prepared by EU Member States). For a further discussion of the relevance of potential PFAS restrictions of gases addressed under the Regulation, please refer to section 5.1.8.4 on cross-media effects and toxicity.

Industrial Emissions Directive

Directive 2010/75/EU on industrial emissions ('Industrial Emissions Directive') stipulates that either of the following must be submitted to the competent authority to verify compliance: emission limit values (fugitive or total), the requirements of the reduction scheme under Part 5 of Annex VII, or the derogations granted in Article 59. Member States must also electronically submit representative data on emissions and other forms of pollution, as well as on the application of best available techniques (BAT) in accordance with Articles 14 and 15, to the EU Commission. However, these emissions are aggregate values for all HFCs and therefore give little indication on the climate impact (due to varying GWPs for HFC species). More granularity on these data would be useful to complement the reporting data collected under the Regulation.

Emission limit values are set by the competent authority and should not exceed emission levels associated with the BATs. The BAT Reference Document for the Food, Drink and Milk (FDM) industries includes limits for some refrigerant gases used in the dairy industry. A more systematic consideration of F-gases in the development of BREFs as a key environmental parameter would be useful.

EU LIFE programme

F-gases are also a priority area under the EU's LIFE programme, the EU's funding instrument for environmental and climate action. F-gas related projects aim to replace F-gases with natural refrigerants in various RACHP applications, train service technicians in the use of low GWP alternatives and raise awareness of climate-friendly technologies in various sectors (European Commission, LIFE Programme, 2021). Relevant projects (which all complement the Regulation) are summarised below.

Table 52: Current F-gas projects under the EU Commission's LIFE Programme

Project Title & Code	Coordinator	Duration	Summary
NATURAL HVACR 4 LIFE - Replacing F-gas: demonstration of innovative, integrated HVACR installations with natural refrigerant. **[LIFE18 CCM/BE/001182]**	Daikin Europe N.V. (Belgium)	Jun 2019 - Jun 2022	The project aims to install a combined air conditioning and refrigeration system, which uses CO_2 as a natural refrigerant, across both temperate and warm climate supermarkets. The energy efficiency and safety of the 21 installations will be monitored to provide a risk mitigation strategy as the basis for a large-scale application of CO_2 as a natural refrigerant. The project will contribute towards the implementation of the EU F-gas Regulation, as well as the Paris Climate Agreement, Climate Change and Energy Efficiency legislation and the EU's 2030 climate and energy framework (COM(2014)15).
RefNat4LIFE - Refrigerants, Naturally! for LIFE **[LIFE18 GIC/DE/001104]**	Heat GmbH (Germany)	Jun 2019 - Dec 2021	The project aims to increase training for service personnel in the use of climate-friendly equipment and alternatives, as well as to raise awareness and increase the uptake of climate friendly cooling alternatives in the organic food retail sector. The project will contribute towards the implementation of the EU F-gas Regulation, as well as Climate Change and Energy Efficiency legislation and the EU's 2030 climate and energy framework (COM(2014)15).
LIFE GRID - Greenhouse gas Reduction process via an Innovative high voltage circuit breaker Development **[LIFE18 CCM/FR/001096]**	Grid Solutions SAS (France)	Jul 2019 - Jan 2022	The project aims to replace SF6 in high voltage (420 kV) circuit breakers with the environmentally friendly alternative g3, with the support of Transmission System Operators (TSOs). The project will contribute towards the implementation of the EU F-gas Regulation and also target Climate Change & Energy efficiency legislation.
LIFE ZEROGWP - The first double duct residential air conditioner with near-to-zero Global Warming Potential natural refrigerant **[LIFE17 CCM/IT/000026]**	INNOVA S.R.L. (Italy)	Jul 2018 - Jun 2021	The project aims to validate a monobloc residential air conditioning system using Double Duct technology with R290 refrigerant. A field test campaign in Italy, Czech Republic and Slovakia will demonstrate performance while life cycle assessment and life cycle costing analyses will demonstrate environmental efficiency and cost sustainability. The project will contribute towards the implementation of the EU F-gas Regulation, as well as targeting Climate Change & Energy efficiency legislation, Industrial emissions Directive 2010/75, Industry and Product Policy, the EU's 2050 low carbon roadmap (COM(2011)112), and the EU's 2030 climate and energy framework (COM(2014)15).
LIFE ICEGREEN - Greening the ice-cream sector through low-GWP refrigerants and innovative business model [LIFE18 CCM/IT/001106]	Nemox International srl (Italy)	Jul 2019 - Jun 2021	The project aims to demonstrate the technical feasibility, safety and commercial viability of innovative ice cream machines which contain propane as a non-fluorinated refrigerant. The new technology will enable a new business model to be developed, using test shops called ICEGREEN corners. The project will contribute towards the implementation of the EU F-gas Regulation and also target Climate Change & Energy efficiency legislation.

