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IMPACT ASSESSMENT REPORT

Accompanying the document

Proposal for a
REGULATION OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL

on fluorinated greenhouse gases, amending Directive (EU) 2019/1937 and repealing Regulation (EU) No 517/2014

{COM(2022) 150 final} - {SEC(2022) 156 final} - {SWD(2022) 95 final} -
{SWD(2022) 97 final}

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Glossary

Term or acronym	*Meaning or definition*
AC	Air conditioning which here is considered to also include heat pumps
AnaFgas model	Detailed bottom-up model for sectors and sub-sectors using F-gases. AnaFgas = „Analysis of fluorinated greenhouse gases in the EU“
AR (4/5/6)	4^{th}, 5^{th} or 6^{th} Assessment Report of the International Panel on Climate Change (IPCC)
Bank(s)	The amount of substance (e.g. HFC) contained in existing equipment (e.g. refrigerators, foams), chemical stockpiles and other products, including after their end of useful life; or recovered and stored ready for use
BDR	EEA's "business data repository", where annual reporting by companies is received and stored
Bulk (HFC, F-gas)	Refers to HFC gas/F-gases in containers (for transport, storage etc.) as opposed to already filled into products (e.g. an aerosol spray can) or equipment (e.g. an air conditioner)
Capex	Capital expenditure
CERTEX	IT system that allows to exchange data ("certificates") on relevant F-gas shipments between the central EU F-gas Portal & HFC Licensing System and custom offices in the Member States directly; IT precursor of the European Single Window Environment for Customs
CDW	Construction and demolition wastes
CN	EU Combined Nomenclature; tool for classifying goods to meet the requirements of common customs tariff and external trade statistics https://ec.europa.eu/taxation_customs/business/calculation-customs-duties/customs-tariff/combined-nomenclature_en
CO_2e(quivalent)	The CO_2 equivalent is the quantity of a gas in metric tonnes multiplied by its associated global warming potential (GWP). This is used to compare the emissions from various greenhouse gases based upon their global warming potential
Consumption	The quantity of HFC produced plus imported, minus exported minus destroyed. Calculation of consumption under the Montreal Protocol excludes non-virgin bulk imports and exports, as well as substances intended for feedstock and process agent use
ECHA	European Chemicals Agency
EEA	European Environment Agency
EPEE	European Partnership for Energy & Environment. An industry association that includes inter alia large F-gas producers, large equipment manufacturers and service personnel representatives
ESR	Effort Sharing Regulation: Regulation (EU) 2018/842 as well as the proposal for a Regulation amending this regulation (COM(2021) 555 final)
ETS	EU's Emission Trading System
F-gases	Fluorinated greenhouse gases

Feedstock use	Use of a substance, e.g. an F-gas, in a process where it undergoes chemical transformation to synthesise other chemicals and in which the substance is entirely converted from its original composition
F-gas Regulation	Regulation (EU) No 517/2014
GDP	Gross domestic product
GHG(s)	Greenhouse gas(es)
GWP	Global Warming Potential. It is a metric for determining the relative contribution of a substance to climate warming. The GWP indicates how much (solar) energy the emissions of 1 ton of a gas will absorb (and thus contribute to climate warming) over a given period of time, e.g. 100 years for GWP_{100}, relative to the emissions of 1 ton of carbon dioxide (CO_2).
HFCs	Hydrofluorocarbons; F-gases listed in Annex I of F-gas Regulation
HFC-23	Trifluoromethane; an HFC with a very high GWP (14,500 according the IPPC`s 4^{th} Assessment Report)
HFOs, HCFOs	Unsaturated HFCs that can substitute HFCs in many applications. Synthetically produced substances that break up quickly in the atmosphere and therefore have a low GWP. HCFOs are slightly different chemically as they also include a chlorine atom in the molecule. Both are listed in Annex II, Section I.
HFEs	Fluorinated ethers, listed in Annex II
HV	High-voltage
IPCC	Intergovernmental Panel on Climate Change. United Nations body for assessing the science related to climate change. https://www.ipcc.ch/
ISG	European Commission Inter Service Group accompanying the impact assessment
Kigali Amendment	Added HFCs to the regulated substances under the Montreal Protocol
MAC	Mobile air conditioning (in particular as relating to AC in passenger cars)
MDIs	Metered dose inhaler used for medical purposes, e.g. asthma sprays
MMR	Monitoring Mechanism Regulation (Regulation (EU) No 525/2013): mechanism for monitoring and reporting greenhouse gas emissions and for reporting other information at national and Union level relevant to climate change
(Montreal) Protocol	The Montreal Protocol on Substances that Deplete the Ozone Layer, an international treaty governing the protection of stratospheric ozone. It also regulates the HFCs since the Kigali Amendment (2016).
MV	Medium-voltage
NF_3	Nitrogen trifluoride (an F-gas listed in Annex II)

ODS	Ozone-depleting substance(s)
Opex	Operational expenditure
Person days	Full-time equivalent (working time)
PFAS	Per- and polyfluoro alkyl substances, synthetic organofluorine chemical compounds that have multiple fluorine atoms attached to an alkyl chain. They are substances of concern due to the longevity in the natural environment (“forever chemicals”).
PFCs	Perfluorocarbons; F-gases listed in Annex I of F-gas Regulation
PfS	Production for sale
POM (Placing on the market)	Supplying or making available to third persons within the European Union for the first time, for payment or free of charge
RAC	Refrigeration and air conditioning (includes heat pumps)
Reclamation	Reprocessing of a recovered ODS in order to meet the equivalent performance of a virgin substance, taking into account its intended use
Recovery	Collection and storage of ODS from products and equipment or containers during maintenance or servicing or before disposal
Recycling	Reuse of a recovered ODS following a basic cleaning process
REIO	Regional Economic Integration Organisation; The EU is considered a REIO under the Montreal Protocol
RSB	Regulatory Scrutiny Board
RV	Reference value
SF_6	Sulphurhexafluoride; an F-gas listed in Annex I of the F-gas Regulation
SME	Small and medium enterprises
Single Window	European Single Environment for Customs; https://ec.europa.eu/taxation_customs/general-information-customs/electronic-customs/eu-single-window-environment-for-customs_en
SO_2F_2	Sulfurylfluoride, an F-gas used in pest control currently not listed in the F-gas Regulation
Switchgear	Switchgear is used to in electric transmission and power systems to control, protect and isolate electrical equipment
TARIC	TARIC = Integrated tariff of the EU
(M)tCO2e	(million) tonnes CO_2 equivalent
TFA	Trifluoroacetic acid; a persistent chemical that is formed by the breakdown by some HFCs and HFOs in the atmosphere; accumulates in surface and

	fresh waters and has been shown to have phytotoxic effects
Totex	Total expenditure
UNFCCC	United Nations Framework Convention on Climate Change
VRF system	Variable Refrigerant Flow; an AC system that allows endusers to control several air conditioned spaces (e.g. rooms) individually

1. INTRODUCTION: POLITICAL, SECTORAL AND LEGAL CONTEXT

1.1. EU Climate Ambition, Paris Agreement and Montreal Protocol

Fluorinated greenhouse gases (F-gases) are man-made chemicals that are very strong greenhouse gases (GHG), often several thousand times stronger than carbon dioxide (CO_2). Together with carbon dioxide, methane and nitrous oxide, they belong to the group of GHG emissions covered under the ***Paris Agreement on Climate Change***.

F-gas emissions amount today to 2.5 % of EU's total GHG emissions, but have doubled from 1990 to 2014, in contrast to other GHG emissions which have fallen. This is because F-gases typically replaced ozone-depleting substances (ODS)[1] in areas where the EU prohibited ODS[2] to protect the Ozone layer, as required under the ***Montreal Protocol on substances that deplete the ozone layer*** (hereafter the Protocol). Since 2006 the EU has had policies in place to reverse this increasing trend of F-gas emissions and the ***EU Regulation on fluorinated greenhouse gases***[3] (hereafter: the Regulation[4]) is one of the key instruments at EU level to do so and contributes to reaching the EU climate targets.

Recently, the EU increased its climate ambition through the ***European Climate Law***[5], adopted in 2021. This law establishes a binding overall net GHG reduction target of at least 55% by 2030 compared to 1990 and climate neutrality by 2050. The law is based on the 2030 Climate Target Plan[6] which underlines that achieving this ambition will require action in all sectors and that **all policy instruments relevant for the decarbonisation of our economy must work in coherence**, while setting the agenda to reinforce them. In this context, the proposed revision of the ***Effort Sharing Regulation (ESR)***[7] increases the ambition of the binding annual greenhouse gas emission targets for Member States from 2021 to 2030 for sectors not covered by the existing EU Emissions Trading System (ETS). F-gas emissions[8] are included in the ESR and represents almost 5% of all GHG emissions covered. Member States' individual targets relate to this overall basket of GHGs and there are no sub-targets for the sectors covered. Consequently, the EU or the Member States do not have any binding targets specific to F-gas emissions.

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1 Note that F-gases themselves are not relevant for ozone depletion
2 Regulation (EC) 1005/2009 on substances that deplete the ozone layer. https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=celex%3A32009R1005
3 Regulation (EU) No 517/2014 on fluorinated greenhouse gases. https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=celex%3A32014R0517
4 The EU started its F-gas policy in 2006 with Regulation (EC) No 842/2006 on fluorinated greenhouse gases and Directive 2006/40/EC relating to emissions from air conditioning systems in motor vehicles (MAC Directive). The Current Regulation has applied since 2015.
5 Regulation (EU) 2021/1119. https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=celex%3A32021R1119
6 COM(2020) 562 final. https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A52020DC0562
7 COM(2021) 555 final. https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=COM%3A2021%3A555%3AFIN
8 A very small fraction of F-gas emissions is covered by the EU ETS (perfluorocarbons emissions in the production of primary aluminium). There are also fluorinated GHG not covered by the ESR and the ETS, e.g. gases listed in Annex II of the F-gas Regulation (except for NF_3), and other, as yet unlisted fluorinated GHG.

The Regulation could contribute more to achieving the EU's climate targets. It is targeting a number of sectors falling within the scope of the ESR, where EU action has proven to be particularly well placed to achieve emission reductions in a cost-effective manner. By reviewing and reinforcing this Regulation, additional F-gas emission savings at EU level can help Member States achieve their proposed higher ESR GHG emission target and improve the overall cost-effectiveness, while leaving margin to Member States on how best to achieve the required overall GHG targets across all sectors and gases in the ESR. For F-gases Member States can e.g. apply national fiscal measures (see Annex A5.4.2.2 on additional Member States action).

In addition, there is an urgent need to **improve implementation and enforcement** (see section 2.1.3) and to align **fully with new obligations under the Protocol** (see section 2.1.2), whose initial principal objective was to protect the ozone layer. However, because hydrofluorocarbons[9] (HFCs) emissions were increasing also globally (partly as result of the ODS phase-out) and knowing that the Protocol had eliminated ODS successfully in similar applications, the Parties decided in 2016 to contribute to the goals of the *Paris Agreement on Climate Change* by imposing the Protocol's tried and true obligations also for HFCs ("***Kigali Amendment***"). Therefore, since 2019 the EU and its Member States must respect mandatory maximum annual limits for production and consumption of HFCs that are being gradually reduced over time ("phase-downs"). This is purely a climate protection measure, **since HFCs themselves are not relevant for ozone depletion. Moreover, there are no emission monitoring or targets under the Protocol.** Instead, HFC emissions are monitored under the Paris Agreement**.** It has been estimated that the Kigali Amendment alone will prevent, until 2100, climate warming of up to 0.4 degrees. In the latest IPCC report[10], pathways to limit global warming at 1.5°C require emission decreases for F-gases of up to 90% by 2050 *globally* compared to the year 2015. In addition to phasing down HFCs, the Protocol requires Parties to have **a trade licensing system and report annually on HFC production and trade**. All Parties must take their own action to fulfil their obligations.

There is general support for fine-tuning the Regulation and many stakeholders and Member States have signalled that it should be done with urgency. The European Parliament called "*… on the Commission to present an ambitious revision of the F-Gas Regulation by the end of 2021 in order to accelerate the phasing out of hydrofluorocarbons (HFC); [..] believes that additional action should also be taken against the use of sulphur hexafluoride (SF_6)*"[11].

The Commission has therefore decided to propose changes to the Regulation and this report is an **impact assessment** of the measures considered. It also includes an evaluation of the current Regulation in Annex A.5.

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9 HFCs are the most commonly used F-gases and contribute most of the emissions of this substance group

10 IPCC Special Report. Global warming of 1.5 C (August 2021). https://www.ipcc.ch/sr15/

11 Texts adopted - UN Climate Change Conference in Glasgow, UK (COP26) - Thursday, 21 October 2021 (europa.eu), see point 94.

1.2. Sectors involved and need to perform a sectoral analysis

The main uses of F-gases are as **refrigerants** in refrigerators/freezers, air conditioners (AC, which is hereafter understood to include heat pumps); as **blowing agents** for foams; as **solvents**; and in **fire extinguishers**, **metered dose inhalers (MDIs)**[12], technical **aerosol spray** cans as well as an insulation medium in **electrical transmission**. Emissions occur when these appliances are manufactured, used, or taken out of service. Some of them leak throughout their lifetime (e.g. refrigeration), others can be 100% emissive at the time of use (e.g. MDIs). As the different F-gases have different climate impacts, it is necessary to determine F-gas **demand/use in the different sectors concerned and the specific gases used in order to estimate future emissions**. Furthermore, emission abatement costs vary significantly between sectors. For comparability to other GHG emissions, F-gases are expressed in terms of the warming impact ("climate forcing") they would have in a 100 years timespan relative to CO_2, referred to as the Global Warming Potential (GWP) [13]. Thus, this report distinguishes between **demand for F-gases and emissions** of these gases and expresses both of these **quantities in tonnes CO2 equivalent, i.e. tCO2e**[14] **and their weight in metric tonnes (t)**. **Hydrofluorocarbons (HFCs) are by far the most relevant F-gas group**, as they represent ca. 85% of F-gas emissions (see Annex A5.4.1.4), but use and emissions from other substances such as **perfluorocarbons (PFCs)**, **sulphur hexafluoride (SF_6)** and **nitrogen trifluoride (NF_3)** are also relevant.

1.3. The EU F-gas Regulation (Regulation (EU) No 517/2014)

F-gas emissions can be reduced by (i) **avoiding that F-gases are used** in the first place (i.e. reduce the demand for F-gases), or (ii) ensuring there are measures to **prevent emissions or leaks** when the gases are produced, used and disposed of ("containment"). To this end the 2014 Regulation had the following **specific objectives**:

- **Discourage the use of F-gases with high Global Warming Potential** and encourage the use of alternative substances or technologies when they result in lower GHG emissions without compromising safety, functionality and energy efficiency;
- **Prevent leakage from equipment and proper end of life treatment** of F-gases in applications;
- **Facilitate convergence towards a potential future agreement** to phase down HFCs under the Protocol;
- **Enhance sustainable growth, stimulate innovation, and develop green technologies** by improving market opportunities for alternative technologies and gases with low GWP.

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12 HFCs used as propellants in aerosol inhalers for medical use, e.g. asthma sprays.

13 Global Warming Potential. It is a metric for determining the relative contribution of a substance to climate warming. The GWP indicates how much (solar) energy the emissions of 1 tonne of a gas will absorb (and thus contribute to climate warming) over a given period of time, e.g. 100 years for GWP_{100}, relative to the emissions of 1 tonne of carbon dioxide (CO_2).

14 To obtain these quantities of tCO2e, the metric tonnes of F-gases are multiplied with their respective GWP

It was also intended that the F-gas sector would **contribute its fair share to achieving the EU 2030 climate targets** (as per Roadmap 2011[15]). At the time the Commission prepared its proposal in 2011, it was estimated that costs would be up to €50/tCO2e abated economy wide to achieve the old, (less ambitious) climate targets. This threshold was applied to design the measures in the Regulation. Subsequently, it was estimated that these measures would result in F-gas emission reductions of 60% in 2030 compared to 2005.

Many F-gas appliances use electricity and lead to indirect GHG emissions related to energy use, which over the lifetime of the equipment are typically higher than the direct emission of F-gases. Therefore, climate-friendly alternatives to F-gases in such appliances are only considered to be more climate-friendly in this assessment if they can **reach at least the same level of energy efficiency** as the existing F–gas technology. In parallel, the EU Eco-Design Directive[16] is ensuring progress on indirect emissions by setting minimum standards on efficiency. The alternatives must also be **safe to use**.

The current Regulation avoids emissions (by reducing demand and ensuring better containment, see above) and enables control and oversight through **the following measures** (more detail in Annex A5):

- A **quota system limits the HFC amount importers and EU producers may place on the EU market** every year (measured in tCO2e). Quota is principally needed for HFC gases in bulk[17], but HFCs charged into certain equipment also fall under the quota system. The quota system results in reducing the HFC supply to the EU market. This (initially) results in higher HFC prices that incentivise a shift towards climate-friendly alternatives and reduces future HFC demand. It also promotes leakage prevention, recycling and reclamation of HFCs that can be used without need for quota. The amounts available each year are meant to only cover the need for HFCs in those new and existing appliances where the analysis done in 2011[18] expected it to be too expensive or infeasible to use climate-friendly alternatives. There are some exemptions, e.g. HFCs used for MDIs, military and semiconductor manufacture do not require quota.
- **Prohibitions restrict the placing on the market (POM) of specific F-gas products and equipment** (e.g. types of new refrigeration and AC equipment, foams and aerosols) and **some F-gas uses** (e.g. servicing (refilling) of larger, existing refrigeration systems with high GWP HFCs). Prohibitions relating to HFCs complement the quota system since they prevent that actors that could easily replace HFCs continue to use them e.g. due to lack of awareness of alternatives (market failure). This reduces the risk of undue shortages and HFC prices for the sectors that are depending on HFCs.

15 http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=COM:2011:0112:FIN:EN:PDF
16 Directive 2009/125/EC
17 "Bulk" HFCs or gases refers to substances in containers (for transport, storage etc.) as opposed to HFCs or other F-gases already filled into products (e.g. an aerosol spray can) or equipment (e.g. an AC)
18 F-gas Regulation Impact Assessment. SWD(2012) 364https://ec.europa.eu/clima/document/download/4a34340e-9f82-41e7-adcb-5ce4035b764b_en

- The **measures to prevent emissions where F-gases are produced or used** include requirements to avoid intentional releases or leakage, mandatory leak checks of equipment, keep company records on F-gas related activities, recover gas at the end of equipment life, compulsory training and certification of technical personnel, and producer responsibility schemes (the latter only encouraged). Most of these “containment” measures were already introduced by the 2006 F-gas Regulation.
- For the purpose of **controlling and monitoring** the policy as well as anticipating global rules on HFCs under the **Protocol**[19]**,** licensing of imports and exports, labelling of F-gas containers and equipment as well as annual company reporting on their F-gas related activities including independent verification of their data is required. Furthermore, Member States must have effective, proportionate and dissuasive **penalties;** in case a quota is exceeded, the Commission must also impose a quota reduction.
- While Member States are not required to report directly on emissions under the Regulation they must establish **systems to acquire F-gas emissions data** that enable them to report F-gas emissions under the EU’s GHG monitoring mechanism.[20]

The Regulation covers **F-gases listed in Annex I (HFCs, PFCs and SF_6) and Annex II (H(C)FOs**[21]**; fluorinated ethers, alcohols and others)**. In general, measures only apply to Annex I gases, except that production, trade and some uses of Annex II gases must be reported annually by companies. Each F-gas has a designated name (e.g. HFC-134a or R-134a) and a specific GWP (e.g. HFC-134a has 1430). In many cases the gases are not used in their pure form but as mixtures (or “blends”, e.g. R-404a, which includes 3 different HFCs listed in Annex I). On the basis of their composition it is possible to assign a specific GWP also for mixtures. Because F-gases are used in many types of appliances, many different actors are affected by the Regulation, and in different ways. This is also because there are different gas types covered (e.g. HFCs, PFCs, SF_6) and/or the activities these stakeholders carry out are diverse (e.g. import of gas or equipment, production of gas or equipment, equipment maintenance, equipment or product use).

After a preceding decade of increasing year-on-year emissions of F-gases, they **started to fall from 2015, resulting in a 6% reduction by 2019** (see A5.6.2.1.1). This is a **direct result of the EU F-gas policies** which began in 2006 (see A5.2.1.3), lowering the use of (i.e. demand for) HFCs as well as better containment (and thus less emissions from equipment) in the major HFC-using sectors (e.g. refrigeration, AC). Conversely, emissions of SF_6 and PFCs, where there are no strong, direct policy drivers at EU level, have been rather constant since 2010 (see A11.1.1). Annex II gases result in smaller amounts of up to 1MtCO2e/year; NF_3 and F-gases used as inhalation anaesthetics (i.e. isoflurane, desflurane) being the most

[19] Which were agreed in 2016 (Kigali Amendment). Some alignment was achieved via implementing acts, e.g. Regulation (EU) 2017/1375 and Regulation (EU) 2019/522

[20] https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32018R1999&from=EN

[21] Hydrofluoroolefins (HFOs) and hydrochlorofluoroolefins (HCFOs) have been introduced as climate-friendly alternatives to HFCs. They break up quickly in the atmosphere and therefore have a very low GWP.

relevant. H(C)FOs are emitted in large metric quantities, but their climate relevance is low (see 6.1.4). There are also some on-going emission of some F-gases not yet controlled or monitored (see 2.1.4).

The Regulation has close links to other EU legislation notably **Directive 2006/40/EC on Mobile AC** which bans refrigerants with a GWP higher than 150 to be used in the AC of new passenger cars from 2017. There are also some similarities with the **Regulation (EC) 1005/2009 on substances that deplete the ozone layer**, which is being reviewed in parallel. While the two reviews will not impact on each other, they affect similar stakeholders and sectors, as well as similar activities (trade, equipment use etc.) by using similar control measures.[22] Both industry and authorities have therefore called for them to be closely aligned on the relevant rules (e.g. regarding custom controls, leakage rules, definitions etc.). Furthermore, given the relevance of indirect emissions from energy use of F-gas equipment (see above), there are close synergies with energy policies, in particular the **Eco-design Directive[23].** Furthermore, there are important links to EU waste and chemical (e.g. REACH, industrial emissions) legislation as well as to rules for customs, market surveillance, environmental crime, whistleblowing and the setting of safety standards. More detail is provided in Annex A5.6.4.2.