Project Title & Code	Coordinator	Duration	Summary
Demonstration and validation of two economic viable climate-friendly alternatives for SF6 FREE high-voltage applications **LIFE17 CCM/BE/000113 - LIFE_SF6-FREE**	Ion Beam Applications SA	Jul 2018 – Nov 2020	The project aimed to conduct the first full-scale demonstration of an innovative waste heat recovery concept for glass furnaces using technology called Optimelt. The project aimed to achieve energy consumption and greenhouse gas emission savings of at least 20% compared to best available technology in the glass industry (oxy-fuel combustion). However, the project failed to reach its objectives and it had no concrete environmental, climate or socio-economic impacts to report on. It was terminated in March 2021.
LIFE innovative SF6 free electrical switchgear **LIFE18 CCM/FR/001155**	Schneider Electric Industries Sas	Jul 2019 – Feb 2024	The project will give EU regulators the necessary proof of concept for the 2023 proposal on SF6 and on broader fluorinated gases regulation, as an update to the existing EU regulation on fluorinated greenhouse gases. The projects proposed solution is to combine dry air or HFO1234zeE (also known as HFO), depending on voltage, with an innovative breaking device. The project will run prototypes at various sites in real conditions in order to validate that dry air and HFO are safe and reliable alternatives to SF6.
The demonstrative installation for the separation of refrigerant waste mixtures **LIFE18 CCM/PL/001100**	PROZON Fundacja Ochrony Klimatu	Jul 2019 – Dec 2021	The objective of the project is to limit the emission of fluorinated greenhouse gases into the atmosphere by the refrigeration and air-conditioning sector. It is assumed that at the end of the project, an HFC emission reduction of 74 000 t CO2 equivalent/year will be achieved. Expected results include Assembly of demonstration technology for separation of refrigeration waste; Environmental and social monitoring of the demonstration technology and improving public awareness of air pollution.
Carbon 4 Retails' refrigeration **LIFE17 CCM/IT/000120**	EPTA S.p.A.	Jul 2018 – Jul 2021	The project aims to demonstrate the economic and technical feasibility of an innovative technological solution that greatly reduces greenhouse gas emissions (GHGs). It aims to achieve this by substituting the synthetic fluorinated refrigerants (HFCs) with CO2, in the commercial refrigeration sector. Applications of the technology include cold transportation, households and industrial buildings.

Renewable Energy Directive (RED II) In response to the OPC, one stakeholder also identified a need for alignment with the Renewable Energy Directive (RED II) 2009/28/EC, which will be reviewed in 2021. The review will lead to an acceleration in the installation of new switchgear units which may imply impacts on the implementation of the Regulation in this specific sector. If this new installation base is not SF_6-free, there is a risk that renewable energy growth will promote the growth of the most potent GHG (SF_6) which could lead to more harmful concentrations of GHG in the atmosphere.

5.4.1.3 *Coherence with EU policies on customs, market surveillance and environmental crime*

Customs legislation

There is a need for stronger coherence with customs activities, as highlighted by stakeholders (interviews with MS and customs). Indeed, lack of coherence with customs legislation is viewed by many as a facilitator of illegal imports, and hence a clearer link between the Regulation and the Union Customs Code Regulation (EU) No 952/2013 is key to reducing this issue (Interviews with industry).

First, there is a lack of clarity around the role of customs with respect to the Regulation. The Regulation at present does not explicitly include any obligations for customs authorities to control F-gases, leading to potential ambiguity about the role of customs in the enforcement of the Regulation. By extension, there is a lack of clarity regarding who is responsible for monitoring elements of the Regulation. In

Austria, the national F-gas laws therefore supplement the Regulation's requirements and make reference to the EU Market Surveillance Regulation. This has achieved some success, but is not believed to be as effective as the electronic licencing system deployed under the Ozone Regulation (which in Austria is also coupled with national customs legislation regarding the import and export of Ozone).

Second, no clear cross-reference is made to the specific procedures of the Union Customs Code with which the requirements of the Regulation interact (interview with Member States).

Third, there is a disconnect between the information gathered for customs checks and under the Regulation (e.g. HFC Registry). For example, net mass (a critical data element for quality control) is currently not part of some customs data sets (e.g. customs warehousing), and CO2 equivalent are generally not specified. Furthermore, it is challenging to identify the difference between 'entering the EU' and 'placed on the EU market' (interview with customs).

As a consequence of the factors above and the fact that importers need to comply based on an annual balance, customs authorities are not able to check the validity of quotas at the moment when HFCs enter the EU (interview with Member States, OPC).

To achieve better controls and a more harmonised approach across EU regulations, a proposal for a 'EU Single Window environment for Customs' was published on 28 October 2020, whereby economic operators will be able to electronically submit information required by both customs and non-customs legislation for EU cross-border movements of all goods. By adding real-time, automatic checking of F-gas bulk quota and authorisations, transparency and compliance between the HFC Registry and customs systems can be improved. This in turn could facilitate stronger enforcement by Member States through enhanced control and verification. That said, stakeholders noted that linking to customs procedures would be complex and not all customs procedures can be used for F-gases. It would need to be made obligatory for economic operators to include the CO_2 eq of F-gases in products and equipment in all customs declarations, including a requirement for F-gas ID and F-gas quantities expressed in CO_2 eq to also be captured and other data requirements, such as the TARIC code used to identify substances for special procedures like transit will also be required if the Single Window approach is to monitor such trade flows.

Fourth, where illegal activities are identified, the remedial approach can differ between Member States. It is unclear how confiscated goods should be treated (interview with Member State). In some cases, customs authorities face challenges as regards what they should to do with illegal shipments that are seized causes because storage and destruction of confiscated items comes at a cost for customs authorities and may not be a long-term option. On the other hand, re-export of illegal shipments to the country of origin does not necessarily address the issue of illegal imports as the HFC shipments can be re-routed to alternative Member States.

Furthermore, although Article 25 of the Regulation sets out the obligation for EU Member States to lay down national penalties for infringements of the Regulation that are proportionate, dissuasive and effective, it does not specify the type of penalties; EU Member States may opt for administrative and/or criminal sanctions.

Whilst ensuring greater consistency with customs legislation, stakeholders (interview with Member States) also highlighted an opportunity to also ensure greater consistency with the legislation concerning pressurised equipment[78]. Given refrigerants are often transported in pressurised tanks and cylinders, it would be productive to ensure all issues associated with imports and exports are checked at once.

78 DIRECTIVE 2010/35/EU OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 16 June 2010, on transportable pressure equipment and repealing Council Directives 76/767/EEC, 84/525/EEC, 84/526/EEC, 84/527/EEC and 1999/36/EC, https://eur-lex.europa.eu/legal-content/EN/ALL/?uri=CELEX%3A32010L0035

Market surveillance legislation

Regulation (EC) No 765/2008 ('Market Surveillance Regulation') established conditions for the placing of 'products' on the Union market. It therefore compliments the controls set out in the Regulation and reinforces their implementation. The revised Market Surveillance Regulation (EU) 2019/1020 explicitly states that the Regulation falls under its scope of application. In addition, the role of market surveillance authorities (customs or others) is strengthened; for example, such authorities are obliged to suspend the release for free circulation of F-gases where there are reasons to consider that the Regulation requirements are not complied with.

The Regulation opted to establish a different definition for 'placing on the market' compared to the one stated in the Market Surveillance Regulation. However, there is no contradiction in this respect; as lex specialis, the placing on the market definition established under the Regulation is the applicable one vis-a-vis F-gases. That said this difference causes additional complexity (interviews with Member States). In addition, stakeholders (interview with Member States) perceive that definitions of import and export also vary.

Environmental Crime Directive

Article 3 of Directive 2008/99/EC ('Environmental Crime Directive') establishes certain conducts as criminal offences, 'when unlawful and committed intentionally or with at least serious negligence'. The Directive applies vis-à-vis a number of sectoral legislations including the first Regulation (EC) No 842/2006 (see Annex to that Directive). At the same time, the prescribed conducts are too general and outdated to address specific infringements of the current Regulation. For example, the intentional or negligent emission of F-gases is considered a criminal offence, but the illegal import and trade of HFCs is not. The EU Commission will present a proposal to amend the Environmental Crime Directive by the end of 2021; this proposal will update the list of criminal offences to take into account more recent legislation and related challenges (e.g. illegal import of HFCs). Coherence between the two revised pieces of legislation must be maintained.

5.4.1.4 *Coherence with safety standards and building codes*

An important area of consideration with respect to coherence is around the interaction with safety standards and building codes. An extensive discussion of this interaction, and the barriers posed over the evaluation period is presented above in EQ2a.

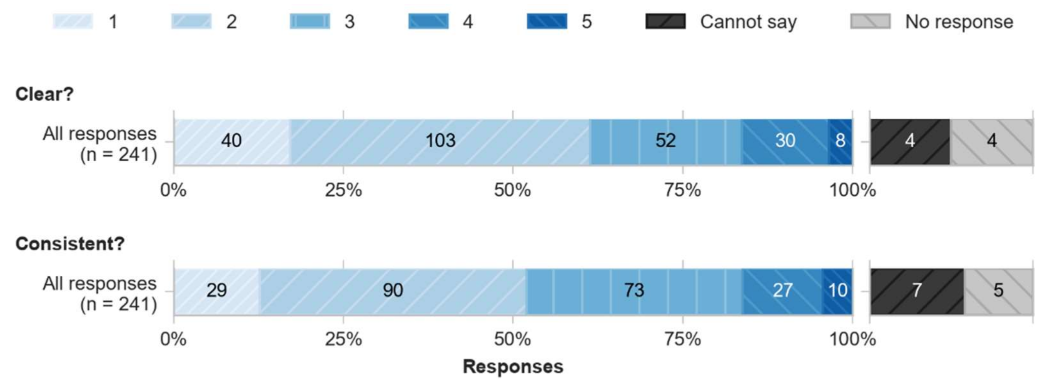
5.4.2 EQ10: To what extent is the Regulation internally consistent and coherent, in particular across its implementing acts? How well do the different provisions of the Regulation operate together to achieve its objectives?