2. PROBLEM DEFINITION

2.1. What is the problem?

The evaluation (Annex A5) found that **the current Regulation has been mostly effective as regards its original objectives and that its individual measures are all required and work well together**. Thus, **the overall concept and approach of the Regulation is not put into question.** This finding is clearly supported by all stakeholders (industry, authorities and others) that consider the current F-gas Regulation the gold standard in the world.[24]

The EU market supply of hydrofluorocarbons (HFCs) has declined by 37 % in metric tonnes and 47 % in terms of tCO2e from 2015 until 2019. There has been a clear shift to the use of F-gas alternatives with lower GWP as well as natural alternatives (e.g. CO2, ammonia, hydrocarbons) in many types of equipment. The quota system had also positive impacts on equipment leakage rates (declining) and reclamation of HFCs (increasing)[25]. There is consensus that the EU leadership demonstrated through the Regulation was instrumental in obtaining an international agreement to reduce HFCs. Finally, as a direct result of the

[22] While HFCs replaced ODS in the past, this is not anymore the case today since ODS have been eliminated in the EU in sectors where this took place (in particular refrigeration, AC, foams, aerosols..). Therefore, changes to the ODS Regulation regulating the few remaining uses of ODS will not affect the Fgas Regulation.

[23] Directive 2009/125/EC. https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:32009L0125

[24] Press Release: EPEE Welcomes the Revision of the F-Gas Regulation: “Fine-tuning the gold standard” is key | EPEE (epeeglobal.org)

[25] The quota system made HFCs significantly more expensive in the EU. Thus, it made reclamation activities more profitable since no quota is needed for reclaimed gases. This is clearly indicated by rising reclamation rates each year since 2014 and quantities reclaimed tripling from 2014 to 2019. See A5.6.1.1**Error! Bookmark not defined.**

legislation, F-gas emissions have decreased year-on-year starting in 2015 after a decade of rising amounts. Nevertheless, the evaluation concludes that there is a need to revise and fine-tune the Regulation to address the following issues:

i. In light of the more ambitious EU climate targets and the observed progress on innovation, there is scope to achieve **further emission reductions.** .
ii. Long-term **compliance with the Montreal Protocol** is not ensured.
iii. There are a number of challenges for current **implementation and enforcement:** Illegal activities, rogue traders and the lack of skilled technicians.
iv. There are some **monitoring gaps** (gases and activities covered and the rules on the reporting process and data verification**)**.
v. There is a need for more **internal clarity and coherence** concerning some prohibitions, instructions to customs, containment measures, and definitions.

These issues, their drivers and potential developments are described in more detail below.

2.1.1. Insufficient emission savings

(i) Status quo of the issue

The evaluation shows that the EU F-gas policy could contribute more to saving climate-relevant emissions and the climate policy ambition has increased:

- The existing F-gas legislation was based on modelling assumptions that aimed at contributing to the 2011 Low Carbon Roadmap for 2050[26], which had an ambition level in line with reducing greenhouse gas emissions by 80% by 2050 compared to 1990.
- **Further emission reductions are possible to support the new climate targets.** Abatement costs for HFC sectors so far have been relatively low (on average €6/tCO2e abated) and **due to recent technological developments there are many areas where further abatement could happen** at costs much below that required in other sectors[27]. The sector has seen huge innovation jumps in recent years (see evaluation, A5.6.1.4) and more alternatives are available that are not fully incentivised by the existing rules.
- The **EU has in the meantime raised its climate ambition** for 2030 by increasing the 2030 target from 40% greenhouse gas reductions to at least 55% net greenhouse gas emissions reductions compared to 1990. The in-depth analysis in support of the Commission Communication on 'A clean Planet for all'[28] already included projections that confirmed that in order to contribute to a credible pathway towards climate neutrality, also F-gas emissions reductions would have to be stepped up. The impact assessments in support of the policy initiatives under the Fit for 55 package proposed in 2021 included an updated Reference projection (which includes the

[26] COM (2011) 112. https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A52011DC0112&qid=1646129502434
[27] While significant technological developments have resulted in new climate-friendly alternatives becoming technically viable, market uptake is slow, for instance for switchgear and air conditioning (AC).

existing F-gas legislation) as well as a number of policy scenarios. Also for these projections, using the GAINS modelling tool to represent all non-CO2 emissions, significant additional F-gas emission reductions should be achieved by 2030 compared to the existing policies under Reference projections[29].

- Modelling done in the course of the evaluation indicated that F-gas emission reductions in the baseline will fall short of what was estimated to be a cost-efficient contribution to meet the EU greenhouse gas ambition from the 2011 Low Carbon Roadmap (see Annex A11).
- Furthermore, to reach climate neutrality by 2050, **further replacement of F-gases is already needed *in the medium term*** due to a long lag between the new use of F-gases and the point in time where such use results in emissions (usually several years and can be over 50 years in the case of insulation foams and switchgear)[30].

(ii) Drivers

- The fundamental underlying problem is that the market will not deliver the possible emission savings without policy intervention (market failure), due to a number of factors including upfront costs (even though there are energy savings during the project lifetime) and unwillingness to move away from past technologies.
- No quota limits are set after 2030 and the allowed total quota of HFCs is higher than needed (i.e. too much HFCs are allowed even where alternatives could be used instead). As the quota system is based on a modelling exercise using existing technologies in 2011, F-gas appliances that could easily use alternatives today are not sufficiently forced to do so. HFC uses exempted from quota are not subject to any limitation (e.g. MDIs).
- The evaluation also identified other areas with potential for reducing F-gas use and thus emissions, e.g. inhalation anaesthetics as well as SF_6 in switchgear (see A5.6.3), where there is no direct policy driver in place.
- The general obligation to limit F-gas emissions does not cover all relevant F-gases or actors.
- There is no clear obligation to recover HFCs from insulation foams at the end of life.

(iii) How the problem will evolve

An unnecessarily high use of F-gases will continue and have lock-in effects for a considerable amount of time due to equipment servicing needs and long equipment lifetimes. This will lead to future F-gas emissions that could be avoided. Assuming that the quota limit in 2030 is not exceeded until 2050 (despite the current lack of a legal limit for that time horizon), the annual baseline emissions will decrease to about 44 MtCO2e by 2030 and 27 MtCO2e by 2050, from 92 MtCO2e in 2020. The emissions will come mostly from switchgear (ca. 6 MtCO2e), MDIs (ca. 4 MtCO2e), stationary AC (ca. 8 MtCO2e in 2050)

[28] See figure 79 of the In-Depth Analysis in support of the Commission Communication COM(2018) 773

[29] https://energy.ec.europa.eu/publications-new/excel-files-mix-scenario_en

[30] F-gas equipment and products leak during their lifetime and at the end of their useful life. Thus use of F-gases in new products and equipment is resulting in emissions over a long period of time.

and mobile AC (ca. 5 MtCO2e). Refrigeration is the only major sector where emissions mostly disappear by 2050 (see Annex A11.1).[31]

2.1.2. Long-term compliance issues with the Montreal Protocol

The evaluation found that the current **Regulation is not fully aligned with the rules of the Montreal Protocol** and that for this reason long-term compliance was not ensured (see A5.6.4.1.1). Irrespective of the need to save more climate-relevant emissions to achieve the EU Climate targets (2.1.1), non-compliance with the global rules must be avoided, since this would imply clear reputational losses for the EU, not least since the EU is a clear frontrunner in setting ambitious F-gas policies that often serve as best practice example for the actions of many other countries.

(i) Status quo of the issue

The following issues complicate future EU compliance:

- **The Protocol's future targets on HFC consumption.[32]** The EU consumption is today safely below the limit set in the Protocol but the quota system as currently regulated does not continue beyond 2030. Simply extending the current rules beyond 2030 may not be sufficient to meet the future Protocol targets. This is linked to the fact that the quota system metric used by the Regulation (i.e. "placing on the market") uses other parameters than the Protocol's "consumption" metric. For instance, "placing on the market" includes some HFC equipment, but exempts some HFCs (e.g. for MDI or other uses) that are fully counted under the Protocol. Depending on how these different parameters develop in the future (e.g. if HFCs used in MDIs keep growing strongly[33]), EU compliance on the Protocol's consumption limit may be jeopardised. Also, the Regulation's exemption from the quota system for small quantities is not aligned with the Protocol where no such exemption exists.
- **The Protocol's separate limits for HFC production: There are currently no specific production limits in the EU[34]** and it cannot be guaranteed that a Member State would not exceed its national production limit (including starting new production). Several Member States have called on the Commission to include a separate production phase-down.[35]
- **The Protocol's reporting requirements**: Data are not collected on small trade transactions while this is prescribed by the Protocol.

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[31] HFCs in insulation foams is only a modest problem but is relevant due to the synergies with ODS policies. See 6.1.2.2.

[32] e.g. 80% reduction from baseline levels in 2034, 85% reduction from baseline levels in 2036.

[33] As the evaluation shows, HFCs used for MDIs have grown by 45% between 2015 and 2019

[34] Even though production is one of the relevant parameters of the quota system ("placing on the market") and is thus indirectly regulated.

[35] Only two Member States maintain HFC production today (France and Germany). 98% of EU production rights under the Protocol are assigned to five Member States (also ES, IT and NL). The EU has the option of complying with the production obligation at EU level, but Member States have so far not agreed on this (see 3.2.).

- **The Protocol's prohibition to trade with non-Parties from 2033:** This concerns importers from and exporters to countries that have not yet ratified the Kigali Amendment. Currently no such provision exists in the Regulation.

(ii) Drivers

- The Regulation **does not regulate quotas** beyond 2030.
- **Some uses of HFCs are only exempted under the EU quota system (not by the Protocol):** The exempted use of HFCs for MDIs represented 10% of the overall EU HFC market in 2019 and the use has grown by 45% since 2015. The exempted uses for semiconductors and military represent below 1% of the market.
- The Regulation does not allow **direct control of produced HFC quantities**.
- There are **minimum annual HFC thresholds**[36] for quota and reporting which exempts these quantities while such an exemption is not foreseen by the Protocol.
- **Trade with non-Parties** to the Protocol is allowed under the Regulation.

(iii) How the problem will evolve

- **Protocol Consumption phase-down***:* **EU-27 compliance from 2034 onwards is not automatically ensured** (even if the 2030 limit is extended)**.** In a 'low-consumption' scenario[37], the calculated consumption would end up below the Protocol limit set for the EU in 2036, but in a 'high-consumption' scenario the EU would exceed the Protocol's consumption limits already from 2034. This is mainly due to potential use for **MDIs that could represent 30% of the HFC demand in 2030**.
- **Protocol production phase-down:** The risk that a Member State is not complying increases over time as the production limits become stricter and the placing on the market of HFCs for MDIs remains unrestricted.
- **Protocol reporting requirements**: EU reporting will remain incomplete as regards small trade transactions.
- **Protocol prohibition to trade with non-Parties from 2033:** Without specific action, the EU will not comply with the Protocol. In the meantime, the absence of EU action will not help incentivise ratification elsewhere.

2.1.3. Challenges to implementation and enforcement

The evaluation highlighted a number of challenges[38] related to implementation and enforcement that are reducing the effectiveness of the Regulation:

[36] I.e. companies below the threshold currently do not fall under the obligations to report, have quota, be registered etc. Industrial stakeholders such as large chemical firms also pointed out that this threshold facilitated illegal imports (repeated imports).

[37] The EU phase-down concerns placing on the market (POM: includes import and EU production) whereas the Montreal Protocol regulates consumption (slightly different parameters than POM). To take into account these differences, a "low consumption" and "high consumption" scenario were used to estimate the low and high end and see what the implications would be for EU compliance in the future (OekoRecherche et al., 2021).

[38] The evaluation also identified other challenges: The issue of possible eco-toxicological consequences of HFC and H(C)FOs requires further observation (section 6.1.4), but preventing their emissions is part of the higher ambition objective (section 2.1.1). Barriers to safety codes require remedial action outside of

- **Illegal imports of HFCs** that are not counted under the EU quota system.
- **Rogue traders**: A **multiplication of gas importers** that enter the market for speculative reasons and/or benefit disproportionately from the quota system.
- A **lack of skilled technicians** for equipment using climate-friendly alternatives.

2.1.3.1. Illegal imports

(i) Status quo of the issue

There is clear evidence that HFCs are being imported without quota[39]. Obviously, the amount is by its very nature difficult to determine[40], but the situation is clearly unsatisfactory and harming the effectiveness of the quota system and legitimate business interests. More than half of the respondents in the public consultation considered that certain measures in the F-gas Regulation were not effectively preventing illegal activities. The measure which was rated least effective was Member States penalties. It has been a priority for the Commission to address the issue and while some progress has been made, it has proven to be quite challenging under the current F-gas rules, notably when imported HFCs are neither reported under the F-gas Regulation nor declared at customs (i.e. smuggled)[41]. Industry and the European Anti-fraud Office (OLAF) note that perpetrators are exploiting the fact that custom controls, market surveillance activities and penalties vary widely between Member States[42] and that the use of special custom procedures (e.g. “transit”), goods in “temporary storage”, small customs offices without the relevant know-how and online sales are making enforcement more difficult[43].

(ii) Drivers

- The quota system results in EU HFC prices that are several times higher than world market prices and makes it very profitable to sell HFCs in the EU.

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the scope of the Regulation. Penalties are discussed in connection with Illegal imports and the issue of data verification is discussed under “monitoring gaps” (section 2.1.4).

[39] Besides a discrepancy of trade statistics (exports to the EU by China and the corresponding EUROSTAT import statistics), many shipments of illegal gas are increasingly found at the borders. OLAF has discovered a number of fraudulent activities, and industrial stakeholders at all levels (producers, importers, distributors, service companies) report that they have come across these activities.

[40] https://ec.europa.eu/clima/document/download/8b970e78-c5c3-41fd-b846-c75c1b6b045b_en.
The industry has claimed that illegal trade may be up to 30% of the total quota available in a year, but this assumes that (i) all discrepancies detected in trade statistics would actually be illegal imports while there may be other explanations (e.g. export data inaccuracies such as re-routing of trade) and/or (ii) unexplained higher imports into EU neighbouring countries are automatically assumed to end up in the EU without concrete evidence of the extent of cross-border smuggling.

[41] Data for the quota system (F-gas Reporting) and trade data (EUROSTAT trade statistics) matched very well.

[42] Apparent from the F-gas and custom experts group that met several times between 2019 to 2021 to discuss illegal HFC trade. The Commission financed the group under the *Customs 2020 Programme*.

[43] The unsatisfactory level of illegal trade and *modus operandi* has been evidenced by customs and surveillance authorities, the European Anti-Fraud Office (OLAF), a private investigating firm hired by the industry. 53 stakeholders sent an open letter to policy makers calling for action against illegal imports that is harming their legitimate business. Also, the NGO Environmental Investigation Agency published two reports “Doors wide open: Europe’s flourishing illegal trade in hydrofluorocarbons (HFCs)” (2019) and “Europe’s Most Chilling Crime – The illegal trade in HFC refrigerant gases” (2021).

- The Regulation is not sufficiently clear on the enforcement role of customs and surveillance authorities (e.g. registration checks; quota limit checks; confiscation of illegal goods) and the requirements for importers.
- HFC imports under special customs procedures do not require quota and it is difficult to monitor if the HFCs are suddenly released in the EU without quota;
- It is difficult to monitor imports via on-line sales that are subject to quota;
- Non-EU countries starting later than the EU with HFC restrictions and licensing;
- Very heterogeneous penalties in Member States, some of which may not be dissuasive. While in some countries criminal sanctions are possible, in others the perpetrators risk fines that are considerably smaller than the profit made from gas smuggling.

(iii) How the problem will evolve

The quantities of HFCs circumventing the quota system will remain at an unsatisfactory level. The incentive to trade illegally will continue or even increase as EU HFC prices may increase further, when the quota limits become tighter. The situation may improve somewhat when more and more Parties ratify the Kigali Amendment and CERTEX[44] and the EU Single Window Environment for Customs[45] can be used for more systematic controls of HFC imports. However, this link can only be fully effective with more specific obligations in the Regulation and it will not address HFCs that are not correctly declared.

2.1.3.2. Rogue traders: Multiplication of gas importers with speculative motives

(iv) Status quo of the issue

The evaluation shows that **the number of quota holders increased by a factor of more than twenty** from 2012 to 2019 and that this type of increase is undesirable. It has happened for the following reasons. Quota is allocated partly to market participants based on historic market share, i.e. “grandfathering”, partly from a quota reserve (ca 11%) whose distribution is based on a declared intention to market HFCs, including to new companies. This electronic declaration requires a registration process to the electronic registry operated by DG CLIMA, which was initially a low burden process requiring little more than a VAT number. Many companies were set up without previous links to the gas trade and company owners with several affiliates have applied for multiple quota shares. This is undesirable because: (i) genuine F-gas traders obtain very low quota shares from the reserve, (ii) preventing illegal imports is more challenging due to the high number of quota holders with small quota amounts and (iii) there is a higher risk that the gas is not treated appropriately due to lack of experience of the new players. The Commission clarified the registration rules in the

[44] CERTEX is an IT system that allows to exchange data (“certificates”) on relevant F-gas shipments between the central EU F-gas Portal & HFC Licensing System and custom offices in the Member States directly; IT precursor of the European Single Window Environment for Customs

[45] EU Single Window Environment for Customs: This proposal would make the use of CERTEX for F-gases mandatory in all 27 Member States. https://ec.europa.eu/taxation_customs/eu-single-window-environment-customs_en

Implementing Regulation (EU) 2019/661 and the number of quota holders fell by one third in 2021 compared to 2019/2020. Still, many quota holders appear to be in the system for purely speculative reasons given that quotas are easily obtained and gases can be sold for profit on the EU market. Furthermore, following the change of registration rules, the Commission must now verify if potential quota holders have the same beneficial owner and this delays annual quota allocation to companies which in turn is reducing their planning certainty.

(v) Drivers

- The quotas are allocated for free but represent an important economic value because of an HFC price difference between the EU and world market, which is generated by the EU quota system.
- New entrants may apply for quota without any links to the gas sector and the Regulation is not very prescriptive as to who can apply for quotas.
- There is no flexibility in the quota allocation system e.g. to temporarily withhold quota for future (re-)distribution in cases under investigation and to address major market disruptions.

(vi) How the problem will evolve

The number of quota holders will most likely remain at a high level (around 2000) or even increase if the HFC prices increase further due to the quota system. This high number will make it even harder for genuine traders to sustain their business, as the quota shares will become smaller when the overall quota limits are being reduced. They will also have relatively low planning security and market disruptions cannot be addressed. A high risk of undetected illegal imports will also remain and an excessive and ineffective administrative effort will persist for Member States and the Commission.

2.1.3.3. Lack of skilled technicians

(i) Status quo of the issue

A Commission report[46] from 2016 concluded that there is a lack of skilled technicians that can handle equipment using climate-friendly alternatives such as naturals (e.g. ammonia, CO_2, hydrocarbons) and H(C)FOs. These alternatives have different properties from HFCs, e.g. many of them are flammable and therefore require different skills and handling know-how. While training and skills for Annex I gases are currently ascertained by the extensive rules in the Regulation, there is notably a lack of training facilities offering practical training on the alternative substances[47]. The stakeholder consultation showed that there have been some improvements in the meantime, but this challenge has remained a piecework puzzle and the situation varies greatly between Member States. The lack of qualified technicians can

[46] COM/2016/0748. Commission report on the availability of training for service personnel regarding the safe handling of climate-friendly refrigerants. http://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:52016DC0748

[47] According to AREA, the European service personnel association, only 3.5-6% of F-gas certified personnel are trained on CO_2, hydrocarbons and HF(C)Os,

pose liability issues for equipment manufacturers and a broad range of stakeholders confirmed that this issue is still preventing a wider roll-out of climate friendly technologies.

(ii) Drivers

The Regulation is not requiring Member States to have mandatory training and certification programmes covering the climate-friendly alternatives. It is only required for Annex I gases (since 2006). The legislative framework[48] complemented by existing standards at the European level appears appropriate[28] to ensure safe handling of equipment but a mandatory EU-wide certification scheme does not exist.

(iii) How the problem will evolve

EU-wide availability of training and evidence of skills will not be ensured and a lack of skilled personnel will continue to persist, at least for the medium term. This will slow down the introduction of green technologies.

2.1.4. Monitoring gaps: Gases and activities covered as well as rules on reporting process and data verification

(i) Status quo of the issue

Production, trade activities, destruction and feedstock use of Annex I and II substances needs to be reported, but there is no monitoring of certain **"new" fluorinated greenhouse gases that also appear relevant** (e.g. sulfurylfluoride[49]) as pointed out by the evaluation (A5.6.1.1). Some of these new gases as well as some of the gases already in Annex II (i.e. H(C)FOs, NF_3, F-gases used as anaesthetics) appear to be emitted in relevant quantities (up to 1 MtCO2 annually), but they are not subject to emission prevention measures. MDIs and containers with relevant Annex II substances do not need to carry a label to identify them as F-gases with a GWP such as is the case for all containers of Annex I substances, so users may not be aware of their relevance for climate change. There are also **other data gaps** on emissions from the use of switchgear and RAC equipment. The quantities of gases being reclaimed and recycled (see evaluation, A5.6.1.1) or exported in equipment are unknown and the reporting on exempted gases[50] is incomplete since the recipients of these gases do not report. Finally, the evaluation found **that the requirement to have reporting data linked to quota use verified by a third party auditor**, which is crucial for the ex-post control of quota use and thus for compliance checking and enforcement, **is currently ineffective** as these auditor reports are currently of highly varying quality (see A5.6.1.5). Moreover, 80% of quota holders in 2021 were not obliged to have a verified report because they had dropped

[48] Depending on their respective properties of the alternatives (e.g. flammability, pressure, toxicity) other EU legislation is relevant (Explosive Atmospheres Directive 2014/34/EU (ATEX); Pressure Equipment Directive (PED: 2014/68/EU); 97/23/EC Directive 89/391/EEC – Occupational Safety and Health Framework Directive (OSH).

[49] The full list of gases is given in Annex A6.4.

[50] Exempted are gases that are (i) imported for destruction, (ii) used as feedstock, i.e. input chemical, in chemical production processes, (iii) supplied directly for export, (iv) for use in military applications, (v) for semiconductor manufacture, or (vi) for MDI manufacture.

below the verification threshold. The dates and some thresholds for reporting and verification of bulk and equipment are inconsistent and inefficient.

(ii) Drivers

- Annex II is outdated and Annex I does not list all F-gases with relevant emissions.
- Labelling rules are incomplete (Annex II substances, MDIs).
- The reporting rules do not include leakages, recycling/reclaim activities, recipients of exempted gases, and HFC use beyond placing on the market and export in equipment.
- There are inefficiencies in threshold levels and dates for reporting and verification, and too little detail on the verification process and its requirements.

(iii) How the problem will evolve

Monitoring gaps will persist and pose a risk that new issues cannot be spotted. Important emissions, e.g. of sulfurylfluoride, NF_3, inhalation anaesthetics and H(C)FOs, that could be avoided with prevention measures, will continue to occur. Market surveillance, compliance checking and emission reporting is less effective due to lack of data. The verification and reporting process will continue to place a significant burden on compliant companies, but would remain ineffective in spotting perpetrators.

2.1.5. Lack of clarity and coherence

Ideas on how to improve internal clarity and coherence of the rules have been collected throughout the implementation period and the stakeholder consultation. Such issues hamper the effective implementation of the Regulation and should therefore always be addressed. These clarifications relate to the scope of some of the existing prohibitions and the quota system, the rules on custom controls and market surveillance, the containment measures, and definitions in the Regulation (see Annex A6.5).

3. WHY SHOULD THE EU ACT?

3.1. Legal basis

The legal basis for taking action is Article 192(1) of the Treaty on the Functioning of the European Union, in line with the objective to preserve, protect and improve the quality of the environment; protect human health; and to promote measures at international level to deal with climate change.

3.2. Subsidiarity: Necessity of EU action

The evaluation concluded that implementing co-ordinated action at EU level is required to ensure compliance with the Montreal Protocol. The EU and the EU Member States, as Parties to the Protocol, have a number of requirements to fulfil (see 1.2). There are also similar requirements in international trade agreements that the EU has concluded and reporting obligations on emissions of some F-gases under the UNFCCC. The EU is considered a regional economic integration organisation (REIO) under the Protocol, and therefore complies with these requirements at Union level (e.g. reporting, licensing system, consumption phase-down). This requires relevant legislation at the same level. A hypothetical implementation of these commitments under the Protocol at Member State level is very **difficult to reconcile with the general principles of the EU internal market and the free movement of goods**. The only exception is the Protocol's HFC production phase-down schedule, which requires compliance at Member States level.[51,52]

3. Subsidiarity: Added value of EU action

The Regulation has a **clear added value by implementing co-ordinated action at EU level to facilitate reaching the EU climate goals**. A successful reduction of F-gas emissions has been achieved to date due to the HFC quota system, prohibitions and containment measures working together. If Member States instead were using different measures and ambition levels, this would most likely result in lower overall emission reductions for these gases in these sectors. By way of example, a Union-wide quota system can push for the introduction of alternatives across all (sub-)sectors, including in the more difficult areas, something that cannot be achieved by fragmented approaches at national levels.[53] Furthermore, a key benefit of action at EU level is the **efficiency improvements** and achievement of **economies-of-scale**, avoiding unnecessary costs to industry to adapt to different rules in different Member States. 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, benefiting from the size of the single market and providing an additional incentive for their development and commercialisation. All types of stakeholders overwhelmingly agree on the EU added value, in particular the competent authorities of Member States. The progress achieved as a result of EU policies on F-gases facilitates the task of Member States to reach their own national targets to reduce a basket of GHGs under the ESR.

4. OBJECTIVES: WHAT IS TO BE ACHIEVED?

4.1. General (review) objectives

The review must ensure that the F-gas Regulation contributes to the **ambitious climate objectives** under the European Green Deal. Furthermore, it is paramount to **ensure compliance with rules under the Protocol**, and enable **good enforcement** of the rules in an **efficient, coherent and clear** manner.

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51 Only two Member States continue to have HFC production (Germany and France).

52 Pursuant to Article 2(8)(a) of the Protocol, an EU-level compliance under REIO on production is possible, but this is currently not the case as there was no agreement by Member States.

53 In the 2012 impact assessment it was demonstrated that even for EU-wide approaches the environmental benefit of having prohibitions alone was approximately 25 % inferior to also having am EU-wide phase-down (quota system), as the latter gradually introduces alternatives from an early date also in difficult sub-sectors where a prohibition to cover all or most of the sector would not yet be feasible.

4.2. Specific (review) objectives

To reach those general objectives and based on the findings in the evaluation, the review measures will target the following **specific review objectives:**

A. Achieve **additional F-gas emission reductions** to contribute to reaching the 55% of emissions reductions by 2030 and net carbon neutrality by 2050.
B. **Fully align with the Protocol**.
C. Facilitate enhanced **implementation and enforcement** on matters of illegal trade, the functioning of the quota system and the training needs on F-gas alternatives.
D. Improve **monitoring and reporting** to fill existing gaps and improve process and data quality for compliance.
E. Improve **clarity and internal coherence** to support better implementation and understanding of the rules.

There is no expected trade-off between these review objectives and therefore also no hierarchy. The aim is to target all of them. However, whereas the objective to fully align with the Montreal Protocol does not leave much margin for manoeuvre, the other objectives can be achieved to a varying extent. As the aim of this review is the fine-tuning of the Regulation currently in force, its original objectives as listed in section 1.3 remain valid. The only exception is the original objective to facilitate reaching an international agreement. Since this was achieved in 2016 (see 1.1), that objective has become obsolete. Instead, the Regulation must now aim to ensure compliance with those new international rules (objective B above).

In the public consultation, stakeholders were asked to what extent they agreed to the first three review objectives on a scale from 1 (fully agree) to 5 (strongly disagree). The objective *improving implementation and enforcement*, was seen as the most relevant with an average response of 1.6. This was followed by the objective to *ensure EU long-term compliance with Montreal Protocol* (with an average response of 1.8). The objective to *raise ambition in light of the Green Deal and technological progress* was also generally supported, albeit to a slightly lower degree (an average response of 2.2), with some industry organisations commenting that the key focus needed to be on improving implementation and enforcement while aligning with the Montreal Protocol in case where such alignment is necessary. The same organisations added that the Regulation does not need to be aligned "downwards" in case in-depth analysis would reveal that the Regulation is more ambitious than the Kigali Amendment.

5. WHAT ARE THE AVAILABLE POLICY OPTIONS?

5.1. What is the baseline from which options are assessed?

The baseline, against which policy options are assessed, assumes that the Regulation remains in place unchanged. The **demand for F-gases (and their resulting emissions) are modelled taking into account the existing F-gas using applications, their emissions rates and the amount and type of F-gas used** (see section 6 and Annex A4.2.1). F-gas demand is the sum of quantities of F-gases used in the initial first filling of equipment and the re-filling in the servicing of equipment during its lifetime. Emissions are the sum of emissions of F-gases lost during the lifetime of equipment (lifetime emissions) and F-gases that are released to the atmosphere during disposal of old equipment (disposal emissions).[54]

The ongoing review of the ODS Regulation will not affect the F-gas baseline, as the changes envisaged do not affect F-gas use (i.e. demand; see also section 1.2 and 1.3). As regards the proposed higher ESR targets for Member States, any emission savings that are not achieved by (future) EU legislation, including for F-gases, would have to be picked up by the Member States themselves to achieve their overall GHG target, by taking additional measures **in any of the sectors regulated** by the ESR. This includes additional action on F-gases to achieve their overall GHG reduction targets, as they have done in the past (e.g. taxes on HFCs, tax breaks for using alternatives, measures to further encourage better HFC management or waste practices (see A5.4.2.2)). Whereas existing Member State F-gas actions already form part of the F-gas baseline, future F-gas actions at Member State level that **could** increase F-gas emission savings in the EU are not assumed at this stage, e.g. measures that further prevent emissions at the stage of use or decommissioning of installations. This is because the degree to which Member States will pursue further action in this policy area in the future is difficult to foresee. It is however rather unlikely that Member States will introduce further sectoral prohibitions or more detail on national reporting rules, while further action on e.g. waste policies or financial incentives for alternatives are probable. Furthermore, some types of actions (e.g. national HFC prohibitions) would not reduce EU F-gas emissions further, as they would rather tend to shift HFC demand and emissions within the EU and/or between sectors, given that the EU has one common EU HFC quota limit. Finally, even if Member States are taking additional new F-gas measures at a later stage, the latter are unlikely to have a decisive impact on the effectiveness of the measures chosen at EU level, given that they would be rather of a complementary, auxiliary nature (e.g. incentives, waste policies, market surveillance).

Overall demand for F-gases in tCO2e will decrease until 2030 and increase slightly thereafter until 2050, see Figure 1. This is driven by a decrease in demand for HFCs from 89 MtCO2e in 2020 to 25 MtCO2e in 2050, while demand for SF_6 increases from 28 to 48 MtCO2e. Other F-gases (PFCs, H(C)FOs and NF_3[55]) are only contributing with less than 1 MtCO2e per year. The HFC demand is strongly decreasing in refrigeration equipment (elimination of R404a) and in some AC applications until 2030[56] (see Annex A11.1.1). Climate-friendly alternatives to the propellant used in MDIs are also emerging, but industry is expecting a rather slow market uptake, i.e. only 1% in 2026 going to 50% in 2050[57]. The increase in SF_6

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54 Therefore changes to emitted quantities usually follow changes in demand only with several years of delay.

55 Other gases listed in Annex II are not included but their quantities are very small. F-gases not listed in the Annex I or II are similarly not included.

56 R32 replacing R410a in stationary AC and HFC-1234yf replacing HFC134a in passenger car AC due to the Directive 2006/40/EC relating to emissions from air conditioning systems in motor vehicles (MAC Directive).

57 HFC-134a and HFC-227ea are currently used but in 2025 industry expects HFC152a (GWP 124) to become marketable after testing, homologation and approval by the European Medicines Agency. Research is also currently conducted on HFC-1234ze (GWP 7).

demand is due to a market growth of 2 % for electrical equipment[58] that continue to use SF_6, e.g. for smart grids and infrastructure for renewable energies. Other sectors contribute relatively little to the overall demand after 2023, e.g. demand for uses such as foams, fire protection, non-medical propellants and solvents mostly disappears.

As a result of these developments of the demand, **emissions will decline from 92 MtCO2e in 2020 to 44 in 2030 and 27 MtCO2e in 2050** (see A11.1.2)[59]. This is mostly related to declining HFC emissions (highest demand decrease), while the share of SF_6 emissions is growing from 16% to 26% between 2030 and 2050 (even if there is also a decline in absolute quantities, 7MtCO2e (2030) and 5 MtCO2e (2050)). As regards SF_6 emissions, the electrical transmission industry informs that losses are low and thus emissions are assumed to be relatively low (EU-wide monitoring data are not available). There are also some persisting legacy emissions of SF_6 (from windows[60], etc.), other SF_6 uses and F-gas losses from production (by-production and fugitive emissions). Due to the long lifetimes of insulation foams in buildings (e.g. 50 years), emissions of end-of-life losses when these foams are broken down or landfilled are expected to pick up after 2050.[61]

The total annual **cost of technological change[62]** in the baseline scenario would on average be 240 Mio €/year in the period 2024-2036. Most costs would be incurred in the refrigeration and the mobile A/C sector (without the passenger cars). By 2050, costs of technological change would be strongly negative (i.e. cost savings due to less operational costs, e.g. energy savings) in refrigeration and stationary AC, while there would still be some costs for mobile AC. See detail in Annex A12.5. Due to the increasing scarcity of quotas until 2030, higher HFC gas prices may impact on those users that still use HFCs.[63]

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[58] https://www.zvei.org/fileadmin/user_upload/Presse_und_Medien/Publikationen/2020/April/SF_6_Reduktion/Szenario-zur-Reduktion-von-SF6-Betriebsemissionen-final-eng.pdf

[59] There are also indications that emissions of some F-gases e.g. sulfurylfluoride (SO_2F_2; not currently listed in the Regulation) and others used for inhalation anaesthetics exceed 1 MtCO2e per year and would possibly increase without regulation (see also 2.1.4).

[60] Insulation of windows with SF_6 is prohibited since 2008.

[61] HFCs started to replace ozone-depleting substances in insulation foams from 1995.

[62] The cost of technological change is an adjustment cost and is borne by the equipment operators investing into alternatives to existing F-gas technologies and therefore experience additional capital costs (e.g. acquiring new hardware) and operational costs (e.g. costs for electricity, fuel, maintenance costs including leak checking and repairs). See Annex A4.2.10.

[63] The average price premium (difference of price to the situation without a quota system, i.e. relative to 2014 or to world market price) in the period 2015-2019 was 8€/tCO2e. Assuming the 2030 quota limit is maintained until 2050 a worst case simulation gives a €40/tCO2e premium on world market price (see section 6.2.1.2).

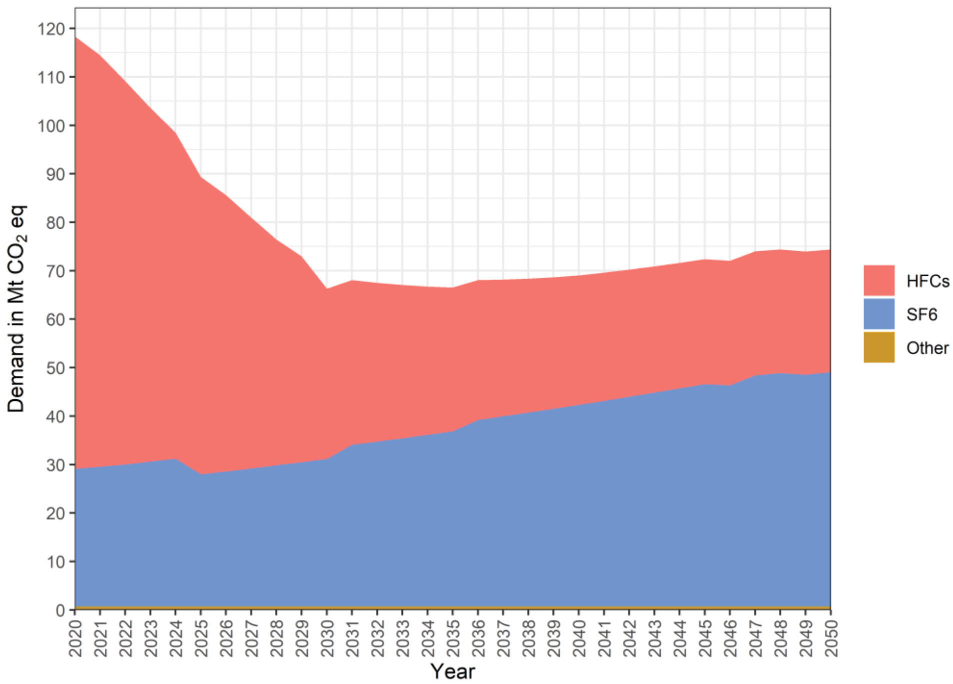

Figure 1. Baseline demand of HFCs, SF_6 and other F-gases in climate terms (MtCO2e)

A factor in the baseline development is also be the underlining demand for the products that may make use of F-gases. Other EU policies can impact this. This is for instance the case for the demand for heat pumps due to energy and climate policies. Recent developments following the invasion of Ukraine by Russia have increased the call for a faster energy transition. The REPowerEU Communication[64] underlined the role of increased uptake of heat pumps in the heating of buildings in this specific situation. This can improve energy efficiency and reduce natural gas consumption. It pointed towards doubling the pace of deployment of heat pumps, with 10 million newly installed heat pumps over the next 5 years and 30 million by 2030. With a focus on replacing existing gas boilers, this ambition mainly relates to the installation of hydronic heat pumps (e.g. air to water or ground to water heat pumps). Whereas it was not possible for this impact assessment to capture the consequence of such developments in the baseline, a short assessment was made of what its impacts would be on the considered options consider in section 6.1.4.

5.2. Description of the policy options

As mentioned above, the overall approach relying on a quota system for placing on the market HFCs, accompanying prohibitions of use of F-gases and containment measures to reduce any remaining emissions should be kept. Most stakeholders agree to this and abrupt changes would result in uncertainty for business. Consequently, **this review is fine-tuning the Regulation with the aim to provide policy responses to the problems identified**

[64] COM(2022) 108 final

(section 2). The relationship between the problems, the specific review objectives and the required policy responses are visualised in Figure 2.

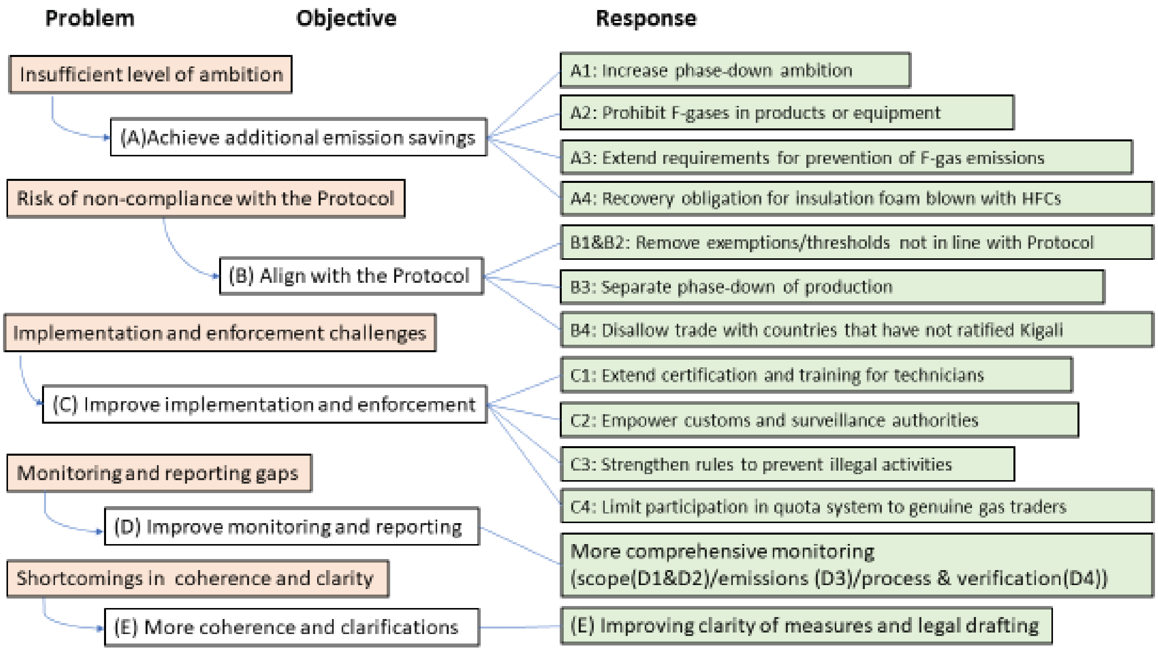

Figure 2. Relationship between the problems, review objectives and policy responses

To develop policy responses, detailed policy measures (e.g. a specific prohibition, a specific improvement on custom checks) were collected from stakeholders and external experts during the consultations, including from F-gas authorities and customs, and/or designed on the basis of the expertise acquired implementing this policy. Some of the collected measures were deemed infeasible and discarded from the outset based on different considerations of feasibility as outlined in Annex A6.6. A detailed description of all the detailed measures is given in Annex A6.

Three different policy options were then **designed by assigning detailed measures to each of the options.** As there is no EU target for F-gas emissions, it is a political choice to how much the Regulation should contribute to saving emissions, and what the effort should be in addressing the issues of implementation and monitoring. However, compliance with the Protocol must be safeguarded in all cases. Thus the detailed measures were assigned on the premise that all options should do the latter as well as improve internal clarity and coherence, but that the **resulting contribution to the other objectives should give a choice on the basis of the different expected levels of costs and effort (low-medium-high).** The ensuing assessment then establishes how much the options actually contribute to the other objectives, and a policy choice can be made on the basis of the balance between achievable benefits and the cost and effort level involved. The original assigning of measures to the options was done on the basis of ex ante expected impacts and efforts and/or costs involved. This approach was considered the most useful, in particular since Option 1 largely reflects the view expressed by some industry associations in the stakeholder consultations, which maintain that today`s Regulation is sufficiently ambitious and the review should merely align with global rules and address the challenges to implementation and control. Option 3 is advocated by other stakeholders, notably the NGOs and by some manufactures that want to invest in innovative climate-friendly technologies also in niche sectors where this may become expensive and Option 2 reflects the middle ground. It is therefore politically relevant to explore the impacts of all three options.

The three options are described in more detail below and an overview of the bundling of individual measures in the three options are given in Table 1. The individual measures are mostly compatible and complementary to each other[65] and all complementary measures included in Option 1 are also included also in Option 2, just as all complementary measures in Option 1 and 2 are also included in Option 3. Moreover, any improvements seeking to clarify the rules or make them more coherent are included in all three options.

- **Option 1: Align with the Protocol & low cost measures**

This option is a l**ow cost/low effort option**. It includes all measures to ensure long-term compliance with the Montreal Protocol. It also includes any beneficial measures in the responses to the objectives that were expected to result in very low costs and effort, if any.

To align with global rules, the sizeable quota exemption for MDIs and the *de minimis* thresholds for quota and reporting are removed. The HFC quota levels after 2030 are set to (just) ascertain that the Protocol consumption phase-down can be met in the long run and under all circumstances. A separate HFC production phase-down, a ban on trade with non-parties to the Protocol from 2033 and flexibility to allow further alignment with new international rules are introduced. **To complement the HFC quota system**, some *low-cost* prohibitions to use F-gases in new cooling and fire equipment and a *low-cost* measure to prevent emissions from one specific type of insulation foam ("sandwich panels") using HFCs[66] is included. **Low cost measures to improve control, implementation and monitoring** include that energy efficiency aspects are added to the training curriculum for equipment service personnel. Furthermore, rules for customs will be clarified and reinforced and it will be stipulated that importers need to have sufficient quota and appropriate labelling at the moment of import or physical entry[67]. The improvement of the rules concerning reporting and verification increases efficiency and supports compliance checking. Some new relevant substances are added.

- **Option 2: Achieve proportionate emission reductions and implementation improvements**

Option 2 requires moderate costs and effort. In addition to the measures in Option 1, Option 2 will seek to **reduce emissions further, but only to the point where a sub-sector would not have to pay more than marginal sectoral abatement costs expected for the**

65 Exceptions are the different HFC phase-down schedules for the quota system (A1), the deadline for non-part trade (B4) and the electronic database of company data relevant for emissions (D3) that is encouraged in Option 2 and mandatory in Option 3.

66 By requiring HFCs to be recovered during building renovation and demolition activities and destroyed (or reused). See Annex A15.

67 While currently quota compliance is based on an annual balance, which implies that border controls cannot be effective and compliance checking must rely on ex-post reporting on verified data only.

economy overall to reach carbon neutrality in 2050 (see below). The **alignment measures** are essentially the same as Option 1, but the prohibition to trade with Parties that have not ratified the Kigali Amendment is slightly advanced to 2028, in order to provide an incentive for timely ratification by remaining Parties and to ensure that the global HFC reduction measures of the Kigali Amendment provides the envisaged benefit to the climate.