This section examines if there are any identified cases of gaps, overlaps, inconsistencies and/or other conflicts within the Regulation or with its implementing acts and considers whether the provisions of the Regulation are coherent with its objectives. The analysis of internal coherence is based on literature review as well as expert and stakeholder input from the targeted interviews and the OPC.

In the targeted interviews, Member State competent authorities stated that the Regulation is generally coherent, while also indicating some inconsistencies that have been observed since its entry into force (see following sections).

As part of the OPC, approximately 59 % of the stakeholders rated the clarity of the Regulation with one of the two highest scores (fully agree and agree), while the share was slightly lower (52 %) when asked about the Regulation's consistency.

Figure 55: Survey results from the question: Is the Regulation clear and consistent?



For the following **implementing acts**, issues of internal coherence have been identified:

- Commission Regulation (EC) No 304/2008 on certification of service technicians and undertakings in the fire protection sector needs to be updated as intervals for leakage checking are still based on charge sizes expressed in kilogrammes instead of tonnes of CO_2 eq. This inconsistency leads to practical problems as it is not clear for the service technicians and undertakings concerned which legislation is to be applied.
- The same problem arises with Commission Regulation (EC) No 1516/2007 on leakage checking requirements for stationary RACHP equipment containing certain F-gases. This implementing act also needs to be adapted to the current thresholds for charge sizes based on CO_2 eq.

The following **definitions** currently contained in the Regulation were considered not sufficiently clear to some stakeholders:

- **'Placing on the market'** (Article 2 No 10): The current definition is limited to the supplying or making available to another party in the Union for the first time but may be extended to also include further distribution on the market, in line with the Ozone Regulation (see section on external coherence).
- **'Hermetically sealed equipment'** (Article 2 No 11): The wording of this definition is considered to be unclear, while lacking a definition of capped valves and capped service port. This is important to ensuring correct application of exemptions relating to hermetically sealed equipment.
- **'Non-refillable container'** (Article 2 No 13): The final clause 'without provision having been made for its return and refilling' provides difficulties for implementation.
- **'Recycling'** (Article 2 No 15): This definition is not considered precise enough and needs to be adapted as it is e.g. currently possible in practice to circumvent the use of virgin gases with a GWP of 2500 or more (Article 13 (3)) by topping up the refrigeration equipment with F-gases recovered from other installations, which may be contaminated with acids, water or gas composition that is different from the required composition of the virgin gas.
- **'Reclamation'** (Article 2 No 16): It was noted that the current definition is not sufficiently clear and needs some clarification which purification stages the reclamation process should include.
- **'Destruction'** (Article 2 No 17): The current definition does not distinguish between intentional and unintentional destruction. The latter is difficult to regulate.
- **'Installation'** (Article 2 No 20): Construction of new equipment from parts, including outside the factory, and supplying it or making available to another party should be considered 'placing on the market' and not 'installation', as it is currently not clear whether the placing on the market

bans would apply to constructing the equipment outside the factory. This could help avoiding the circumvention of Annex III placing on the market bans for equipment.

- **'Maintenance or servicing'** (Article 2 No 21): It was noted that the definition seems to have been formulated primarily for RAC&HP installations, but also needs to cover the requirements of other installations.
- **'Stationary'** and **'mobile'** (Article 2 No 23 & 24): Current definitions should be more precise to also cover movable, quasi-stationary or quasi-mobile installations.
- **'Refrigerated truck'** (Article 2 No 26): From the current definition, it is not clear whether 'mass' is the maximum allowable mass or the nominal mass.
- **'Technical aerosol'** (Article 2 No 28): Common types of aerosols used for disinfection of cosmetic applications are not explicitly covered by this definition which could be a loophole. In addition, the term aerosol dispenser is not yet defined.
- **'Undertaking'** (Article 2 No 30): It was noted that the term 'undertaking' is currently in some articles (e.g. Article 3 (4), 6 (2)(b), 6 (3)) in the sense of 'legal person', while the actual definition includes both natural and legal persons.

It was also stated that clear definitions to avoid the circumvention of prohibitions of placing on the market or use by simply renaming the equipment are necessary for the categories **'refrigeration equipment', 'air-conditioning equipment'** and **'heat pump equipment'**. For the same reason, it is also required to clearly assign certain special appliances such as refrigeration machines, ice makers, laundry dryers, humidifiers, dehumidifiers, etc. to these three categories.

Another potential issue is that a definition has not been provided as to what determines 'pre-charged equipment'. This could cause potential for discrepancies as to whether or not producers and importers have determined their equipment to be pre-charged.