The **HFC quota levels are more restrictive** than in Option 1**.** The levels are set to ensure that HFCs are only available for appliances where it is not yet possible to replace (highly warming) HFCs. As replacement is undertaken with gradually increasing costs, such marginal abatement costs at sub-sectoral level should remain below €390/tCO2e until 2050. This cut-off to exclude difficult sectors was chosen as a benchmark to be comparable to the effort needed in other areas following the 2050 Roadmap modelling. **Additional F-gas prohibitions with specific GWP limits and dates** complement the phase-down. They relate to stationary AC; smaller refrigeration equipment; personal care products and skin cooling equipment, inhalation anaesthetics and switchgear. Where prohibitions conflict with safety rules (e.g. use of flammable substances) or where F-gases are needed in niche applications, they may still be used. Obligatory F-gas recovery and destruction (or re-use) from insulation foams will cover also laminated boards (besides sandwich panels) which in this way would achieve full synergies with a similar measure proposed in the review of the ODS Regulation. Finally an obligation to prevent emissions during activities such as manufacturing, storage and transport will be extended to all actors on the Union market and also cover some Annex II and new gases to be added.

Additional measures at moderate costs to improve control and implementation are included, e.g**. a price to pay for quota** to disincentivise speculative behaviour and to limit the participants to serious gas traders and EU producers. The initial allocation price is set at 3€/tCO2e[68]. This measure will also include some flexibility to manage the quota system[69]. Moreover, **penalties at Member State level will be subject to more prescriptive requirements**. Labelling will be slightly extended and the type of evidence needed when placing bulk gases on the market will be specified in more detail. Also, Member States are required to provide certification and practical training for relevant climate-friendly alternatives and equipment containing H(C)FOs, and installing, servicing, maintenance or repair that involves the refrigerant-carrying circuit with H(C)FOs will only be allowed by certified personnel in analogy to other F-gases. **To close monitoring and reporting gaps**, a new obligation to report for recipients of quota-exempted HFCs and some reclamation facilities not yet covered is also added. To facilitate the mandatory verification of F-gas reporting, an electronic verification process will be included. Member States are encouraged

[68] The allocation price must be below the addition price that quota holders would normally ask when they sell HFCs to avoid that the quota allocation price in itself increases the price for end-users. Given the uncertainty about future price developments, a price has been chosen which is very likely to be below the price increase while still having the effect that unserious traders will not request quota. The quota price would affect importers and EU-based producers in the same way.

[69] In case the quota allocation price is having unintended effects; in case of major HFC market disruptions; when cases are unsettled at the moment of annual quota allocation or to require certain skills/characteristics of quota-holding companies.

to establish databases on activities such as servicing, leak checking and sales, for better market control and to derive real-world emission rates.

- **Option 3: Maximum feasibility and implementation improvements**

Option 3 is a **high cost option**. In addition to the measures in Option 1 and Option 2, Option 3 will include all measures that seek to **achieve the maximum GHG emission reductions based on today's technical feasibility while taking into account energy efficiency and safety** aspects. It also includes **all measures regarded as feasible to improve control, implementation, and monitoring**, including those proposed by stakeholders, regardless of the price or effort involved. This option was examined in order to see what price tag would be necessary to take all feasible measures considered, and what would be the added value of achieving them.

This option has the **steepest quota system** that is assuming replacement of high and medium high GHGs *as soon as* this is technically possible, even if marginal abatement costs at sub-sectoral level go up faster, and beyond €390/tCO2e already before 2050. Additionally, it **removes exemptions** for military equipment and semiconductors, which both relate to small amounts being consumed.[70] To further improve implementation, measures that come with a relatively high burden are included, e.g. **mandatory certification for importers and online sellers and a requirement to have a declaration of conformity and record keeping** to prove the origin of the gases for all **downstream HFC sellers**. Reporting would be extended to exporters of equipment to better gauge the effect of EU produced goods elsewhere and to recycling companies (in addition to reclamation). **Better estimation of emissions** are obtained by requiring operators of switchgear in electrical transmission to report and Member States to establish databases on available company data on servicing, leak checking and sales data.

Table 1 shows the individual measures and their grouping under the review objective they are targeting, and how they relate to each policy option. A more detailed description of the measures is given in Annex A6. Mutually exclusive measures are indicated with an '*'. All other measures are complementary and are shown as follows:

- Option 1 includes all measures shaded [white].
- Option 2 includes measures shaded light grey plus [white] (except "* Option 1")
- Option 3 includes measures shaded dark grey, plus those in [white] and light grey (except "* Option 1" and "* Option 2")

Table 1. Individual measures considered under the three options, by objective and policy response

Objective A – Achieving additional emission reductions
A1: Increasing the ambition of the HFC quota system (mutually exclusive)

[70] Maintaining these exemptions in Option 1 and 2 does not endanger Protocol compliance as these small amounts can be compensated by a slightly higher phase-down ambition for all other sectors. Given that the savings potential is very low while causing possible hardship to two special stakeholder types, e.g. the military and the semiconductor industry, this measure was not considered in the moderate cost/effort Option 2.

• * Option 1: Steps included after 2030 to ensure long-term compliance with the Protocol, only
• * Option 2: Steeper phase-down with HFC replacement where feasible at proportionate costs
• * Option 3: Steepest phase-down ensuring maximum HFC replacement where feasible at any cost
A2: New prohibitions for F-gases above a certain GWP limit and from a specific date
• Prohibitions related to F-gases in **fire protection equipment and small hermetic RAC systems** and PFCs in **RAC equipment**
• Prohibitions related to **stationary AC, smaller refrigeration equipment, personal care products** (e.g. creams, mousses, foams), **skin cooling equipment, one inhalation anesthetic and switchgears**. F-gases still allowed if strictly necessary e.g. due to health or safety rules, and lack of alternatives. Such exemptions will be subject to labelling.
A3: Extend requirements for the prevention of F-gas emissions
• Require emission prevention also for some **Annex II and newly added gases,** and for **all EU actors** during gas production, equipment manufacturing, storage, transfer and transport
A4: Recovery obligation of insulation foams blown with HFCs
• Require destruction or reuse of HFCs in **metal-faced panels**
• Require destruction or reuse of HFCs in **laminated boards in built-up structures and cavities**, unless infeasible and subject to documentation

Objective B – Seeking alignment with the Montreal Protocol
B1 & B2 : Achieve alignment, remove (some) exemptions not foreseen by the Montreal Protocol
• Include HFC use for **Metered dose inhalers (MDIs) under the quota system** and **remove minimum thresholds for the quota system and reporting**
• Include HFC use for **military & the semiconductors under the quota system**
B3 & B4 Achieve Montreal Protocol alignment production phase down limits and non-Party trade
• Include a **separate HFC production phase-down at entity level** mirroring the Protocol and prohibit trade in bulk HFCs from/to **any country not Party to the Kigali Amendment** (from 2033 in * Option 1; 2028 in Option 2 and 3)

Objective C – Improving implementation and enforcement
C1: Extend certification and training for RAC[71] technicians
• Add **energy efficiency** aspects to the required knowledge for training and certification
• Require that certification/training covers equipment with **F-gas alternatives,** and require certification when carrying out certain activities on **RAC equipment containing H(C)FOs** (now only for Annex I)
C2: Including detailed rules to empower customs and surveillance authorities; C3: Facilitate the use of the EU "Single Window Environment for Customs" & C4: Limit the quota system to genuine F-gas traders and producers
• Reinforced rules on **special custom procedures** and physical entry of **prohibited goods** • Tighter rules on **quota use and availability**
• Require **minimum penalties for non-compliance** • Require **evidence to be provided** by EU producers and importers on HFC23 destruction of by-production and **require labelling** of some Annex II and new gases as well as labelling MDIs as containing F-gases • Introduce an **allocation price of €3/CO2e for EU producers and importers.** Use the revenue to cover administrative costs to operate the quota registry and the Protocol licensing systems. Also, include **flexibilities** to react e.g. if the quota allocation price is having unintended effects; in case of

[71] RAC: refrigeration and air conditioning (including heat pumps)

major HFC market disruptions; when cases are unsettled at the moment of annual quota allocation or to require certain skills/characteristics for quota holding companies
• Require **documentation for downstream sales** for bulk HFC/F-gases (e.g. “declaration of conformity”) and record keeping and **mandatory certification for bulk importers** and **undertakings selling bulk F-gases online**

Objective D – Improving Monitoring and Reporting
D1: Reporting scope – substances
• Include new PFCs in Annex I and include new substances in Annex II
D2: Reporting scope - F-gas related activities
• Include recipients of quota-exempted HFCs and all undertakings performing reclamation of F-gases
• Include exporters of products and equipment containing F-gases and other fluorinated substances (plus registration obligation and undertakings performing recycling (in addition to reclamation) of F-gases
D3: Emission reporting
• ***Option 2: Encourage Member States to use electronic reporting systems** for collection of F-gas and emissions data (mutually exclusive)
• *** Option 3**: **Require Member States to use electronic reporting systems** for collection of F-gas and emissions data (mutually exclusive) and **operators of switchgear and electrical equipment** to report on SF_6 emissions
D4: Reporting process and data verification
• **Streamline reporting and verification rules, thresholds and dates** for EU producers and importers of bulk and of equipment
• Introduce **an electronic verification process** (separately for bulk and pre-charged products and equipment)

Objective E – More Clarity and Coherence
Envisaged improvements to make the Regulation more clear and coherent
Are included in all three options, see Annex A6.5 for details

The different ambition levels for the HFC quota system in Options 1, 2 and 3 are shown in Table 2, alongside the maximum quota under the baseline. However, the baseline is not directly comparable to the three options because, contrary to the three options, HFCs used for MDIs do not require quota in the baseline (exempted) and thus the baseline quota is not covering any need for HFCs for MDIs.

The quota limits for Option 1 are set to ensure that the Protocol’s consumption limits can be met. Option 2 is based on the need to supply HFCs for appliances, for which it is not feasible to use climate friendly alternatives by 2050 below marginal abatement costs of €390/tCO2e or not feasible at all. Option 3 only ensures supply for appliances where it is infeasible to use alternatives. The feasibility is based on technologies known today. Thus by the time the future F-gas Regulation is reviewed, it is highly likely that the quota system schedule can be further strengthened in line with new technological developments.

Table 2. Total annual quota allowances for HFCs (POM) under the three options and the baseline [MtCO2eq]

Years	Baseline[72]	Option 1	Option 2	Option 3
2024-2026	37.54	49.04	41.70	41.04
2027-2029	25.17	36.67	17.69	15.96
2030-2032	19.87	31.37	9.13	6.92
2033-2035	19.87	28.72	8.45	5.79
2036-2038	19.87	20.54	6.78	5.47
2039-2041	19.87	20.54	6.14	5.01
2042-2044	19.87	20.54	5.49	4.54
2045-2047	19.87	20.54	4.85	4.08
2048 and later	19.87	20.54	4.20	3.62

Note: Quantities needed for MDIs are only included in the options but not in the baseline, this explains why all options have higher initial quota allowances (MDIs are ca. 10 MtCO2 today)

5.3. Options discarded at an early stage

The possibility to repeal the Regulation and rely on voluntary agreements or national measures was discarded from the outset. Firstly, the current measures have overall been effective to meet its objectives. The Regulation remains necessary and has clear EU added value in light of EU climate objectives as well as the EU's international commitments. Secondly, voluntary action or national measures would result in lower emission reductions and would even endanger the progress made so far. Thus the option would be inconsistent with the EU's new and more ambitious climate objectives. Thirdly, the existing types of rules provide a clear signal to industry and are accepted by stakeholders, as clearly shown by the consultations.

Furthermore, a number of detailed measures that would appear to target the problem drivers (including measures proposed by stakeholders) were discarded at an early stage because they did not fulfil certain criteria that were applied to screen the options (See discarded measures and the reasoning behind eliminating them in Annex A6.6).

6. What are the impacts of the policy options?

A detailed bottom-up stock model of the F-gas using sectors was constructed (AnaFgas model) in order to calculate **demand and emission[73] scenarios** of F-gases, for the baseline and the policy options, as well as energy use of the relevant equipment, for the EU27+UK in the period of 2000 to 2050[74]**.** An attached cost module allows quantification of related costs to the operators of equipment relying on F-gases or their alternatives. In AnaFgas, all

[72] MDIs exempted, maintaining of the total annual quota limit after 2030 assumed, remaining at 2030 levels (currently not regulated)

[73] See also 1.1 on the relationship between demand and emissions.

[74] A detailed description of the model, its validation and modelling scenarios is found in Annex A4.2. The early years, i.e. before 2015, were used in order to better validate the model with existing emission data.

emission and demand estimates are derived from bottom-up approaches, i.e. by estimating demand and emissions per sector through the use of underlying drivers.[75] Macroeconomic effects were modelled using the JRC's GEM-E3 model. The models are described in detail, including the assumptions behind and any limitations, in the Annexes A4.2 and A4.3.

6.1. Environmental impacts

6.1.1. Emission savings from quota system and prohibitions

The reduction in future emissions is determined largely by the ambition level of the quota system and accompanying prohibitions. Option 1 will lead to higher emissions compared to the baseline scenario until 2046, falling slightly below thereafter (Figure 3). The *total cumulative* emissions of Option 1 from 2024 to 2050 are 1,050 MtCO2e, which is higher than the baseline emissions of 1,016 MtCO2e. *Annual* emissions in 2050 are estimated to be 25 MtCO2 for Option 1, which is 7% below the baseline. The total higher cumulative emissions in Option 1 is somewhat counterintuitive. It is related to the fact that on the one hand it is not necessary to impose any additional limitations on the use of HFCs for the sectors already covered by the phase-down in the early years (the EU consumption is currently well below the Protocol limit) and on the other hand, the way MDIs are being included under the quota system. In the *initial phase* 2024-2026 significantly more quota is allocated to fully provide the MDIs with HFCs (i.e. starting the 'phase-down' with 100%) to allow for a smooth transition of this sector. This careful approach is likely to give the sector more time initially than needed in practice, and assumed in the baseline, for starting the technological transition. As a result, there would be more quota available for other sectors (e.g. refrigeration, AC), thus slowing down the pace of replacement in these other sectors and leading to higher amounts of HFCs stored in equipment. This will slightly increase the amount of emissions in the short to medium term. The HFC demand (i.e. "use") in Option 1 does fall under the baseline from 2037 onwards, but emissions only fall below the baseline from the year 2046.

By contrast**, both Option 2 and Option 3 will lead to significantly lower emissions** compared to the baseline (and Option 1). Emission savings are achieved starting already in 2025 and continue until 2050. **The difference in savings between Option 2 and 3 is relatively small** and is mainly due to further abatement in a few sub-sectors (mobile AC in buses, metro and trains)**.** The total *cumulative* emissions until 2050 would be 763 and 736 MtCO2e under Option 2 and 3, respectively. Compared to the baseline (and Option 1), this is **a further drop in cumulative emissions of 25% and 28%,** respectively (253 MtCO2 less in Option 2 and 280 MtCO2 less in Option 3). *Annual* emissions in 2050 are estimated to be 14 and 13 MtCO2e for Option 2 and 3, respectively (see also Annex A11.1.2). The remaining emissions for Option 1 in 2050 are almost double that amount (see above).

[75] The drivers include annual changes in equipment stock, composition and charge of the equipment, leakage during equipment lifetime and during disposal. Some of these components are driven by other factors such as population development, GDP growth or technological changes. Based on these drivers, annual emissions and banks as well as use can be calculated for each year, sub-sector and EU Member State. A full list of parameters used to identify these emissions can be found in the external study.

Option 2 and 3 are considered to be in line with the objective of reaching climate neutrality by 2050. They reduce the need for carbon-removal policies to compensate for emissions that cannot be avoided in 2050 to achieve net climate neutrality. It is likely that even stricter F-gas policies can be introduced later (before 2050) at lower costs than today in light of new future technological developments.[76]

At a sectoral level the differences in emissions relate largely to the stationary AC sector and MDIs (Table 3). There are significant differences in transition speed between Option 1 (and the baseline) on the one hand, and Option 2 and 3 on the other. Some further savings are also achieved in refrigeration and mobile air-conditioning[77] by the more ambitious options. Restrictions on switchgear introduced by Options 2 and 3 would lower demand compared to Option 1 and the baseline, but emission reductions would happen rather slowly due to the very long lifetimes of the equipment (50 years). For the remaining sectors[78] the differences between the options (and the baseline) are small.

[76] In the modelled scenario for the in-depth analysis supporting Commission Communication COM(2018) 773 (The EU long term strategy for a climate-neutral economy), while using a different set of modelling tools, less sectoral granularity and less fluorinated substances considered, F-gas emissions were reduced to as much 5 MtCO2e by 2050, with total non-CO2 emissions reducing to as much as 286 MtCO2e by 2050.

[77] Note that for Mobile AC abatement related to new passenger cars is part of the baseline (MAC Directive).

[78] Al and non-ferrous metal production, production of fluorinated gases, semiconductor use, foams, technical aerosols, solvents, fire fighting, legacy emissions from windows, etc.

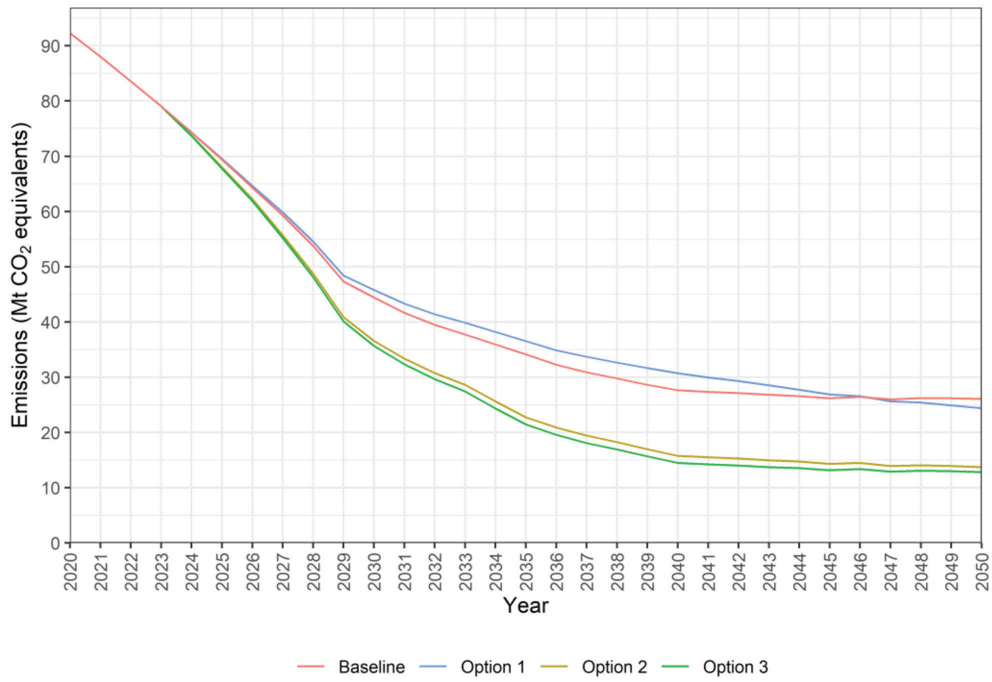

Figure 3: Modelled emissions of F-gases for the different options in the EU27 (based on reductions from the quota system and prohibitions only)

Table 3: Sum of modelled cumulative emissions of F-gases in $MtCO_2e$ from 2024 (i.e. estimated entry into force of new Regulation) to 2050 for the different options from important sectors in the EU-27 (based on quota system and prohibitions only)

Sector	Baseline	Option 1	Option 2	Options3
Refrigeration	128	134	112	107
Stationary AC	284	311	169	169
Mobile AC	187	187	150	127
Switchgear	78	78	71	71
MDIs	138	138	66	66
Other	200	200	196	196
Total emissions until 2050	**1 016**	**1 050**	**763**	**736**

Source: *AnaFgas modelling*

6.1.2. Other emission savings

6.1.2.1. Emission savings from enlarged obligations to prevent emissions

In addition to the savings above, Options 2 and 3 can further reduce emissions by requiring emission prevention measures for some Annex II and new substances, notably SO_2F_2 as well as some inhalation anaesthetics.[79] *Yearly* emission savings from 2024 could be at least 1 MtCO2e each for both SO_2F_2[80] and the anaesthetics[81]. For NF_3 the savings potential is

[79] Option 2 and 3 also prohibit the use of desflurane from 2026

[80] Based on the recent IPCC AR6 report's GWP for SO_2F_2 of 4 630, estimated emissions in Europe amount to 1.16 $MtCO_2e$

[81] 0.8 MtCO2e in 2020 but use growing rapidly

lower.[82] Climate relevant emission savings from H(C)FOs are small and prevention is targeting the avoidance of possible persistent breakdown products (see 6.1.4). Thus **Option 2 and 3 could add ca. 54 MtCO2e by 2050 cumulatively to emissions saved by the phase-down and prohibitions.**

6.1.2.2. Emission savings from the recovery of insulation foams

Recovery of HFC insulation foams, when buildings are being renovated or demolished, can also result in emission savings. About 1.9 MtCO2e could be emitted as a result of inappropriate end-of-life treatment until 2050 (all in the period 2045-2050), but in the time thereafter end-of-life emissions will rise further and persist for a long time in the baseline due to remaining foams in buildings of ca. 45 MtCO2e of HFCs in 2050.[83] Option 1 would recover up to 20% of these emission, while Options 2 and 3 could recover at least 35% of these emissions[84] (see Annex A15). There are strong synergies with the envisaged recovery of foams containing ozone-depleting substances (where there is a much higher potential to avoid emissions), as the collection and treatment process would be the same.

6.1.3. Energy use

The technological conversion to more climate-relevant alternatives results in some energy savings in the refrigeration and AC sector. For Options 2 and 3, average energy savings are approximately 2-3 GWh per year for the 2024-2036 (i.e. 2030) period (Annex A12.6), due to the deployment of slightly more energy-efficient low-GWP technologies (alternative solutions are not accepted if they result in lower energy efficiency). For Option 1 average 2024-2036 final energy use is about 1 GWh per year higher than the baseline. In the 2050 time horizon, all three policy scenarios result in energy savings, ranging from 2 GWh per year (Option 1) to 8-9 GWh per year (Option 2 and 3). These savings are however relatively small (about 0.1 % - 0.3 % of baseline energy use in the RAC (i.e. refrigeration, air conditioning including heat pumps) sectors in the 2024–2036 time horizon, or 0.1 % – 0.5% in the 2050-time horizon. The energy savings result from the early replacement of older equipment with new alternative equipment that is more energy efficient. The savings are therefore higher for the more ambitious options.