As regards reclamation, it was noted that a definition for **'reclamation facility'** should be included, especially to provide a clear distinction from recycling processes.

With respect to **activities**, the following coherence issues were identified:

- While holding a quota authorisation is mandatory from a threshold of 100 tonnes of CO_2 eq, Article 19 (4) of the Regulation sets a threshold of 500 tonnes of CO_2 eq for reporting on pre-charged products and equipment containing F-gas and other F-gases that have been placed on the market.
- The reporting threshold of 500 tonnes of CO_2 eq is also inconsistent with the reporting threshold for producers, importers and exports of bulk HFCs of one metric tonne or 100 tonnes of CO_2 eq as set out in Article 19 (1).

In addition, the following **issues** have been raised for which further clarification might be needed.

- Article 6 (1)(c) that requires operators of equipment to include information on quantities of recycled or reclaimed F-gases in their records, currently only refers to installed, but not to added gases. This is important in the context of the ban on use of refrigerants with GWP of 2 500 or more for certain equipment with exemption for recycled or reclaimed refrigerants.
- In Article 6 (1)(f), the information to be included in the records does currently not cover details about leakage repairs. However, rephrasing the provisions as follows 'the dates and results of the checks carried out under Article 4(1) to (3) and of leakage repairs' is needed in conjunction with the Article 3 (3) requirement to repair leakages without undue delay.

- Although Article 8 (1) states that recovery may only be done for the purpose of recycling, reclamation or destruction, one national public authority raised that it is common practice among service technicians that the refrigerant recovered from the equipment is returned to the equipment for e.g. the purpose of repair without any basic cleaning. Returning the potentially contaminated refrigerant to the equipment can lead to malfunctioning and increased energy consumption. Hence, it should be clarified that the recovered refrigerant cannot be used for fill or refill equipment unless it has been recycled or reclaimed.
- According to one public authority, the wording ‘appropriately qualified natural persons’ (Article 8 (3)) is vague and leads to different interpretations.
- Article 11 (5) provides that non-hermetically sealed F-gas equipment shall only be sold to the end user if proof is provided that the installation is carried out by a certified company. Clearer guidance on how to implement this provision was considered useful.
- Article 13 (3)(b) allows the use of recycled F-gases with a GWP of 2500 and more for the servicing and maintenance of existing refrigeration equipment until 2030, provided they have been recovered from such equipment. However, while reclaimed F-gases have to fulfil the requirement to meet the equivalent performance of a virgin substance, recycled F-gases only have to undergo a basic cleaning process before further use, without any requirements on the actual quality of the substance (see also section on definitions).
- Some requirements related to the import of pre-charged equipment according to Article 14 are not clear enough in the main part of the Regulation and should be further specified (e.g. the point in time when the authorisation needs to be indicated in the HFC Registry (date of import, end of year, end of reporting period), if the check of authorisations is performed by customs or as part of the annual reporting).
- It should be clearer in Article 14 (2) that verification of HFC pre-charged in imported equipment is required as of 100 tonnes of CO_2 eq.
- In Article 15 it should be clear that the placing on the market of HFCs in excess of the quota limits is strictly prohibited. The current provision ‘shall ensure’ is not strong enough to avoid the need for national public authorities to impose an additional prohibition to be able to designate the violation as a criminal offence.
- Article 17(4) provides that competent authorities, including customs, shall have access to the HFC registry for information purposes. However, the provision does not specify whether and to what occasion the authorities should actually use the HFC register.
- The deadlines for submitting of F-gas and verification reports according to Article 19 are currently not aligned. While it is stated each undertaking reporting the placing on the market 10 000 tonnes of CO_2 eq or more of hydrofluorocarbons during the preceding calendar year must additionally ensure that the accuracy of the data is verified by an independent auditor by 30 June each year, reporting on production, import, export, feedstock use and destruction of the substances listed in Annexes I or II is, however, set to take place by 31 March each year.

5.4.3 Conclusions on coherence

Regarding external coherence (EQ9), the Regulation interacts with a number of regulatory instruments, both in the form of other EU policy but also international agreements. In general, it can be concluded that the Regulation shows strong consistency and coherence with other interventions that have similar objectives, although there are some important areas of incoherence.

- There are differences in the phase down schedules defined by the Regulation and under the **Kigali Amendment to the Montreal Protocol.** Some of these differences add complexity, but do not necessarily create a risk of incompliance (as long as the EU's HFC consumption is compliant with the reduction steps required by the Montreal Protocol). However, there are some areas of incoherence, specifically: need to continue phase down post 2030, the requirement to phase down production under Kigali, and the thresholds for reporting. The EU F-gas Portal, consisting of the HFC Registry and the Business Data Repository (BDR) ensures compliance with that requirement of the Montreal Protocol by requiring that all importers and exporters must be registered before undertaking such activities. It has been concluded that licensing system would be more effective if it would take advantage of the 'EU Single Window Environment for Customs'.