6.1.4. Other environmental effects

Impact on H(C)FO emissions

The reduced use of highly warming HFCs is resulting in an increased use and emissions of the climate-friendly H(C)FOs; e.g. HFO-1234yf being the most frequently used. HFO-1234yf emissions today come mainly from ACs in passenger cars and are expected to triple between 2020 and 2029 for all policy options and the baseline (mostly due to the MAC Directive).

82 Average emissions in 2010-2019 from the most important use in electronics industry were ca. 80,000 tCO2e

83 HFCs have only been used in foams since 1995 replacing ODS, and due to the long lifetime of foams (and buildings) most effects will be after 2050

84 Assuming a 25% recovery rate from laminated boards, which may increase in the future as better separation technologies are developed

After 2029, emissions will only be increasing slightly under the baseline and Option 1[85], whereas emissions under Option 2 and 3 will rise more strongly and be 16% higher than the baseline by 2050 (see graph in Annex A11.2). While they contribute very little to climate change, H(C)FOs emissions may lead to the formation of trifluoroacetate (TFA) in the atmosphere[86]. TFA is considered as being highly persistent and highly mobile in the environment and appears to accumulate in surface waters (and groundwater). It is still a matter of on-going research to what extent higher levels of TFA in the environment would result in dangerous ecotoxicological consequences in the future.[87] Furthermore, a recent publication has linked some H(C)FOs to the formation of HFC-23, which has a very high GWP.

Impact of faster role out of heat pumps as envisaged by REPowerEU

To reach the 2030 climate target and climate neutrality by 2050, the Commission has proposed to increase the share for renewable energy in the energy mix by 2030 to 40%. To reach that share, a high growth rate for heat pumps is assumed leading up to the installation of notably around 30 million hydronic heat pumps by 2030. In response to the natural gas crisis due to recent geopolitical events, the Commission has proposed to advance this roll-out and achieve a doubling of deployment rates and install 10 million of such heat pumps in the next 5 years.

While it is necessary to reduce both emissions from energy use and from F-gases, it is crucial that the quota system includes sufficient quantities of HFCs for those new and existing heat pumps that still need HFCs.[88] Based on AnaFgas modelling, and under the policy option 2, the total required HFC demand for heat pumps (including air-to-air splits and VRF systems) for new systems as well as for servicing the existing systems will decrease very rapidly over the years in CO2e. By 2030 its demand will only be about 25% of that in 2020. Even if growth rates should turn out to be higher than those assumed in the AnaFgas model, it would not dramatically alter the total required HFC demand. In the assessed option 2, with a prohibition for stationary heat pump with a rated capacity of up to 12 kW with F-gases with a GWP of 150 or more except if required to comply with safety rules, most new heat pumps are within this category and thus do not need HFCs after 2025.

Even if the ban on some installations would be implemented at a later moment, for instance from 2027 onwards to allow the market to accommodate the ramp up of initial production to

[85] By 2029 most cars on the road will be using HFO-1234yf, so when cars are replaced it no longer results in additional HFO emissions. Any increases of emissions from 2029 onwards result from other sectors, i.e. as a result of the F-gas Regulation.

[86] See Behringer et al. (2021): Persistent degradation products of halogenated refrigerants and blowing agents in the environment: type, environmental concentrations, and fate with particular regard to new halogenated substitutes with low global warming potential, UBA-TEXTE 73/2021.

[87] According to the Protocol`s Environmental Effects Assessment Panel (October 2021), TFA has been recently detected even in beer, tea, herbal infusions and indoor dust, but so far only at levels that are magnitudes below those that would be considered toxic.

[88] The quantities needed is determined by both the growth rate of new equipment and by the existing stock and its servicing needs, the type of heat pump, its leakage rates and charge sizes, as well as the refrigerant used and how fast HFCs can be replaced in each appliance.

accommodate significant short-term growth in heat pumps in the 5 year period 2022-2026, impacts on required quota for this additional deployment is very limited. An estimate was made what the impact would be on demand for F-gases of meeting the increased heat pump ambition as expressed in REPowerEU, assuming that the prohibition for stationary heat pump with a rated capacity of up to 12 kW with F-gases with a GWP of 150 or more would only start in 2027. It was estimated that the additional growth needed would increase the annual demand for F-gases by around 3.1, 2.7 and 1.4 million tCO2e in the years 2024-2026[89]. This is small compared to the 41.7 million tCO2e available as quota under option 2, also considering that the MDI sectors is allocated a 100% of quota in these years even though alternatives to replace HFCs are available and quantities of quota authorizations covering several years of HFC equipment imports[90] are currently banked by equipment importers (i.e. they will not require additional quota in the next years).

The heat pump categories that still need some HFCs in new equipment in 2030 (i.e. medium-sized heat pumps and VRF systems) can also significantly reduce the GWP of the refrigerant used[91], which implies that their need expressed in CO2e will decline very rapidly.[92]

The total demand for heat pumps is small relative to the total HFCs needed for all HFC-using sectors (12% in 2030 and 5% in 2040). Since the quota system is designed to cover the required amount for all HFC-using sectors (no earmarking), there is considerable built-in flexibility for higher consumption than expected in some sectors, as it may be counterbalanced by lower than expected consumption in other sectors. If the uptake of alternatives is too slow, this would result in higher HFC prices until the market reacts, but would in principle not result in gas unavailability.

It should be noted that if the situation should occur that a market disruption is threatening (which has not been the case in the first six years of the phase-down), all options include the possibility for the Commission to adjust the quota level.

Thus, the phase-down appears coherent with the targets for renewable energy, even if the significantly higher heat pump growth needed in the light of the current natural gas

[89] Based on the assumption of extra demand compared to the AnaFgas modelling for the period 2024-2026 of 9.5 million hydronic heat pumps (both packaged and split systems) and 4.9 million single split air-to-air heat pumps. The refrigerant used is assumed to be R32 (originally) and propane (increasingly) with an increase over time of the penetration rate (respectively 25%, 50% and 75% natural refrigerant in the years 2024 up to 2026), in anticipation of the prohibition in 2027.

[90] Close to 70 million tCO2e are banked as unused quota authorisations (EEA Report on fluorinated gases, 2021).

[91] In Option 2 and 3, 27% of medium-sized heat pumps (12-200 kW) would still require an HFC mixture with a GWP of at least 466 in 2030, but 73% could go to very low, single-digit GWP; 41% of VRF heat pumps would require a GWP of at least 675, while 59% could use an HFC mixture with a GWP of lower than 150. These are significant reductions of the GWP, as conventional technology until recently used to be R-410A with a GWP of 2088, e.g. even an HFC with a GWP as high as 466 would still only require only about a fifth of the quota measured in CO2e than does an R410A equipment with the same charge size.

[92] In addition, the transition to climate-friendly alternatives results in significant savings for the end users in terms of energy efficiency and is another incentive to use heat pumps in larger numbers

energy crisis and a resulting slightly slower conversion of small heat pumps to climate-friendly alternatives is taken into account.

6.2. Cost to business

6.2.1. Technological costs and HFC costs for F-gas using industries / equipment operators

Business may be faced with changes in costs relating to:

- Technological adjustments resulting in changes in investment costs and operating expenditures (e.g. energy use, maintenance costs) for users of mainly new equipment that are shifting to (more) climate-friendly alternatives.
- Higher HFC prices ("HFC price premium") resulting in higher HFC equipment prices and maintenance costs for users that continue to rely on equipment using HFCs.

Based on the experience of the last six years, both types of costs are fully passed through to the end user of the equipment. However, it should be noted that the user costs resulting from the HFC price premium will benefit the sellers of HFCs, who receive the quota free of charge mainly based on historic grandfathering. Thus the net effect of higher gas prices on the economy is neutral (distributional effect). If a quota allocation price is introduced (Option 2 and 3), the effect would similarly be neutral overall, but some of the net costs would result in revenue for the authorities from the quota allocation price.

To correctly describe the different costs for different stakeholders, we discuss in the following the (i) technological adjustment costs for users of new alternative equipment, (ii) related emission reduction costs, (iii) HFC price premiums paid by users relying on HFCs, (iv) total adjustment costs for all equipment users, and (v) distributional effects of higher price premiums and the impact of an allocation price.

6.2.1.1. Technological adjustment costs for users that shift to climate-friendly solutions

Average annual costs that arise from changing to climate-friendly equipment, either new investment into alternative equipment or operating alternative equipment, **e.g. the technological adjustment costs, will vary between 2, 12 and 116 Mio €/year for Options 1, 2 and 3**, respectively, for all sectors combined in the time horizon 2030 (i.e. the 2024-2036 interval[93]). At sector level there are large differences (Table 4). The targeted refrigeration and air conditioning (RAC) users will in fact see benefits because higher investment costs are in general counterbalanced by lower operating cost (e.g. better energy efficiency). These savings are highest under Options 2 and 3 where beneficial alternatives are introduced more quickly. On the other hand, users of new mobile AC (excluding passenger cars[94]) and new

[93] i.e. the time period that covers the presumed entry into force of the new Regulation (2024) until the last (lowest) compliance step of the Protocol (2036). Annual costs for these years are determined and averaged over the period.

[94] The options will not target new passenger cars as they are already required to use climate friendly refrigerants.

switchgear without SF_6[95] will have higher costs compared to the baseline. Additional costs for these sectors are estimated to be 3.6 % for switchgear/SF_6 under both Option 2 and 3, and 0.4% (Option 2) and 1.0% (Option 3) for mobile AC of the baseline costs.

In the long run (2050) equipment users will overall save costs compared to the baseline, in particular for the more ambitious Options 2 and 3. Option 2 and Option 3 differ only slightly. In 2050, these options have savings of just over 1 billion €/year, which is more than twice the amount resulting from Option 1. The largest savings are achieved in AC applications including heat pumps as well as commercial refrigeration. The savings achieved result from replacement of older equipment with new alternative equipment (lower maintenance costs) and are therefore mostly related to the effects of the quota system and the accompanying prohibitions. Data at sub-sector level is given in Annex A12.3.

Table 4. Annual adjustment costs due to technological change for the three policy options vs. baseline between 2024-2036, and in 2050 [Mio €/year]

Sector	time horizon	Option 1	Option 2	Option 3
Refrigeration	2024- 2036 average	-24.2	-67.5	-124.8
Stationary AC	2024- 2036 average	26.1	-82.6	-82.6
Mobile AC	2024- 2036 average	0.0	109.1	270.6
Propellants, solvents & fire protection	2024- 2036 average	0.0	3.1	3.1
Foam	2024- 2036 average	0.0	0.0	0.0
Other HFCs	2024- 2036 average	0.0	0.0	0.0
Switchgear (SF_6)	2024- 2036 average	0.0	49.3	49.3
Annual cost for all sectors combined	**2024- 2036 average**	**1.9**	**11.5**	**115.7**
Annual cost for all sectors combined	***In 2050***	***-456.1***	***-1024.6***	***-1040.1***

6.2.1.2. Emission reduction costs

To judge the cost-efficiency of the options, emission reduction costs (i.e. abatement costs) are calculated. Since new equipment will leak (i.e. emit) over many years, emission reduction cost compare the cost of technological change for investment in and operation (e.g. maintenance costs, energy use) of equipment based on low-GWP alternatives during its lifetime to the emissions saved during the lifetime of the respective equipment. These costs are determined for new equipment installed (i) each year during the 2024-2036 timeframe and (ii) in 2050. The HFC price premium (see 6.2.1.3) is not considered here, because it is (i) a distributional cost, and not a net cost for the economy (see 6.2.1.5), and (ii) these premiums are paid by the users of HFC equipment, rather than those using alternative equipment as a

95 This concerns only Option 2 and 3, as no mitigation actions for those sectors is expected in Option 1.

result of the policy options assessed. The resulting estimated emission reduction costs are shown in Table 5.

In the **2024-2036 time horizon, Option 2 and 3 will result in cost savings** (i.e. negative costs) **of 36€/tCO2e abated and 23 €/tCO2e abated,** respectively for the economy as a whole.[96] In the **long-term perspective (2050)**, **Option 1 results in cost savings at almost -178 €/t CO2 abated**, since emissions savings would be mostly limited to the cost-efficient sub-sectors of refrigeration and AC (and the other sectors therefore do not show up in the calculation). Under **Option 2 and 3, the analysis shows average benefits for the economy as a whole, estimated at 63 €/t CO2e and 52 €/tCO2e**, respectively. The cost savings come mostly from reduced maintenance costs, in particular energy use. This indicates that **action in most F-gas sectors is very cost-efficient. It is therefore also in general more economical in view of actions taken elsewhere, in other sectors of the economy.**

There are however large differences in the marginal abatement costs at the sub-sectoral level (see Annex A12.4). Costs related to Option 3 (through a stricter phase-down) reach up to 2,111 €/t CO2e abated (train AC), whereas the highest abatement costs under Option 2 are estimated to be 334 (buses AC) and 336 (switchgear) €/tCO2e. Thus, **Option 3 will have, in a few sub-sectors (e.g. AC in trains, buses and metros), marginal abatement costs that are significantly higher than what is being estimated as necessary** (390 €/t CO2e abated by 2050) **for the economy as a whole in modelling until 2050.**

Table 5. Emission reduction costs (i.e. abatement costs) per sector and in total for all sectors.

Sector	time horizon for new installed equipment	Option 1			Option 2			Option 3		
		total emission reductions vs. baseline*	Cost of technological change	emission reduction cost+	lifetime-integrated emission reductions compared to baseline	Cost of technological change of lifetime-integrated emission reductions	Calculated emission reduction cost+	lifetime-integrated emission reductions compared to baseline	Cost of technological change of lifetime-integrated emission reductions	Calculated emission reduction costs +
		Mt CO_2e	Mio €	€ / t CO_2e	Mt CO_2e	Mio €	€ / t CO_2e	Mt CO_2e	Mio €	€ / t CO_2e
Refrigeration	2024-2036	-1.9	-5.5	NA+	1.7	-120.8	-72.5	2.1	-188.6	-91.6
Stationary A/C	2024-2036	-3.0	196.9	NA	7.3	-559.4	-76.3	7.3	-559.4	-76.3
Mobile A/C	2024-2036	0.0	0.0	NA	1.7	96.2	57.9	2.9	303.9	106.4
Propellants Solvents Fire fight.	2024-2036	0.0	0.0	NA	2.5	3.3	1.3	2.5	3.3	1.3
Foam	2024-2036	0.0	0.0	NA	0.0	0.0	NA	0.0	0.0	NA
Other HFCs	2024-2036	0.0	0.0	NA	0.0	0.0	NA	0.0	0.0	NA
SF_6	2024-2036	0.0	0.0	NA	0.7	79.5	115.8	0.7	79.5	115.8
For all sectors	**2024-2036**	-4.9	191.4	**NA**	13.8	-501.1	**-36.3**	15.4	-361.2	**-23.4**

96 This is not relevant for Option 1 since there are no emission savings compared to the baseline.

For all sectors	**In 2050**	4.4	-781.1	**-178.1**	16.1	-1005.2	**-62.7**	16.3	-841.2	**-51.7**

Source: *AnaFgas cost modelling*

*negative values indicate emission increases vs. baseline

+ NA: not applicable: no emission reduction costs can be calculated as emissions increase

n.b. The emission reduction costs shown relate to new equipment installed in the period 2024-2036 (average) and in 2050

6.2.1.3. HFC price premium for users that rely on HFCs

From 2015-2019 the phase-down system resulted in an increase in HFC prices on the EU market compared to the prices before the phase-down started. While EU prices have been fluctuating[97], on average the price increase (premium) is estimated to be around 8 €/t CO2e at gas distributor level (see Annex A5.6.1.1 and A4.2.10.1). Thus, new HFC equipment and products and the servicing of such equipment (e.g. refilling supermarket refrigeration or old passenger cars with virgin HFCs) became more expensive for users. To determine the future impact on users it is necessary to understand how this premium would change under each option compared to the HFC price development that would occur under the baseline. *Temporarily* higher prices are required to drive replacement in the more difficult sectors with high marginal abatement costs. However, significant uncertainty exist about HFC price developments over 30 years when estimating price effects related to the options.[98]

Still, for the purpose of illustrating the potential distributional impacts of the HFC premium, some assumptions about the potential development have been made in Table 6. It has to be underlined that these price assumptions are not predictions. They may however be assumed to represent a conservative scenario, or so called worst-case scenario, as regarding long-term price developments, as it is expected that over 30 years many new technological developments will take place that allow the replacement of F-gases also in the sectors where abatement is difficult, which would result in lower demand. This, in turn, would lower the price premium resulting from the decrease in HFC supply. These demand effects are not factored into the assumed prices in Table 6.

Table 6. Worst case assumptions about the HFC price premium vs 2014 pre-phase-down price levels

Scenario	Unit	2025	2030	2035	2040	2045	2050
Baseline	€/t CO2e	28	37	38	39	40	40
Option 1	€/t CO2e	27	29	33	41	46	50
Option 2	€/t CO2e	37	68	95	119	138	161

[97] C(2020) 8842 final. REPORT FROM THE COMMISSION on the availability of hydrofluorocarbons on the Union market. https://ec.europa.eu/clima/document/download/11f89677-c97e-420d-97b7-97b9ad14618a_en

[98] A comparative analysis is difficult because on the one hand, options with a stricter phase-down have lower HFC supply and therefore HFC prices would tend to be higher. On the other hand, a stricter phase-down promotes technological change, which in turn will decrease demand for HFCs and thus prices. Also, HFC prices may be lower for options with additional prohibitions since prohibitions reduce HFC demand. Since 2015, prices were stable in the first two years of the quota system, shooting up very strongly in 2018 and then coming back down in 2019 and 2020 (See evaluation, Annex A5.6.1.1).

Option 3	€/t CO2e	38	74	112	141	159	180

Source: *AnaFgas cost modelling*

In Option 1, the sectors that are covered by the phase-down will first have lower HFC premium until 2040 and then slightly higher HFC premium, compared to the baseline. For all options, the users of pharmaceutical MDIs that continue to use HFCs will have to pay these HFC price premium costs over time. This is contrary to the baseline where these users do not pay the premium, as MDIs are exempted from the phase-down in the current Regulation. However, the higher HFC premium compared to the total product price is very low in this case (less than 0.1%) and a smooth introduction of alternatives is thus promoted. The new quota system will start with an allocation of HFC quotas that covers 100% of the MDI sector needs.

In Option 2 and 3, higher HFC prices are assumed to impact on all users that are still buying new HFC equipment (including MDIs) or need to refill existing equipment. For all operators collectively the higher HFC premium compared to the total product price is very low, at 0.1%. However, some sectors will see bigger reductions in HFC content in equipment than the increase in HFC premium price, resulting in a net decrease in costs for HFC prices paid. In absolute terms, the stationary AC sector for instance sees the biggest net cost decrease in HFC price paid, because the cost associated with increasing HFC price premiums are more than compensated by the reductions in remaining HFC demand. For more sectoral detail see A12.3.

6.2.1.4. Total adjustment costs to users of equipment and products

In the **2024-2036 time horizon**, total adjustment costs for **users** (e.g. equipment owners), taking into account both technological change and HFC price premium, range from about 210 Mio €/year in Option 1 to 410 Mio €/year in Option 2 and 442 Mio €/year in Option 3 (see Annex A12.3). In the long-term perspective (2050), users are expected to benefit overall, as costs related to technological adjustments are negative in all policy scenarios (see 6.2.1.1), with costs to those users that still rely on new HFCs in 2050 ranging between 115-190 Mio €/year for the 3 options. However, in all options, the user costs are linked to HFC price premium assumptions[99] which are uncertain and deemed worst-case scenarios. Moreover, the quota holders and other companies in the HFC supply chain benefit from a higher price premium as they are able to sell the HFCs at a higher price (see next section below).

6.2.1.5. Distributional effects between equipment operators and undertakings of the HFC supply chain and impact of the quota allocation price

The cost to F-gas using industries (e.g. equipment operators) due to the price premium are revenues for other operators in the HFC supply chain and profit bulk gas importers, producers/distributors and service companies. In the baseline scenario, the quota system could generate, if taking the high price premium as assumed in 6.2.1.3, revenue at about 2.1

[99] Of total costs in 2024 -2036 price increases account for approximately 99% in Option 1, 95% in Option 2 and 80% in Option 3.

billion €/year on average in the period 2024-2036. In the 2050 time horizon, the costs/revenue would decline to 1.4 billion €/year. The experience of the quota system so far shows that the revenue gain is split 60% to 40% between the importers, EU producers and distributers on the one hand and the service companies on the other.

A quota allocation price measure (Option 2 and 3) would provide for a more evenly distributed sharing of the burden between industry players as it reduces the revenue for the actors (EU gas producers, importers, distributors, service companies) in the F-gas supply chain. Due to the high uncertainties about the HFC price development resulting from the phase-down, it is proposed to keep a relatively low quota allocation price to avoid any risk that an unnecessary higher allocation price is passed on to end-users. If the allocation price is set to 3 €/tCO2e[100], the revenue would be around €125 million initially (2024) and that revenue would decline over time as the quota allocated is being reduced. It would be important to have flexibility to adjust the quota allocation price in case it appears to be too high (pass on) or too low (insufficient limitation to genuine traders). See Annex A7.3 for more details on this measure.

6.2.2. Administrative Costs

Industrial stakeholders were asked to provide information on additional administrative costs of the measures included in the policy options. Given that the Regulation affects many different types of companies (gas producers, distributors, importers, equipment manufacturers, service companies, end users etc.) and in many different ways (different measures affect different company types), the data collected needed to be complemented by further analysis, in particular also for data regarding company size. This detailed analysis, assumptions made and data considered are given in Annex A14).

For the **EU Commission** the costs were estimated by DG CLIMA. The data for the **EEA** are based on EEA time recording and invoice information from EEA's contractors. The 27 **Member States** competent authorities were asked to fill out a questionnaire related to the administrative costs associated with the implementation and enforcement of the Regulation. The respondents were not able to provide answers to all the questions and the figures obtained include a combination of time effort and monetary expenditure estimates. The level of certainty ranges from 'definitive' to 'rough estimates.' Nonetheless, a good base of data was collected from the competent authorities on which an estimate of administrative costs could be made. In total 13 Member States provided information on administrative burden[101], with six noting upfront costs.

[100] €3/tCO2e would be below recent market levels on the HFC price premium (6 €/t CO_2e as OEM purchasing prices from 2015-2019) and thus the 'allocation price' would normally decrease benefits in the HFC supply chain whereas it would not be passed on and result in an additional burden to end-users.

[101] 13 Member States provided data based on time effort required, and 9 Member States provided data on financial costs.

6.2.2.1. Additional administrative costs for industry

Some measures will result in one-off administrative costs whereas others will entail costs every year. Table 7 gives the expected additional administrative costs for each policy option by review objective.