- Lack of coherence with **customs legislation** may facilitate illegal imports. The role of customs in enforcement of the Regulation. The EU Single Window environment for Customs has the potential to aid customs enforcement. Furthermore, remedial approaches differ across Member States which compound to undermine the prevention of illegal trade. One enforcement issue identified by a Member State authority is that the quota system is not yet directly linked to the reporting system and does not allow for real-time checking of quota. This will be remedied once the EU Single Window environment for Customs is integrated with the quota system.,
- **Safety standards** at international, European and national level regarding the use of flammable refrigerants continue to be an important barrier to the uptake of climate-friendly alternatives to HFCs, despite recent actions of the EC.
- There are synergies regarding **energy efficiency** and the Ecodesign Directive, in particular through Article 11(2) of the Regulation, which allows an exemption from the placing on the market bans set out in Annex III if the equipment with HFCs would achieve lower overall life-cycle GHG emissions. There are claims that for a few examples a trade-off could occur in practice, which creates a perception amongst some stakeholders that there is incoherence between the Regulation and Ecodesign (although this may also reflect a lack of awareness amongst industry of existing provisions concerning this interaction). The same stakeholders have not been able to produce clear examples of such trade-offs.
- Although not directly conflicting, the complexities of the interaction of the Regulation with **waste legislation,** in particular around the classification of waste, has created uncertainty for market players. Second, legislation around the transboundary shipments of waste is viewed by some stakeholders (but not all) to present a barrier to reclamation.

Concerning internal coherence (EQ10), overall, on the basis of the analysis and the input from stakeholders, it can be concluded that the issues regarding the internal consistency and coherence of the Regulation are limited. Areas identified that require further consideration and adaptation include: the updating of implementing acts, the clarification of existing definitions and the inclusion of some new ones, the alignment of some activity thresholds and some clarifications in individual provisions.

5.5 EU added value

5.5.1 EQ11. To what degree has the Regulation enabled successful and cost-effective EU action regarding the reduction of F-gases beyond what would have been possible at national level?

This question aims to examine whether the Regulation has allowed for: higher environmental ambition, facilitated compliance and coherence with international requirements under the Montreal Protocol, led to higher benefits and cost savings for competent authorities in EU Member States and created a level playing field for the affected industry compared with a national level approach.

The Regulation has delivered added value by adopting ambition exceeding that anticipated at Member State level and has better ensured ensure compliance with the Montreal Protocol (specifically the Kigali Amendment). Without the Regulation, each Member State would need to introduce mechanisms to regulate their national F-gas consumption. These options could not guarantee compliance with the Montreal Protocol. For example, a quota system would not be feasible at Member State level as an import quota into one Member State from another would not facilitate consistency with the core principles of the EU internal market and free movement of goods. Furthermore, Member States would instead need to rely on other instruments such as taxes, additional prohibitions and import/ export licences. However, as examined under Effectiveness, the successful reduction of F-gas emissions to date is due to the phase-down and prohibitions working together and so Member States using different measures would likely result in inconsistent and lower reduction in F-gas emissions across Europe (the 2012 impact assessment for the Regulation showed that the environmental benefit of having prohibitions alone was approximately 29 % inferior to also having a phase-down). This conclusion that the Regulation has achieved a higher level of ambition than what would have occurred at individual Member State level is corroborated by stakeholders (interviews with competent authorities, OPC).

Recital (26) of the Regulation outlines the need for action at EU level due to the transboundary nature of the global warming effect of greenhouse gases. Looking forward, although intervention at EU level has seen a reduction in F-gas emissions and compliance with the Montreal Protocol, the problem still persists, and is evolving (see EQ7). There is a need for continued EU action in order to ensure that F-gas emissions reduce in line with the climate ambitions of the EU Green Deal (raising the EU's 2030 GHG emission reduction target, including emissions and removals, to at least 55 % compared to 1990, and reaching GHG neutrality by 2050) and the Montreal Protocol (phase down steps beyond 2030). These targets are in an order of magnitude that requires strong political and effective policies in place, and as described above, this would be more difficult to achieve on the basis of actions at 27 national levels.

Alongside delivering additional ambition against the core objectives, a further key benefit of action at EU level is the efficiency improvements and cost savings that stem from co-ordinated action. For the Regulation, there are multiple cost savings of action at EU level:

- National approaches to effectively meet the individual HFC phase-down targets would present a very fragmented and costly situation for all the different industry sectors concerned, particularly those which place their goods on the market in multiple Member States. An EU approach allows for these central requirements to be consistent across Member States, with only small deviations in some countries that have introduced more restrictive or additional measures (see EQ1f), minimising compliance burden for market players. One stakeholder (interview with Member State) noted specifically that common elements such as definitions, labelling, etc. would be complicated to agree at national level. This has therefore also reduced decision making burden on Member States.
- Under the EU quota allocation system, quotas are not allocated to certain Member States, sectors or applications, but to the whole EU market on an annual basis by the EU Commission.