Table 7. Additional recurrent administrative costs expected for industry stakeholders by the three policy options and by review objective (in million € per year)

	Option 1	Option 2	Option 3
Net Costs Objective A	-	4.4	4.4
Net Costs Objective B	0.02	0.02	0.02
Net Costs Objective C	-0.8	5,7	6,2
Net Costs Objective D	-1.1	-2.5	-1.3
Net Total Cost	**-1.8**	**7.6**	**9.4**

Option 1 results in some cost savings for undertakings (-1.8 million € per year). Option 2 and 3 result in total costs of €7.6 and €9.4 million € per year, respectively, in addition to one-off costs of €3 and €21 million, respectively. As regards individual measures, "certification programmes to include alternatives"[102] and "additional requirements for prevention of emissions" result in the highest recurrent costs (both measures are only in Options 2 and 3). High one-off costs are linked to the measure of a "Member States electronic tool to register emission-relevant company data" (Option 3 only). Relevant cost savings for companies are achieved by "having new entrant declarations only every 3 years, instead of annually" (all Options), "relaxing the verification thresholds for equipment" (all Options), and "enabling an electronic verification process" (Option 2 and 3). The detailed costs per measure are given in Annex A14.2. Some of the measures resulting in additional costs are needed to align with international rules or achieve better implementation by reducing illegal activities (€1.9 million in total).

6.2.2.2. Additional administrative costs for authorities

At European level

The European Commission is responsible for implementing the quota system and the company registry EU-wide. This is already a considerable task and a number of measures would increase the burden on the Commission, in particular the introduction of a quota allocation price, which would result in significant resource and budget implications (ca. 10 annual full-time equivalents (i.e. 2200 person days) plus IT costs, in addition to 2200 person days one-off staff and IT costs). However the price will also generate a revenue and could be used to outsource some of the activities on a permanent basis, e.g. to an agency such as the European Chemicals Agency (ECHA). In addition, the implementation of a tighter phase-down including on production and a more comprehensive and complex legislation on prohibitions will also increase administrative costs. Option 1 would increase the resource effort for the EC by only ca 100 person days, while Options 2 and 3 would require more than

[102] In addition, there are 20.8 million € costs estimated for attending additional training courses which is considered an additional adjustment cost for service companies.

2,300 person days in addition to similar one-off costs, mainly due to introducing the quota allocation price (2200 person days by itself). In addition, there are one-off costs of 12 (Option 1) and 2,215 (Option 2 and 3) person days. These costs do not include efforts of further developing the CERTEX/EU Single Window for Environment.

The European Environmental Agency (EEA), which has been entrusted with collecting and analysing the annual reporting data, would have additional costs due to slightly extended and/or modified reporting obligations, as well as enabling the electronic verification system. Option 1 may result in slight overall savings for EEA, Option 2 would slightly increase the current effort (430 person days) by 10 person days, while Option 3 would increase the effort significantly by 327 person days, mostly due to enabling the reporting on exports of equipment, switchgear and recycled gases. There are also one-off costs of 42, 142, and 292, respectively, for Options 1, 2 and 3. Detailed costs are given in Annex A14.4.1.

At national level

Member States can expect higher costs for enforcing the quota system, e.g. requirements for customs and importers[103] (all options) and new prohibitions (mostly Option 2 and 3); for updating certification and training programmes (Option 2 and 3) and for setting up national databases (Option 2: encouraged and 3: required). Further costs may relate to other new measures, e.g. the requirement to recover foams at end of life (all options). Cost savings are expected due to the alignment of reporting and verification thresholds and the obligation to submit nil reports (all options). Overall, Option 1 will add few costs, while the recurrent costs for Option 2 and particularly Option 3 are somewhat larger (An average of 310 (Option 2) and 468 (Option 3) additional person days per year and per Member State). Option 3 also adds some upfront costs, see Table 8 and Annex A14.4.2.

Table 8. Additional administrative costs expected for authorities as a result of the three policy options in person days (EC: European Commission, EEA: European Environmental Agency, MS: Member States)

Person days		**Option 1**	**Option 2**	**Option 3**
EC	Upfront (one-off)	10	2,215	2,215
	Ongoing (per year)	102	2,313	2,338
EEA	Upfront (one-off)	42	142	292
	Ongoing (per year)	-2	10	327
MS (total)	Upfront (one-off)	246	246	9,092
	Ongoing (per year)	3,101	8,364	12,644

6.3. Macroeconomic effects

The effects of the three policy options on the EU economy were modelled using the JRC-GEM-E3 model. The policy scenarios were assessed in comparison to the EU reference scenario 2020 of Fit for 55[104]. As the latter includes the (unchanged) measures of the current

[103] Benefits related to automatic controls through the Single Window for Customs are in the baseline and saved payments to the EU Budget due to the quota price revenue transfer in Option 2 and 3 are not included.

[104] European Commission (2021). EU Reference Scenario 2020: Energy, transport and GHG emissions - Trends to 2050.

F-gas Regulation, it is comparable to the baseline used in the current work. In the JRC-GEM-E3 model the analysis focuses on modelling the economic consequences of additional abatement cost, cost savings (e.g. from lower energy use or reduced equipment expenditure) and increased user cost (in end user cost due to the value of the HFC quota). A description of the model and of the setup of the scenarios are given in Annex A4.3.

Overall the economic implications of the more ambitious options 2 and 3 are slightly positive in the long run (2050). There are a number of industries that will profit, in particular linked to equipment manufacture and its supplying industries. There may be some very small inhibitive effects until 2030 in Options 2 and 3.

6.3.1. Effects on GDP

Overall, the GDP impacts are very small (see Annex A13), as the changes included in the different options concern only limited areas of the EU economy. **For the more ambitious options (2 and 3), the GDP would slightly increase in the long run** (0.005-0.006%), which reflects that cost savings (e.g. from energy use; see section 6.2.1.1).) lead to an increase in GDP, as the same goods can be operated with less input and thus less expenditure is needed for the same purchases. These savings can be used to purchase other goods and services, thus increasing GDP. Conversely, option 1 shows very small positive effects until 2030 (0.002%) as there are less initial adjustment costs, but no positive effects in the longer timeframe (as e.g. energy savings are not achieved).

4. Effects at sectoral level

Different industries could be affected in different ways depending on their role in F-gases abatement. Some providing goods and services used for abatement would benefit while others may face reduced demand or increased costs from abatement efforts.

At sectoral level, changes are observed for the **electricity sector and fossil fuel supply sectors (output reductions).** Option 1 leads to higher electricity use in 2030 (0.06%) and some savings by 2050 (-0.09%). These **savings are significantly larger for Options 2 and 3** (-0.07 and -0.14% in 2030, -0.35 and -0.37% in 2050, respectively). There is also an **increase in output for the equipment goods** sector (e.g. production of cooling equipment including AC and heat pumps) for Options 2 and 3 (0.13 and 0.15% in 2030, 0.19 and 0.20% in 2050, respectively). Option 1 leads to lower output from the equipment sector in 2030 (-0.14%), and a moderate increase by 2050 (0.09%) (see Annex A13). **Sectors that deliver input to equipment manufacture also show positive effects** for options 2 and 3, e.g. metal sectors, electric goods. There are **small positive effects also on chemical industry** from an increase in demand. Conversely, there is a **small decline in the transport sectors** (commercial land transport and water transport) as these face a net cost from the policy in case of Option 2 and 3 (maximally -0.01 and -0.02%, respectively in 2030). The overall **service sector** in the model includes too many different activities to show any noticeable effect attributable to the F-gas maintenance sector. Other sectors that are not directly affected show very small impacts.

6.3.3. *Effects on consumption, investment and innovation*

For Options 2 and 3 there may be some very small initial inhibitive effects on investment until 2030, but EU27 investment is changing **positively in response to the increased GDP in the long run**, by up to 0.002% (Option 2) and 0.003% (Option 3). Investments in the power sector decline due to lower demand for electricity, while there are increases in some other sectors (mainly equipment manufacturing) that benefit from increased demand for replacing equipment. Similarly, **Options 2 and 3 lead to higher consumption in the long run** (2050: 0.007 to 0.009% in 2050), especially in the EU South (up to 0.011%) (see Annex A13), as savings from energy are invested in other goods and services. These positive effects materialise after 2030, when the cost savings from early abatement start bearing fruits. Consumption increases in appliances and equipment, which become cheaper to operate, while cost savings also lead to increases in household consumption of other services.

The evaluation found that R&D and innovation were positively affected by the quota system and the prohibitions, in particular in the refrigeration and air conditioning equipment manufacturing sector. The quota system raises prices for HFC gases and therefore incentivises that end-user convert to lower GWP or non-F-gas technologies more quickly. Prohibitions provide end-points in certain sub-sectors and a clear signal as well as business opportunities for innovators and manufacturers of alternative equipment. Stakeholders generally supported this finding. **Further incentives for investment in R&D and innovation are to be expected in particular for Options 2 and 3 due to a steeper phase-down and more prohibitions, while little additional impact on R&D and innovation is expected from Option 1.** This is supported by the JRC-GEM-E3 modelling results which points to additional investment in particular in the 'other equipment goods sector' in Option 2 and 3 (approximately +0.15% in 2030, and + 0.2% in 2050) (see Annex A13).

6.3.4. *Distribution of cost across EU regions*

No strong regional differences between Northern and Southern European countries were found. F-gas using equipment is not equally distributed over the EU, due to climatic differences, that fact that natural alternatives are already more frequently used in the North and different structure of the relevant sectors[105]. Hence, investments in replacement technologies and the types of equipment used could be expected to show some variations (see Annex A4.2.8). An analysis of these patterns between northern and southern EU countries as to their relevance on costs shows that, for Option 1, the cost distribution is almost proportional to the population. In the more ambitious Option 2 and 3, **costs rise more for the EU North relative to population**. These small differences are mostly due to a shift away from HFC technologies in small stationary AC systems that are prevalent in the South, resulting in cost savings for operators in comparison to the baseline, both for the HFC charge and re-fill and for other technical cost. Regional patterns were also assessed for the macroeconomic indicators GDP, consumption, investment and employment. As overall

[105] E.g. in the South smaller shops are comparatively more relevant, requiring different types of equipment.

effects for those indicators were found to be very small, no strong regional patterns could be established. Regional patterns were also assessed with GEM-E3 for the macroeconomic indicators GDP, consumption, investment and employment and overall effects for those indicators were found to be also very small (< 0.01% changes in comparison to baseline developments).

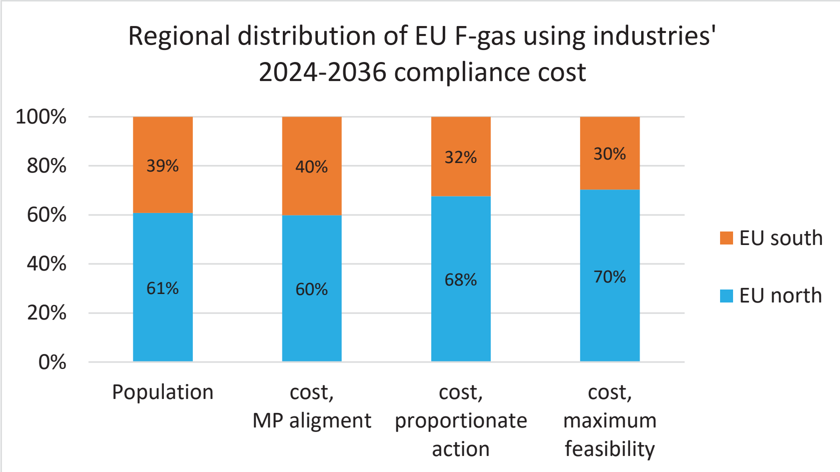

Figure 6: Regional distribution of EU F-gas using industries' 2024-2036 compliance cost

Note: EU South: Bulgaria, Croatia, Cyprus, France (25% of FR population), Greece, Italy, Malta, Portugal, Romania, Spain; EU North: other EU27 MS, including 75% of the French population.

"MP alignment" is Option 1, "proportionate action" is Option 2, "maximum feasibility" is Option 3

Source: AnaFgas cost modelling

6.3.5. Impact on consumer prices

Private consumers are not expected to bear any significant costs. Private consumers are endusers (i.e. equipment operators) only in a few sub-sectors (e.g. small AC units, AC in passenger cars[106] or MDIs). Users of small AC (e.g. heat pumps, single-split) benefit from energy efficiency savings, which lead to cost savings already in the 2024-2036 timeframe (Table 39 in Annex A12.3). Owners of older cars will have to pay more for the HFC gas if the AC system needs refilling. The relative cost increases for these sectors are very small and thus are not expected to impact on consumer prices significantly. Patients using MDIs for asthma and other conditions will practicably not be affected as the propellant gas costs is a very small fraction of the total price of inhaler and the medicinal agent (<0.05% of total costs). The JRC-GEM-E3 model confirmed that consumption price increases for the 'medical care and health' sector overall are only about 0.04% - 0.05% for 2030 and about 0.03% for 2050, compared to the baseline. Finally, electricity network operators warned that higher prices due to replacing SF_6 switchgear would be passed on to customers through higher network tariffs.

In most other cases, private consumers are not affected directly, because the operators of equipment are companies which use such equipment in order to provide other goods or

[106] There a no technical adjustment costs linked to mobile AC in passenger cars except that higher HFC prices may increase costs of maintaining AC in some cars dating before 2017.

services to consumers, e.g. refrigeration in food retail, air-conditioned office space or transport or IT services relying on fire-protected servers. Whether or not cost changes for companies will have any significant effect on consumer prices of the good or service they provide will depend on the relative change compared to other costs and the ability to set higher prices for the consumer good. In cases where there are costs, they will be low compared to the total costs related to the consumer good or service. Moreover, in many cases these low costs can be distributed over many different goods. For instance, additional costs for refrigeration or air conditioning on ships are small compared to other operative costs on the ship and can be dispersed on the many products transported over the life time of the equipment. For those applications that exhibit negative adjustment costs (e.g. commercial refrigeration, split air conditioning, see Annex A12), no price effects are expected on the relevant consumer goods. **Thus none of the options are expected to impact on consumer prices in a significant way**.

6.3.6. Distribution of cost across business size

The impacts on SMEs should be moderate. In the public consultation, 37% expected only a slight burden or no burden at all for SMEs, while a similar number (38%) of industry stakeholders[107] expected a significant burden as a result of the policy options of the review.[108] A high share of SMEs is found among equipment importers and the service companies. Equipment importers face essentially the same HFC price premiums when they acquire quota authorisations to import as the EU manufacturers that buy HFCs at high prices in the EU[109]. Price premiums increase from Option 1 to 3 (see 6.2.1.2). Service companies profit from higher HFC prices as they can pass them on (and more) to their customers. On the other hand, service companies will bear some costs linked to training needs (see 6.2.2.1), while the acquiring of new skills also offers business opportunities. SMEs are also found among equipment operators, where adjustment costs expressed in relation to baseline expenses are very low (Annex A12). Accordingly, industry stakeholders expected, related to SMEs, higher staff and training costs due to the need for skilled personnel and some feared a possible disruption of investment plans for smaller end-users, while others saw increased business opportunities for providers of green technologies.

6.3.7. Impact on competitiveness

6.3.7.1. Competitiveness of fluorinated gas producers

EU producers and importers are not expected to suffer competitiveness losses. As regards the production of HFCs, the production levels in tCO2e must be phased down due to the Protocol and the inclusion of a separate HFC production phase-down is designed to ensure that producers will be at least as well off as under a scenario where the Montreal

[107] These answers were obtained from 168 respondents from industry, of which 122 (73%) describe themselves as SMEs.

[108] The remaining percentage (25%) could not say or did not answer.

[109] The quota authorisations price has been developing similar to the HFC price premium. It has been at a low levels since 2019 and many importers have already acquired a substantial authorisations for future use.

Protocol production phase-downs are implemented at national level (by Germany and France) (See Annex A8). Furthermore, producers and importers profit from the quota system, as free quotas and scarcity of HFC gas on the EU market allow to charge higher prices for the gas (see e.g. Annex A4.2.10).

6.3.7.2. Competitiveness of businesses active in the manufacture and maintenance of equipment using F-gases or alternatives

There may be positive effects for competitiveness of equipment manufacturers under the *higher ambition* policy options in the future. The Kigali Amendment will lead to a world-wide increase in demand in climate-friendly technologies. Options 2 and 3 will incentivise R&D and innovation related to equipment operating with low GWP alternatives more than Option 1 and hence more likely increase export opportunities. While some industry stakeholders expected an increase in R&D (39 respondents) and higher competitiveness, including in the field of alternative technologies to SF_6 (17 respondents), other industry stakeholders feared that the competitiveness of export-oriented EU business may be negatively affected by higher HFC prices. JRC-GEM-E3 modelling results show that in monetary units the gains in output of the "other equipment goods" sector to be expected under Options 2 and 3 are by far larger than the losses in exports. Moreover, as mentioned above, EU companies will more and more produce climate-friendly technologies also for export, as the global market will be moving in that direction.

6.3.8. Impact on trade flows (imports and export)

As regards HFC *bulk gases*, future exports will go down as EU production (and consumption) will have to decline compared to 2011-2013 levels as internationally agreed. This is therefore the case for all three options as they all intend to ensure compliance with Protocol rules. **This does not apply to SF_6 gas (or SF_6 equipment)**[110] exports, as no restrictions on exports of this gas apply in any of the three policy options. European companies are also world leaders for the alternative equipment replacing SF_6.

For products and equipment containing HFCs, manufacturing costs will increase due to higher HFC prices depending on the ambition level of the policy options. From an isolated perspective those additional costs may reduce exports, as outside markets are not as advanced as the EU as pointed out by some industry associations. However, as all countries will have to comply with their declining HFC consumption limits under the Montreal Protocol, **there will be a growing demand for climate-friendly equipment, which should consequently affect exports of such equipment favourably in the long run**.

Imports will increase on balance. While imports of *bulk* F-gases will continue to fall, their economic value will go up as the replacement H(C)FOs are considerably more expensive than HFCs. Imports related to equipment will likely increase. The main drivers are an additional demand for such equipment and its supplying sectors, both of which are more significant for Options 2 and 3. According to the JRC-GEM-E3 results, the increased value of

[110] The respective prohibitions for SF_6 equipment under Options 2 and 3 apply for placing on the EU market and installation only.

imports in the 'other equipment goods' sector (comprising cooling equipment) is far more relevant than the import trends for bulk fluorinated gases, as the import share of the higher EU demand for such equipment under Options 2 and 3 is worth about four times the increased value of bulk fluorinated gas imports.

6.4. Social effects

6.4.1. Effects on employment

Employment effects, like GDP, are very small but positive in the long run depending on the ambition level of the option. By 2030, there is essentially no noticeable effect at EU level. **By 2050, all options have positive effects, which is higher for Option 2** (a gain of ca. 6800 jobs) **and 3** (gain of ca. 8500 jobs) **and in the EU South**. Most of these jobs gains are related to the equipment goods sector and related industries.

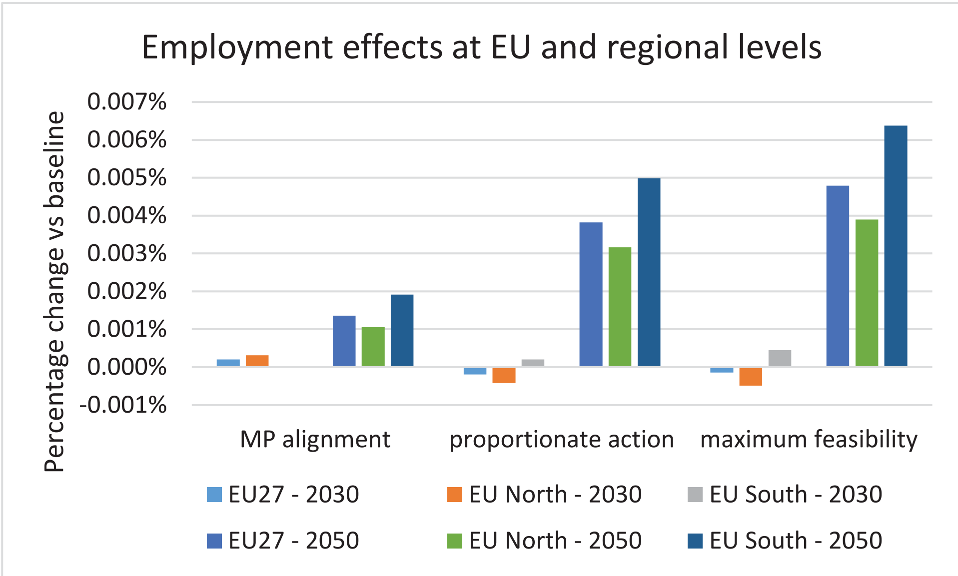

Figure 5: Employment effects

Note: EU South: Bulgaria, Croatia, Cyprus, France (25% of model results for France), Greece, Italy, Malta, Portugal, Romania, Spain; EU North: other EU27 MS, including 75% of model results for France.
"MP alignment" is Option 1, "proportionate action" is Option 2, "maximum feasibility" is Option 3
Source: *JRC-GEM-E3 modelling*

7. HOW DO THE OPTIONS COMPARE?

Table 9 provides an overview of the main impacts of the three policy options. Option 1 effectively ensures compliance with the Protocol and improves, to some degree, implementation, enforcement and monitoring. However, since it turns out that Option 1 results in higher cumulative emissions over the period until 2050 compared to the baseline (Figure 6), and even though its emission levels in the year 2050 are lower than the baseline, thus **Option 1 is *not considered to be sufficiently coherent* with the European Climate Law**. Even if Option 1 were adjusted to generate at least the same level of cumulative emission reductions as the baseline (e.g. a slightly steeper phase-down going beyond what would safeguard compliance with the Protocol), the option would be a missed opportunity considering that it would not at all contribute to the first review objective to achieve more emission savings while noting that there is a high potential to further reduce emissions as demonstrated by Options 2 and 3. In other words, taking Option 1 would mean that the necessary emission savings to achieve at least 55% reductions by 2030 and climate neutrality in 2050 would be considerably more difficult and costly to achieve at the Member State level (as they have to fulfil their GHG targets under the Effort Sharing Regulation), either by taking less effective, disparate measures in the F-gas sector and/or by taking additional, thus more costly, measures in other sectors to compensate for any EU action on F-gases that was feasible and cost-effective but not taken under this option.