This allows the most efficient abatement solution to be found across a broader market, which is likely to lead to lower implementation costs.

- Each Member State would still have to set up a licencing system for goods being imported and exported to and from the EU from their territory. As outlined above, many undertakings do not operate solely in one Member State, but across borders. Thus, that would greatly increase the administrative burden for Member States and undertakings.
- Through the F-gas Portal, the Regulation has introduced a common electronic tool which undertakings can access to register, apply for quota, transfer quota and manage quota authorisations. With no such central system in place, IT infrastructure would have been needed to be developed separately at Member State level. The same applies to the Business Data Repository (BDR), the second component of the central F-gas Portal: The centralised collection of reported F-gas data enables the EEA to publish annual reports on undertakings' compliance with the reporting requirements of Article 19 and at the same time to assess the EU's progress towards the set F-gas reduction targets.
- A joint approach across Member States makes it easier to enforce F-gas reduction policies and allows for lessons learned and knowledge sharing across Member States.
- Common legislation has also enhanced the market for new alternatives (Stakeholder interview).

Although the Regulation has created efficiency savings through EU-level action, it appears there are options to go further. For example, the enforcement and application of penalties is the responsibility of Member States (Article 25). Only in case of quota exceedance does the EU Commission penalise non-complaint undertakings by reducing their quota quantity by 200 % of the amount by which the quota was exceeded (Article 25 (2)). As such there is risk that Member States with relatively low penalties become the gateway to EU for illegal imports. There was support amongst respondents to the OPC for further harmonisation across the EU with respect to penalties to try to tackle the issue of illegal trade (e.g. use of clear minimum penalties and fines).

The HFC phase-down at EU level, implemented by a quota allocation system, not only increases the environmental benefit and reduces costs by setting an EU-wide cap, but also provides certainty on the allowed maximum quota quantity, creating a level playing field for market players operating in a single, integrated EU market. Likewise, the use of EU-wide placing on the market and use restrictions, and requirements for labelling and containment also contribute to this level playing field for the F-gas using industry and end-users. Stakeholders (OPC) agree that the Regulation has created a level playing field across the EU.

5.5.2 Conclusions on EU added value

It is clear that the Regulation has added value by implementing co-ordinated action at EU level to ensure compliance with the Montreal Protocol and the EU climate goals are met. In doing so, the Regulation has also increased ambition relative to that which would have been likely at national level (indeed action at national level may not have been sufficient to ensure compliance) and has created a much larger, common market for alternatives. Alongside additional environmental improvements, a key benefit is the creation of a more efficient and less burdensome regulatory environment for the EU F-gas industry, helping to minimise costs. EU action has also helped create a level playing field for the EU industry.

6 Conclusions and issues identified for further consideration

This study has undertaken a broad and detailed evaluation of the Regulation in order to appraise its functioning to help assess whether the instrument is fit for purpose. As steered by the Better Regulation Guidelines, performance has been assessed against 5 criteria: effectiveness, efficiency, relevance, coherence, and EU value added. Conclusions have been drawn at the end of each of the relevant chapters of Section 5 around each criterion.

In summary:

- It can be concluded that the Regulation has been **effective** in meeting its original objectives. The individual measures of the Regulation have worked together in order to meet the objectives and the effectiveness of the Regulation as a whole would have been impacted if one or more of the measures had not been included. Nonetheless, the Regulation may not fully meet the emission savings envisioned for 2030.
- The Regulation has delivered a range of benefits since its revision in 2014, not least a decrease in F-Gas emissions. The Regulation has been **efficient** in this respect, given the emission savings have been delivered at low abatement costs linked to technological change. Furthermore, administrative burdens are relatively small and next to no areas have been identified as overly burdensome by stakeholders themselves.
- The high-level objectives of the Regulation continue to reflect and respond to the fundamental need of the EU to reduce demand and emission of F-gases; hence the Regulation remains broadly **relevant**. However, developments over the period of implementation, specifically the European Green Deal and a changed international policy environment (Paris Agreement, Kigali Amendment), pose a challenge to the Regulation in its current form, and require more emission reductions.
- Regarding external **coherence**, the Regulation interacts with a number of regulatory instruments, both in the form of other EU policy but also international agreements. In general, it can be concluded that the Regulation shows good consistency and coherence with other interventions that have similar objectives, although there are some important areas of incoherence, e.g. with the Protocol or with custom rules. Internally issues regarding the internal consistency and coherence of the Regulation are limited but would benefit from being addressed.
- It is clear that the Regulation has **added value** by implementing co-ordinated action at EU level to ensure compliance with the Montreal Protocol and the EU climate goals are met, increasing overall ambition and improving efficiency of action in this area.

Although in the main, the Regulation is observed to be performing well across a broad range of areas, several issues have been identified which warrant further consideration. These are presented in the following table.