Option 2 and 3 are rather similar in terms of cumulative emissions saved (difference of 27 MtCO2e) until 2050 (Figure 6), achieving reductions of 16% and more compared to the baseline in 2030 and halving them by 2050 compared to the baseline (Table 9), with Option 3 representing the savings that are technically feasible with today's technologies. While both options are effective and coherent with the objectives of the European Green Deal, **the relatively small emission gains of Option 3 compared to Option 2 come at significantly higher additional costs, which do not appear to be justified by the limited additional savings.** The annual technological adjustment costs per year in the period 2024 - 2036 are 10 times higher in Option 3 (€113 million compared to €12 million in Option 2) and the highest marginal abatement costs in the few additional sub-sectors concerned (e.g. switchgear, AC in buses, metros and trains) will be six times higher in Option 3 (cost up to of 2,111 €/t CO2e abated compared to maximally 336 €/tCO2e abated by 2050 in Option 2). Moreover, by reducing supply under the HFC quota system to the extent that no HFCs are available for a few difficult sub-sectors with very high abatement costs, the risk of HFC shortage would increase with significantly higher HFC prices and thus increase costs for all end-users that are still relying on HFCs. However, Option 3 (as well as Option 2) also delivers cost savings in the long run (and small employment benefits), in particular benefitting the sector of equipment manufacturing and its supply industry, while the impacts of Option 1 are rather neutral compared to the baseline.

Both Option 2 and 3 provide effective responses to the issues of implementation, enforcement and monitoring. However, the additional implementing measures included in Option 3 would add to the additional administrative burden and costs for stakeholders and authorities.

For these reasons it appears that **Option 2 is having the most appropriate cost-benefit balance, achieving a very substantial amount of additional emissions at a modest price tag and avoiding undue hardship for any affected sectors. It is therefore most coherent with the objectives of the Green Deal.** Furthermore, it is likely that even stricter F-gas policies can be introduced later (before 2050) at lower costs than today in light of new future technological developments.

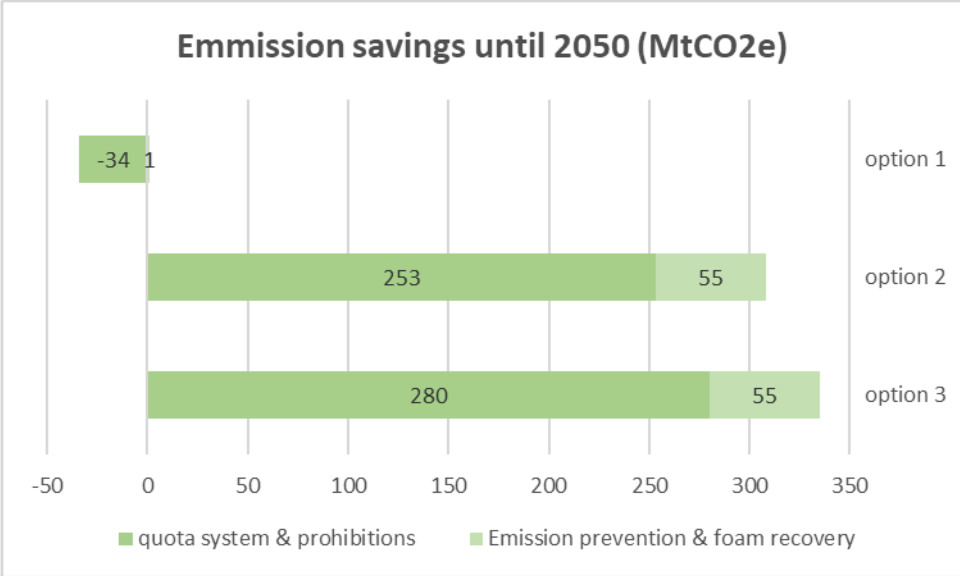

Figure 6: Total additional emission savings vs. the baseline (cumulative) achieved by the three options in the period until 2050.

N.B. Not counted are any emission savings from better implementation, enforcement, monitoring and clarification improvements.

Table 9. Comparison of the impacts of the options

	Option 1	Option 2	Option 3
Achieved Emission reductions vs. Baseline (annual)[111] **In 2030** [MtCO2e] ([change as % of baseline]) **In 2050** [MtCO2e] ([change as % of baseline])	+2 (+5%) -2 (-7%)	-7 (-16%) -13 (-48%)	-8 (-18%) -14 (-52%)
Effectiveness on Protocol compliance, implementation, enforcement and monitoring	+	++	+++
2024-36 Technological Adjustment costs [Mio €/year]	2	12	113
2024-36 Total Adjustment costs (includes distributional costs due to HFC price premium) [Mio €/year]	212	421	557
2024-36 Emission reduction costs, (all sectors, based on technological adjustment) [€/tCO2e]	N/A	-36	-23
Highest marginal abatement costs in sub-sectors (2050) [€/tCO2e]	-48	336	2,111
Net administrative costs for undertakings [MIO €/year]	-1.8	7.6 + 3 *one-off*	9.4 + 21 *one-off*
Administrative costs for authorities [person days/year]	3,200 +300 *one-off*	10,700 +2,600 *one-off*	15,300 +11,600 *one-off*
Long-term macro-economic effects (GDP, consumption, investment, innovation)	+/-	+	+
Long-term effects on employment	+*	+	+
Long-term effects on the equipment sector and its supply industry	+*	++	++

+++/++/+ positive, +/- neutral, -/--/--- negative; N/A not applicable (since no emission savings vs baseline)
*these long-term effects are very small

[111] For total cumulative emission savings see Figure 6.

8. Preferred option

The preferred Option 2 will ascertain a significant amount of additional savings while stimulating green technologies and setting the scene for a better application of the rules and monitoring. In the **2030 context, savings of cumulatively 40 MtCO2e between 2024 and 2030** will complement the efforts taken in Member States to reach their targets under the ESR in a cost-effective way. These savings will come on top of the 430 MtCO2e estimated to result from the current Regulation (baseline vs counterfactual until 2030, see A5.6.2.1.1). **By 2050 the additional savings of Option 2 will be ca. 310 MtCO2e**. This means that the residual annual **F-gas emissions in 2050 are estimated to be only 14 MtCO2e** (see Annex A11.1.3). Option 2 is thus considered to be compatible with reaching net climate neutrality by 2050, reducing the need for carbon-removal policies to compensate for emissions that cannot be avoided in 2050 to achieve net climate neutrality.

The Option will also fully align the EU with international rules and ensure better control at a moderate increase in admin burden for industry and authorities. The changes to the rules should allow for an effective enforcement, tackling the identified existing challenges, in particular those linked to illegal trade. The efficiency of the monitoring rules will be improved at the same time as extending the rules to cover new aspects that have become relevant. The necessary technological adjustment leads to cost savings overall and in many sub-sectors, due to lower energy costs for the users. However, there are some costs for end-users that are not switching to alternatives as a result of higher prices of HFCs under a reinforced quota system. Nonetheless, in the longer run some sectors of the economy will profit from the technology conversion, leading to higher output, innovation and employment. As confirmed by stakeholders the types of measures in Option 2 have EU added value. Consequently, the level of benefits achieved could not have been achieved as cost efficiently for industry and Member States by introducing 27 different additional F-gas policies in Member States. The administrative costs at the level of the individual measures retained in the preferred option are given in Table 11 and Annex A3.

Table 10. Detailed impacts of the preferred Option 2.

	Measures	Environment	Economic impacts – cost increases or savings (per year unless stated otherwise)			Macro-economic effects	Social effects
			Business	Member States	EC/EEA		
A	**RAISING AMBITION: Phase-down, Prohibitions, Emission prevention Recovery obligations**	**++(+)** From phase-down & prohibitions: Savings of 27 $MtCO_2e$ by 2030; 253 $MtCO_2e$ by 2050 In addition: At least 55 $MtCO_2e$ savings by 2050 from expanded emission prevention measures and foam collection (13 $MtCO_2e$ by 2030) Some energy savings **(-)** Scientific discussion on potential increases of persistent breakdown products of synthetic refrigerants	**(+)** Abatement: Overall €-36/tCO_2e technology change cost savings (2024-2036 average); **(-)** Conversion costs up to 336 €/tCO_2e (2050) in some sub-sectors (some mobile AC, switchgear); Costs for HFC equipment users due to rising HFC gas prices; Admin costs of €4.4 MIO plus one-off €3 MIO	**(--)** Admin: 4,850 additional days Plus increased inspection/ enforcement efforts needed	**(-)** Admin: 73 days	Long term: **(+)** GDP/output/ consumption **(+)** R&D, innovation **(++)** Equipment manufacture for domestic market and supplying industries	**(+)** Employment
B	**PROTOCOL ALIGNMENT: MDIs in phase-down, Removal of thresholds, Production quota, No non-Party trade**	Included in phase-down/prohibition effects above	**(0/-)** Cost increases on MDIs minimal (<1%) Admin costs: €0.02 MIO Possible cost for production reduction (international obligation)	**(-)** Admin: 239 days	**(-)** Admin: 48 days plus 31 days upfront		
C	**BETTER CONTROL: More certification and more extensive control provisions**	**(++)** reduced illegal trade; more competence on using alternatives	**(--)** Admin: €5,7 MIO; €125 Mio €/year distributional profits collected from quota holders by allocation price (initially)	**(--)** Admin: 6,055 days; 246 days upfront MS benefit from quota price revenue	**(--)** Admin: 2,248 days; 2,200 days upfront. Costs partly covered by quota price revenue		
D	**MONITORING: new substances, reporting & verification, encourage emission DB**	(+) Better knowledge on potential emissions; better compliance checking	(+) Admin savings of -€2.5 MIO	(+) Admin savings of -2,780 days/year	(+) Admin savings 46 days costs of 126 days upfront		
E	**CLARIFICATIONS**	(+)	(0/+)	(0/+)	(0/+)		
	Total effects	(++)	(-)	(-)	(-)	(+)	(+)

Legend: Scale applied is +++,++,+,0,-,--,--- (very high/positive to very low/negative); Corresponding colour codes are dark/medium/light green, white (neutral), light/medium/dark red

Table 11. Detailed information of the total administrative costs expected for the undertakings for each of the individual measures retained under the preferred option.

Policy Measure	Annual Cost (million €)	One-Off Cost (million €)
Objective A		
Apply requirements for prevention of emissions of fluorinated gases to some substances listed in Annex II and some new substances	-	3
Apply requirements for prevention of emissions of F-gases to manufacturing, transport, transfer and storage of bulk gases also to non-producers	4.4	-
Objective B		
Remove the limit for reporting on production, import, export and destruction of Annex I and II gases (HFCs only) *	0.02	-
Objective C		
F-gas certification programmes also to include HCFOs and F-gas free alternatives and practical training on all alternatives and add energy efficiency issues to be part of training (stationary RACHP)	5.8	
General prohibition of entry into EU territory of non-refillable F-gas containers and other illegal goods under the Regulation and extend the scope to unsaturated HFCs *	0.05	-
Add requirement for producers and importers to be registered and hold sufficient quota at the time of release for free circulation/placing on the market / physical entry into territory *	0.39	-
Add obligation for importers to have quota-exempted quantities labelled during POM/physical entry into territory and that gases must be explicitly labelled as "exempted from quota" *	0.02	-
Strengthen the obligation on destruction of HFC-23 by-production *	0.1	-
Align the establishment of the annual declaration-based quota allocation with the frequency of the quota allocation based on reference values	-1.2	-
Introduction of a registration fee and/or quota allocation price linked to CO2 equivalents *	0.5	
Labelling requirements for H(C)FOs, NF3, SO_2F_2, anesthetics; as well as MDIs *	0.01	
Objective D		
Reporting obligation for recipients of quota-exempted HFCs *	0.04	-
Reporting obligation for undertakings performing reclamation of F-gases *	0.02	-
Lower the threshold for verification of bulk HFCs placed on the market *	0.5	-
Add obligation to submit verification reports for bulk HFCs *	0.2	-
Align reporting and authorization thresholds for placing pre-charged products and equipment on the market	-0.09	-
Align reporting and verification dates between bulk and pre-charged products and equipment	Negligible	-
Relax the verification threshold for placing pre-charged products and equipment on the market	-1.7	-
Add legal basis for electronic verification process (separately for bulk and pre-charged products and equipment)	-1.5	-
Obligation to provide NIL reports for quota holders *	0.02	-
Require reporting by companies on new substances	0.02	-
Total net costs	**7.6** (12.1-4.5)	**3**

(*) required by international rules or to reduce illegal activities (total of 1.9 million €)

9. HOW WILL ACTUAL IMPACTS BE MONITORED AND EVALUATED?

Future monitoring and evaluation of the Regulation can rely on the Regulation's annual company reporting data that is collected and aggregated by the EEA each year[112]. A confidential report on F-gas related activities is drafted by the EEA for Member State representatives and DG CLIMA, which includes inter alia data on imports, exports, production, destruction, and reclamation relevant to bulk fluorinated gases and equipment containing such gases. The background study and this document relies heavily on these data for its analysis. The data reported on HFC production, feedstocks, destruction, imports and exports are presented to the Protocol's Ozone Secretariat to comply with the EU's annual reporting obligation. In addition, there is a public version in the form of a web-based F-gas indicator published and updated regularly by the EEA. The measures considered on reporting and monitoring in this document would improve this data basis further in the future.

In addition, the European Commission has been closely monitoring prices, the workings of the quota system and other market developments of the sector since 2015, which would be continued on the basis of contracts with external experts. Member States regularly update on relevant activities carried out such as (i) the collection and use of data to determine emissions, (ii) producer responsibility schemes, (iii) enforcement and other measures taken on illegal activities including penalties to the Implementation Committee established in the Regulation.

The changes to reporting scope (new substances; recipients of exempted quota; reclamation facilities) will complete the picture on relevant gases and uses. The emission reporting databased encouraged by Option 2 will improve the knowledge on emissions and thus the impact of the F-gas sector as well as better data quality reported to the UNFCCC. The streamlining of reporting and verification rules should also help in achieving better data quality more efficiently.

In addition, to benchmark the Regulation's performance the following can be used:

- Objective A: For emission savings the modelled quantities as described in this document for Option 2 vs the actual emissions as reported under Regulation (EU) No 525/2013 (EU GHG monitoring mechanism;
- Objective B: Any decision by the Implementing Committee of the Montreal Protocol regarding compliance of the EU and its member States with rules regarding HFCs;
- Objective C: Data collected on the workings of the quota mechanism (see above) as well as industry and Member States feedback;
- Objective D: EEA's feedback on the reporting process and DG CLIMA experience with compliance checking;
- Objective E: Stakeholder and Member States feedback.

A good performance of the Regulation would mean that:

[112] https://www.eea.europa.eu/publications/fluorinated-greenhouse-gases-2020

- Emissions of F-gases should fall as predicted by the modelling carried out under this assessment, i.e. in 2030 annual emissions should be 37 $MtCO_2e$.
- There should be no compliance issues with the Montreal Protocol regarding obligations on HFCs.
- Smooth implementation of the quota system and reduction of illegal trade to avoid harm in environmental, economic or reputational terms.
- The monitoring and reporting supports policy evaluation and compliance checking in a more effective but also efficient way.

An evaluation of the Regulation on the basis of these data may be envisaged for 2033.

A1 Procedural information

A1.1 Lead DG, Decide Planning/CWP references

- Lead Directorate-General (DG) of the European Commission: DG Climate Action (DG CLIMA).
- Decide Planning reference: PLAN/2021/11035 "Review of rules on fluorinated greenhouse gases".
- An evaluation of the current Regulation was carried out in parallel with the impact assessment.

A1.2 Organisation and timing

- As per the Better Regulation Guidelines, an **Interservice Group** (ISG) was set up in April 2020 to follow and steer the assessment process as well as the evaluation of the current Regulation. The ISG ensured coherence and comprehensiveness with the Commission's overall responsibilities and activities in related policy areas, such as environment, economic growth and customs.

- The ISG for this evaluation involved staff from the following Commission's departments in addition to DG Climate Action: DG ENER, DG ENV, DG GROW, DG TAXUD, DG TRADE, Legal Service, and Secretariat-General. Also invited to meetings and receiving the background information, but not attending, was DG MOVE.

- The ISG met four times (per videoconference): 14 July 2020, 1 December 2020, 17 March 2021 and 28 October 2021. In addition, there was a short update meeting on 15 July 2021. Through these meetings and several written exchanges, the ISG participated in the whole impact assessment and evaluation process leading to the finalisation of the external study and this Staff Working Document. Prior to submission to the RSB, the final document, after comments from DGs following the meeting on 28 October 2021 had been integrated, was circulated again on 9 December. SG and TAXUD had a few additional comments that were taken into account.

- The Commission signed a contract for a **support study** on the impact assessment (contract ref. 340201/2020/826738/ETU/CLIMA.A.2) on 18 March 2020. The final impact assessment report of the support study was received on 15 December.

- An **inception impact assessment** was published on 29 June 2020 on the Commission's Europa web site[113]. The feedback period was open until 7 September 2020.

- A **public consultation** ran from 15 September 2020 to 29 December 2020 (16 weeks, extended because of the pandemic). The results have been published online.[114]

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113 https://ec.europa.eu/info/law/better-regulation/have-your-say/initiatives/12479-Fluorinated-greenhouse-gases-review-of-EU-rules-2015-20-_en

114 https://ec.europa.eu/info/law/better-regulation/have-your-say/initiatives/12479-Fluorinated-greenhouse-gases-review-of-EU-rules-2015-20-/public-consultation_en

- The meeting with the **Regulatory Scrutiny Board** (RSB) took place on 19 January 2022

A1.3 Consultation of the Regulatory Scrutiny Board

The Regulatory Scrutiny Board was consulted on 19 January 2022. A request to resubmit the impact assessment was received on 21 January 2022. The document was revised and sent to the ISG and a subsequent ISG meeting was held on 4 February 2022. The other services had no comments on the revised version (present: BUDG, ENER, ENV, GROW, SG, TAXUD, TRADE; also invited: AGRI, MOVE, REGIO, SANTE, SJ). The updated document was re-submitted on 8 February 2022 on which a positive opinion with reservations was issued on 25 February 2022.

The Board's main comments received on 21 January were addressed in the following way:

(1) *The Board commented that the report is unclear about the contribution of this initiative to the Climate Target Plan and about the coherent articulation between the F-gas Regulation and the Effort Sharing Regulation (ESR) obligations.*

In response, the introduction and problem definition were substantially revised to better express the relationship of the obligations contained in the Regulation and the ESR. It is clarified that the Regulation requires a review to *inter alia* contribute to increased climate ambition, that it as such contributes to Member States efforts to achieve their own greenhouse gas reduction targets, but that it does not define as such F-gas targets at Member State level, nor does the ESR have specific targets on F-gases per Member State (rather an overall target on a basket of GHGs).

(2) *The Board commented that the report does not sufficiently explain the relationship between the objective to fully align with the existing and long-term Montreal Protocol targets against ozone layer depletion and the objective to increase additional F-gas emission reductions to further contribute to European climate targets.*

In response, the introduction and problem definition explain better the relationship between the Montreal Protocol, notably the Kigali Amendment, and the Paris Agreement. The Kigali Amendment under the Montreal Protocol is putting obligations on Parties to gradually reduce consumption and production of HFC gases in view of preventing *climate-relevant* emissions that will benefit the achievement of the goals of the Paris Agreement, given that HFC gases do not affect the ozone layer. It also explains better that the Regulation, preceding the Kigali Amendment, was originally conceived to reduce GHG emissions in the EU, with measures similar to those aimed at reducing ozone depleting emissions (given that similar sectors and stakeholders are affected), and was as such an example for global action that resulted in the later adoption of the Kigali Amendment. It is also better explained why the Regulation currently does not guarantee that the EU can comply with the new rules on HFCs under the Kigali Amendment. The F-gas Regulation today remains a tool to reduce EU climate emissions further, but is also the main instrument to ensure that the EU complies with the Protocol rules with regard to HFCs.

(3) *The Board commented that the report does not explain whether and how changes in the Effort Sharing Regulation and the Ozone Regulation affect the baseline scenario.*

In response, the introduction including the section regarding coherence with other legislation as well as the description of the baseline have been re-written to underline the relationship with the ESR and the Ozone Regulation. The changes to these two instruments will for the most part not change the baseline for F-gas emissions. As regards the ESR, the focus is here on how a strengthening of existing EU climate legislation can assist Member States in achieving their own greenhouse gas reduction target, while not setting sectoral or Member States specific F-gas targets, and doing so with F-gas measures that are recognised to promote cost efficiency at EU level. As explained, any future Member State additional action on F-gases is not considered for the baseline (as not known presently). Such action may or may not influence baseline development at EU level depending on the action chosen (e.g. prohibitions in one Member State may simply shift F-gas use and emissions elsewhere as the same amount of quota is available, while additional measures to reduce emissions during use or at end-of-life equipment could contribute to saving emissions also at EU level). The ozone and F-gas Regulations have similar measures and target similar sectors but the changes proposed in the Ozone Regulation will not impact on the use/emissions of F-gases that are not ozone depleting. Furthermore, while F-gases have replaced ODS in the past, this is no longer the case as all relevant ODS have been eliminated in the EU, so regulating the remaining uses of ODS further does not affect the F-gas baseline.

(4) *The Board commented that the report does not explain how the 'fair' level contribution figure was arrived at, which sectors it would apply to, and how it relates to abatement cost figures in other 'Fit for 55' initiatives.*

In response, the review objectives were clarified and it is underlined that the assessment of options regarding environmental ambition, and the resulting emission reductions, focusses on what the cost and benefits are related to increased abatement efforts. These costs and benefits are not limited to 2030 but are projected up to 2050. Overall it also allows to conclude if options are in-line with a trajectory that achieves climate neutrality by 2050.

(5) *Not all options appear to be realistic and compatible with the objective to achieve additional F-gas emission reductions to contribute to the climate targets in a fair and cost-efficient way.*

In response, the review objectives and the options were improved. Additional explanations were added to explain why all three options are relevant and self-standing options, supported each by a different sets of stakeholders. Furthermore, it was explained why some measures targeting a specific review objective, like the need to ensure compliance with the Montreal Protocol, see limited variation between the options. The eventual selection of the preferred option is based on the impacts assessed and the related results as included in the impact assessment. This is the purpose of the options: Examining a low-cost option that is favoured by conservative industry players, examining a medium-cost option that avoids high costs for niche applications and a high cost option that considers only technical feasibility as possible today, which is what some stakeholders such as NGOs would be asking. **In the end, a political choice can be made on what should be the right contribution to the climate goals, on the basis of emissions achievable by these 3 options, and the costs and efforts that will be needed to do so.**

The Board also had the following comments for improvement, which were addressed as described below:

(1) *The report should explain the relationship between the objective to fully align with the Montreal Protocol and the objective to achieve additional F-gas emission reductions for climate purposes.*

The text was adjusted to reflect the need to align with the Protocol which is a self-standing objective as the EU cannot afford to risk compliance with global rules, since this would entail a significant reputational damage and threaten the EU's current role as front-runner implementing best practice policies in this field. The Protocol puts limits on consumption and production of hydrofluorocarbons that result in emission reductions that count under the Paris Agreement on Climate Change. The review objective to achieve additional emission saving in the EU is related to the EU objective of achieving the 2030 and 2050 climate targets, to which this sector can make an important contribution. Any additional F-gas emission savings can contribute to Member States' efforts to reach their national targets on a basket of GHGs under the Effort Sharing Regulation. While the Protocol's rational for imposing measures on HFCs is climate protection, the two objectives are not contingent on each other. This is better explained in the introduction and the problem definition.