Table 53: Issues identified for further consideration

Theme	Issue/challenge
increase in ambition of EU Climate objectives	The EU Climate objectives have evolved since the time of the last impact assessment (2012). The EU Green Deal aims at raising the EU's 2030 GHG emission reduction target, including emissions and removals, to at least 55 % compared to 1990, and reaching GHG neutrality by 2050. These targets are in an order of magnitude that demands significantly more action in all sectors to reduce emissions and requires strong political and effective policies in place
Coverage of sectors and activities by different measures	Some gaps with respect to sectors have been identified which may need further consideration (or re-consideration). While reduction measures of the current Regulation address mainly HFC applications, PFCs and SF_6 (as well as Annex II gases) are not covered by the HFC phase-down and their use is only restricted for certain smaller applications. For example, sulphur hexafluoride (SF_6, GWP 22,800), perfluorocarbons (PFCs, GWP 7,400 – 12,200) and nitrogen trifluoride (NF_3, GWP 17,200). Some significant emissions, e.g. Sulfuryl fluoride, are not regulated and a number of relevant substances not monitored.
Compliance with Kigali	Improve coherence to ensure compliance with Kigali, in particular need to continue phase down post 2030, the requirement to phase down production under Kigali, as well as a number of thresholds and exemptions. The Regulation itself does not have the in-built flexibility to automatically align with the Kigali Amendment.
Training & certification	Does not currently cover safe handling of alternatives to F-gases, undermining their deployment and awareness of these options. The availability of technical training could also be improved, with only a little over half of the current training centres able to offer training programmes on safe use of F-gas alternatives including flammable, high-pressure and toxic refrigerants. Training and certification programmes are lacking in and/or unevenly spread across Member States.
Action on illegal trade	Illegal trade is an important issue. This is facilitated by various factors that may require attention: ***1.*** Coherence with customs legislation. This could include: clarification of the role of customs in enforcement of the Regulation. The European Union Single Window Environment for Customs has the potential to aid customs enforcement. Furthermore, remedial approaches differ across Member States which compound to undermine the prevention of illegal trade. ***2.*** Action on penalties ***3.*** Action and enforcement of online trade. ***4.*** Improved market surveillance. ***5.*** Special custom procedures
Containment and leakage checks	Requirements only concern F-gases listed in Annex I of the Regulation, while no such requirements apply to other relevant fluorinated gases listed in Annex II, such as NF_3, hydro(chloro)fluorocarbons, fluorinated ethers and alcohols and other perfluorinated compounds as well as potentially other gases suggested to be added to Annex II (see below). Current emission prevention provisions do only apply to the use of bulk gases, but not to their manufacturing, storage and transport, where leakages can also occur. Enforcement and compliance require further attention to ensure energy efficiency.
Coverage of F-gases	F-gases that are not currently covered by either Annex I nor Annex II of the Regulation but are relevant on the EU market or starting to become commercialised include: sevoflurane (HFE-347mnz1, GWP 216 (AR5)); enflurane (HCFE-235ca2, GWP 583 (AR5)); sulfuryl fluoride (SO2F2, GWP 4732 (AR5)); FK-5-1-12 (GWP) and other UNSATURATED H(C)FCs. There may also be scope to revisit some of the requirements for gases where those do not yet exist (e.g. alternatives to SF_6 in electrical switchgear and other electrical equipment).

Reporting and verification	Although reporting is generally supporting the Regulation, several potential issues and improvements have been identified: • Data collected for reclamation is incomplete as reclamation is only subject to mandatory reporting in case reclamation is performed by undertakings which are also importers of F-gases. • Regulation does not contain mandatory reporting obligations related to exports of F-gases contained in products or equipment. The voluntary reporting option for HFCs supplied to equipment manufacturers for export has hardly been used. Furthermore, there is scope for improving the reporting and verification process.
Alignment of thresholds	Variance in verification obligations between bulk HFC producers and importers and importers of equipment pre-charged with HFCs.
Negative environmental effects associated with some alternatives to F-gases	This is a risk associated with the deployment of certain alternatives that requires further monitoring.
Flexibility to adapt to future challenges	The Regulation itself does not have the in-built flexibility to address serious issues linked to the phase-down, such as market supply or similar.
Quota allocation	Quota is distributed over many entities, some of them not involved in the gas trade or mailbox companies, leading to very low new entrant quotas. Access to the quota system should be ensured for those who need it.
Recovery of foams	The Regulation will ban all types of foams blown with HFCs from 1st January 2023. This ban will stop the additional use, but does not ensure the safe disposal and recovery of HFCs present in insulation material that is currently in use or will be put into use up until 2023. The Regulation states that recovery of F-gases is required at end-of-life from foams where it is “technically feasible and does not entail disproportionate cost”, but the market has in general not responded to this by providing a proper disposal process. As a result, the HFCs currently trapped in insulation foams are likely to be released to the atmosphere unless comprehensive recovery policies are put in place.