(2) *The report should explain to what extent the revision of the F-gases Regulation contributes to the EU climate targets. It should clarify the interaction and complementarity between this Regulation and the inclusion of targets on F-gases as part of Member States' targets under the Effort Sharing Regulation. The report should be more specific on the level of emission reductions targeted by the revision. It should clarify whether the objective to achieve further emissions reduction in a fair and cost-effective manner is a binding obligation deriving from the Climate Target Plan.*

In the new adjusted version, the contribution is given as the total amounts saved by the options (comparison of options & preferred option). Also, for scale, the introduction now refers to the F-gases constituting 5% of ESR emissions. The complementarity to ESR is further explained in the introduction. The main factor is that there is no specific F-gas target for Member States. There is also no binding target for F-gases in the Climate Target Plan. Rather, the F-gas Regulation will help Member States achieve their Effort Sharing target in a cost effective way. Measures at all levels (e.g. EU, national, regional) must be taken, as appropriate. Like other EU legislation (e.g. CO2 in cars and vans, emissions from heavy-duty vehicles), the measures in the F-gas Regulation are very effective and efficient to achieve some savings from this sector. This EU added value is established by the evaluation and shortly explained in the relevant section in the main impact assessment report. The level of emission reduction targeted is a political choice based on the balance between costs and benefits and is thus resulting from the preferred option.

(3) The report should develop the baseline and its evolution in more detail, explaining what would happen if the F-gases Regulation is not revised, taking into account the revisions of the Effort Sharing Regulation and the Ozone Regulation.

It was further clarified in the baseline section that the Ozone Regulation has no impact on the development of the baseline, as HFCs and other F-gases today do not replace any ODS uses anymore. As for the ESR, it was explained that additional actions in the field of F-gases that Member States have taken so far (e.g. fiscal policies, waste management, etc.) are part of the baseline. Future action cannot be included as we do not know if Member States will, and if so, what action they will take in this sector, or in other sectors, to reach their overall GHG targets, as Member States have flexibility to choose the additional tools needed to reach their own target. Some F-gas related actions may contribute to further emission savings at EU level, others (e.g. some prohibitions) may only help achieve Member State level targets, but not the EU target (as there is an EU-wide quota system and if a sector is pushed harder in one Member State could mean that there is quota available elsewhere, i.e. other Member States or other sectors).

(4) *The report should present a set of policy options that can tackle all the objectives. The report should bring out clearly the credible policy choices. If the revision is bound by the objective to achieve additional emission reductions in a fair and cost-efficient manner, the report should acknowledge that options 1 and 3 are not realistic or fair options and thus appear not to be compatible with that objective. The report should better justify the composition of the remaining option and why this would be the optimal set of measures.*

We acknowledge that the review objective on savings emissions could be interpreted as being a sort of compulsory target on F-gases, while there is no such target. Rather, what is needed under the current political circumstances is a contribution of this Regulation, given that action seems cost-effective and have EU added, to the overall 2030 and 2050 climate objectives. Therefore, the review objective (A) on saving emissions has been adjusted in this way. The amount of emissions that can be saved depends on technical feasibility on one hand, and willingness of paying the price and effort needed on the other hand. To give a sensible political choice on the matter, the options were constructed so that it could be assessed what a low, a medium, and a high cost/effort scenario would deliver and what it would cost. Thus there is a real political choice to be made between the options on the basis of the costs and benefits they can generate. The assessment of the options show that Option 1 does not deliver meaningful emission savings and therefore a low cost scenario is not recommended. On the other hand Option 3 only delivers slightly more than Option 2 and therefore it is not recommended to impose a high cost scenario. Furthermore, the three options correspond to preferences expressed by different stakeholders groups and it is therefore useful in the public debate to have clarity about what all three options would imply. More information on this matter is provided in the section on the policy options including how the different measures were grouped into options.

(5) When presenting the options, the report should also better explain the basis and reasoning behind selecting a level of marginal abatement costs of up to EUR 390 /

tCO2e, which sectors this applies to, and how this relates in fairness terms to abatement costs for other greenhouse gases or other sectors in the Fit for 55 package.

As further explained in the description of the options, this cut-off amount is used to distinguish between Options 2 and 3, namely to exclude sub-sectors with high abatement costs that exceed costs asked in 2050 modelling in other sectors. In effect, this eliminates the need to go to some alternatives in the areas of AC in buses, trains and metros. The relation to the Fit for 55 goals is now addressed in the introduction and the problem definition. The 2050 horizon was chosen as a benchmark because most emission reductions will happen in the longer term and not by 2030 because there is a long lag between gradually reducing the use of these gases in new equipment and the emissions saved over the life of time of that equipment.

(*6) The report should improve the overall narrative and reader friendliness, given the technical complexity of the topic. The report should describe in more detail what the underlying problem is and what the evidence for it is, including information on the problems, their scale and the sources of evidence. The report should make links between the problems and the results of the evaluation and any other relevant sources of information. The main report should present briefly the methodology and the main assumptions underpinning it, even if the details are in the annexes.*

The main part has been largely re-written with narrative and reader friendliness in mind. In particular the problem section has been improved by bringing forward evidence, scale etc. from the Annexes, in particular the evaluation, and giving the links. Short descriptions of the methodology was added in the main part, where relevant.

(7) The impact analysis should highlight the main conclusions of the analysis and explain which factors influence its main findings. It should clearly present the expected impacts on the main variables and the average marginal abatement cost for each option. It should explain what is behind the expected changes in the macroeconomic variables, why consumption increases in the long term, why investment does not increase and what are the main conclusions of the analysis on exports and imports.

The sections on comparison of options was improved by a detailed discussion of the relevant parameters that distinguish the options. A graph on emissions and a detailed table summarising the major findings of the impact analysis has been added in this section (Figure 6, Table 9). The section on economic impacts was improved by highlighting the main findings and take-aways, as well as better explaining the reasons behind, including on consumption, investment, exports and imports.

(8) The report should specify how and when implementation will be monitored and evaluated in the future. It should clearly set out what success would look like, clear monitoring arrangements and specific indicators and timescales.

Concrete evidence to be used for future benchmarking was added on all review objectives. A review date was indicated.

(9) The report should include, and better engage with, stakeholder views throughout the report. It should clearly reflect diverging stakeholder views.

This was added throughout the main part.
In addition, the whole document was improved by addressing all technical comments received from the RSB in advance of the meeting of 19 January 2022.

The Board's final comments received on 25 February were addressed in the following way:

(1) The choice of a static baseline ignores the measures that would be taken by the Member States under their Effort Sharing Regulation targets. The report does not convincingly identify the remaining gap between the Kigali Amendment and other GHG targets that justifies more ambitious emission reduction under the initiative.

What to improve:

- *The report should justify its choice of a static baseline given the wide range of other initiatives aimed at GHG reduction and Member States' action. It should justify why it considers that the Effort Sharing Regulation would be ineffective.*
- *The report should explain clearly the problem and remaining gap it seeks to address given the Kigali Amendment to the Montreal Protocol and other EU greenhouse gases reduction measures and commitments. It should demonstrate the need to go beyond F-gases reductions required by the Kigali Amendment, given that there is no gap under the EU's climate targets with the current greenhouse gases reduction measures.*

Regarding the choice of a static baseline, which does not assume further Member State action beyond what is already in place, the report explains that the assessment focuses on estimating what EU legislation can contribute to achieve further F-gas reductions and what the associated costs and benefits of EU action are. As such it allows for a political choice to enhance an existing EU policy instrument to contribute to increased EU climate ambition including beyond what an alignment with the obligations under the Montreal Protocol would deliver. Moreover, the report explains that it is impossible to foresee what F-gas measures the Member States would decide to take in the future.

The fact that some measures are proposed at EU level does not mean that the Effort Sharing Regulation is expected to be ineffective. It is rather that this impact assessment assesses what cost-efficient action could be taken at the EU level to contribute to assist Member States in achieving their Effort Sharing Regulation targets. As with all other EU legislation targeting emissions counted under the Effort Sharing Regulation, the proposed measures are not filling a gap, they are reducing the gap that Member States face when planning how they can meet their national target. If cost-effective action is not taken in the sector of F-gases, it will be more difficult and likely more costly for Member States to reach their targets in the Effort Sharing Regulation. EU action on F-gases has been identified in the evaluation, clearly supported by almost all stakeholders including the Member State competent authorities consulted, as a more cost-efficient and effective way of achieving F-gas emission reductions. This was clarified further in the problem section 2.1.1. The EU added value and the cost-efficiency of such EU action is clearly demonstrated throughout sections 3.3 and 6.2./6.3.

The report explains further that achieving compliance with the Kigali Amendment is only one of the review objectives. It is therefore a self-standing review objective to achieve additional emission reductions to do more in the EU in order to reach our targets of at least 55% net greenhouse gas reductions by 2030 and climate neutrality in 2050. Option 1 turns out to be ineffective in this regard.

(2) The report does not bring out clearly enough the trade-offs and political choice between providing emission reduction flexibility to Member States under the alignment option and more prescriptive EU level measures under the emission reduction options. The feasibility of the most ambitious option remains questionable.

What to improve:

- *The report should explain why the least ambitious option alone is not sufficient, as it would seem to comply with the EU's commitments under the Kigali Amendment. It should also justify and assess the political feasibility of maintaining the most ambitious option given the very high costs involved.*

The report explains that the option that would ensure that the EU simply complies with the Kigali amendment would not see significant further F-gas emission reductions compared to the baseline (see Figure 3). While this would ensure that the EU complies with its obligations under the Kigali amendment, this would be a lost opportunity given that further cost-effective emission reductions are possible as clearly established by this assessment. This was clarified in the discussion of the options (section 7). To give more insight into the quantitative projections in support of this finding, section 2.1.1 was further elaborated with references to greenhouse gas projections made in support of the recent updates in EU climate ambition and the reviews of other EU climate legislation under the Fit for 55 policy package.

In the light of what was stated under (1) above, a trade-off would rather be the case if we chose not to take further EU action beyond aligning with Kigali in this case, given the demonstrated EU added value and cost efficiency. The "alignment option" (option 1) was found in this assessment to fail to deliver more emissions reductions than the current Regulation. Taking this option would mean that the necessary emission savings would have to be achieved by Member States is a considerably more difficult way, either by taking less effective, disparate measures in the F-gas sector or additional action in other sectors to compensate for any EU action on F-gases not taken. This point was added to the discussion of the options (section 7).

The most ambitious option is clearly feasible in technical terms because it is based on existing, mature technologies taking safety and energy first considerations into account. But it can indeed lead to high abatement costs in a few sectors, as was demonstrated though the analysis. This is why the in the end the option was not retained, but it was a realistic and valid option to pursue given that there are alternative technologies available.

(3) The report does not explicitly set out the assumptions and data limitations underpinning the environmental and economic impacts. It also does not clearly present the administrative costs of the preferred option.

What to improve:

- *The report should give a clearer account of the methodology underpinning the assessment of impacts. It should provide a clearer presentation of the overall costs and benefits of the options and compare them in terms of effectiveness, efficiency and coherence. It should clearly present the administrative costs for all elements of the preferred option and explain the basis for the calculations. It should also better present the main assumptions and limitations of the AnaFgas and GEM-E3 models used in assessing the impacts.*

  - The report should clarify the differences between the previous modelling results (EU long-term strategy for a climate-neutral economy) and the current estimates.

  - The report should more explicitly explain what success would look like as regards specific objectives on implementation, monitoring and coherence. It should specify whether the review in 2033 will be an evaluation.

The assumptions and limitations of the models are now also referred to in the main text in the beginning of section 6. Furthermore, text was added on the data collection process and analysis on administrative burden in 6.2.2. The comparison of options was reinforced in section 7. The admin burden linked to each individual measure (where relevant) of the preferred options was added as Table 11.

Additional text was added to show what success would look like as regards the specific objectives in section 9. An evaluation is envisaged for 2033.

A1.4 Evidence, sources and quality

This impact assessment draws on a support study carried out by an external consultant including an extensive consultation of the relevant stakeholders and experts as well as on the internal expertise of the Commission.

The evidence used for the evaluation comes from several data sources, in particular the annual reports on fluorinated greenhouse gases by the European Environment Agency and the consultation with stakeholders, including Member States authorities and undertakings (see Annex A2). The Commission has also previously published a number of technical reports on (i) barriers posed by safety standards, (ii) availability of training of technical personnel, (iii) the quota allocation method, (iv) the availability of HFCs on the EU market as well as alternatives available in (v) split air conditioning systems, (vi) switchgear and (vii) commercial refrigeration systems, which all have provided useful data for this work (see also footnote 128). The support study is the source for data in cases where no particular external source is mentioned. Two models were used to support the analysis: AnaFgas, which is a detailed bottom-up stock model of the relevant sectors and was used for modelling of demand and emissions, as well as costs of switching to alternatives. The JRC's GEM-E3 model was used to derive macro-economic effects and other relevant economic parameters. More information is provided in the Annex on methodology below (Annex A4).

A2 Synopsis report of stakeholder consultations

A2.1 Introduction

This report provides a synopsis of the stakeholder consultation activities carried out for the evaluation of the Regulation as well as the development of policy options and their impacts for its review.

A2.2 Objectives and stakeholder groups covered

The key objectives of the consultation process were:

- To ensure that all relevant stakeholders were identified and provided with an opportunity to engage with the consultation process;
- To provide the opportunity for stakeholders to inform the evaluation, in particular, offering an opportunity to identify elements of the Regulation which could be improved;
- To gather stakeholder opinion on potential policy options, including where possible collecting data and qualitative evidence regarding their impacts.

The consultation strategy[115] developed contained the following main consultation activities:

- Online public consultation (OPC);
- Targeted stakeholder engagement through interviews;
- Targeted stakeholder engagement through a stakeholder workshop.

The consultation activity is complemented by consultations on the Roadmap and broader stakeholder engagement (including in the Consultation Forum set up by the Regulation) which are also directly relevant for this review. Notably, extensive consultations were made as preparation to the following Commission reports on:

- the availability of hydrofluorocarbons on the Union market (2020)[116];
- the availability of refrigerants for new split air conditioning systems that can replace fluorinated greenhouse gases or result in a lower climate impact (2020)[117];
- the availability of alternatives to fluorinated greenhouse gases in switchgear and related equipment, including medium-voltage secondary switchgear (2020)[118];
- the 2022 requirement to avoid highly global warming hydrofluorocarbons in some commercial refrigeration systems (2017)[119];
- the quota allocation method in accordance with Regulation (EU) No 517/2014 (2017)[120];

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

116 https://ec.europa.eu/clima/sites/default/files/f-gas/docs/20201216_c_2020_8842_en.pdf

117 https://ec.europa.eu/clima/sites/default/files/news/docs/c_2020_6637_en.pdf

118 https://ec.europa.eu/clima/sites/default/files/news/docs/c_2020_6635_en.pdf

119 https://ec.europa.eu/clima/sites/default/files/f-gas/legislation/docs/c_2017_5230_en.pdf

- barriers posed by codes, standards and legislation to using climate-friendly technologies[121];
- the availability of training for service personnel regarding the safe handling of climate-friendly technologies[122].

In addition, the Commission has been assisted by an external consortium of experts that have been in close exchange with relevant industry stakeholders and experts for many years.

Table 11 shows the stakeholder groups mapped to each consultation activity covered by this report.

Table 12. Coverage of different stakeholder groups under each consultation activity

Stakeholder type	Consultation Strategy Activity		
	OPC/Roadmap	Interviews	Workshop
EU Institutions (DG CLIMA and EEA)		X	X
Citizens	X		
EU Member States' competent authorities and customs authorities	X	X	X
EU Businesses and trade associations	X	X	X
Consumers and consumer organisations	X	X	X
Non-governmental organisations	X	X	X
International organisations	X	X	X

A2.3 Consultation activities and other information sources

The consultations gathered views on the achievements of the Regulation to date with respect to its relevance, effectiveness, efficiency, EU added value and internal and external coherence. In addition, feedback was also gathered on potential measures and their likely environmental, economic and social impacts, taking into account the European Green Deal and its more ambitious targets and the obligations on hydrofluorocarbons under the Montreal Protocol.

The responses related to the main objectives for the reviews and (potential changes to) the main measures in the Regulation that include: a quota system for hydrofluorocarbons (HFC phase-down) and prohibitions to market or use F-gases in certain equipment, taking into account exemptions from these provisions; containment/leakage prevention measures for F-gas equipment (e.g. in form of mandatory leakage checks) and training and certification of technicians; as well as well as labelling of and reporting on gases and F-gas equipment.

The ***consultation on the review roadmap*** from 29 June 2020 to 07 September 2020 and the ***online public consultation (OPC)*** from 15 September 2020 to 29 December 2020 provided an opportunity for all stakeholders to contribute views on the Regulation, irrespective of the

120 https://ec.europa.eu/clima/sites/default/files/f-gas/legislation/docs/com_2017_377_en.pdf
121 http://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:52016DC0749
122 http://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:52016DC0748

respondents' level of familiarity with the Regulation. These activities received 76 and 241 responses respectively. For the OPC, respondents comprised: individual company/business organisations (124, 51.5%), business associations (44, 18.3%), EU citizens (28, 11.6%), non-governmental organisations (NGOs) (14, 5.8%), public authorities (8, 3.3%), academic/research institutions (6, 2.5%), consumer organisations (3, 1.2%), one respondent identifying as a trade union (0.4%) and several who identified as 'other' (13, 5.4%). Respondents to the OPC also had the opportunity to upload supporting documents. A summary of the OPC results is available on the 'Have your say' website[123].

As a part of the ***targeted consultation***, 34 semi-structured interviews were undertaken. The targeted interviews covered a broad range of stakeholders including: 16 competent authorities, two customs authorities, one Non-Governmental Organisation (NGO), 16 EU business associations and organisations, and several individual companies. In addition, two competent authorities and two customs authorities provided written response to the interview questions (rather than participating in a telephone interview). The selection of interviewees in the case of competent authorities and customs authorities was based on their interest and availability. In the case of industry organisations, interviewees were selected to achieve a comprehensive sector coverage and depending on the open issues and evidence gaps, which needed to be discussed. The interviews followed a pre-set *proforma*, whilst also keeping in mind the respective expertise of the stakeholders interviewed and the availability of data on present and future administrative, implementation and enforcement costs. Stakeholders were given the opportunity to check and complement the interview notes and submit additional information after the interview.

A full-day, online stakeholder ***workshop*** was held on 6 May 2021. At the workshop preliminary results of the evaluation were presented, alongside the draft set of options being considered in the impact assessment and preliminary analysis of the options. The workshop was attended by 355 participants. Participants were given two and a half weeks to provide additional feedback (to 24 May 2021). 69 participants provided written feedback after the workshop. The agenda[124], presentations[125] and briefing material[126] for the workshop are available online.

A summary of the results of the consultations related to the functioning of the existing Regulation is in Section 4 and views on the future Regulation are provided in Section 5.

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

124 https://ec.europa.eu/clima/sites/default/files/f-gas/legislation/docs/20210506_agenda_en.pdf

125 https://ec.europa.eu/clima/sites/default/files/events/docs/20210506_presentation_en.pdf

126 https://ec.europa.eu/clima/sites/default/files/f-gas/legislation/docs/20210506_briefing_en.pdf

A2.4 Results of consultation activities – Evaluation

A2.4.1 Effectiveness

Achievement of 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

There is consensus among stakeholders that the Regulation has had a positive impact with respect to discouraging the use of F-gases with high-GWP in the EU, and promoting the use of alternative substances, positioning the EU as a frontrunner in this area. Industry and NGO stakeholders also described that the energy-efficiency of home appliances and RACHP equipment has improved over the implementation period leading to energy savings. Energy efficiency where alternatives are used is considered to be at least equivalent (or often better) than the best HFC systems. The use of alternative refrigerants was generally not considered to have resulted in a trade-off in terms of lower energy efficiency, and synergies with linked legislation (e.g. Eco-design) have been broadly exploited.

With regard to the individual measures in the Regulation, stakeholders agreed that the HFC phase-down has been an effective measure, especially in combination with prohibitions. Some stakeholders suggested that the HFC phase-down has been the most important measure of the Regulation as it provides flexibility and clarity, whilst also driving efficient change. Stakeholders also broadly agreed that the prohibitions to market or use F-gases has been effective. Stakeholders agreed 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.

There are mixed opinions amongst stakeholders with respect to reporting and verification. Industry, business associations and citizens tend to consider that reporting has been generally effective (although there is variation within these groups). The overall opinion is more neutral amongst NGOs, whereas a slight majority of competent authorities consider that these obligations have not been effective in supporting the Regulation in achieving its objectives and noted that reporting alone is insufficient, and that more and better verification is needed.

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

Stakeholders noted that containment has clearly improved and leakage rates have reduced drastically over the period of implementation. Data on trends of leakage rates was provided by only one competent authority: Poland (this was complemented in the evaluation by data gathered from the literature for DE, SK and FR). The data for Poland demonstrated that the annual average leakage of F-gases from RACHP equipment (that is subject to mandatory leakage checks) dropped for every equipment category from 12.6% to 3.12% in the period 2016 to 2019.

The evidence provided by industry stakeholders was helpful in elaborating the actions that industry has taken (in particular in the switchgear industry in some countries) in response to the Regulation to demonstrate the reduction in leakage rates achieved. Examples include: use of more compact equipment, use of state-of-the-art sealed gas-compartments, with end-of-life handling of the equipment undertaken professionally by specialized industry partners.

Stakeholders also provided feedback on areas for improvement. It was highlighted that the collection of data on refrigerant containment and F-gas emissions was not comprehensive and that compliance with containment/leakage obligations could be further promoted, e.g. through electronic databases recording the data related to leakage checks. Although stakeholders agreed that the Regulation has had a positive effect overall with respect to recovery and reclamation, stakeholders highlighted that there is little data available on reclamation due to no self-standing reporting obligation for recycling and reclamation undertakings, and a better understanding and monitoring would help promote these activities.

Regarding effectiveness of training and certification, stakeholders were able to provide data on numbers of certified persons in each MS and the training activities undertaken by different industry representatives (although precise data are missing for certain sectors). The positive performances of the training and certification measures were reaffirmed by stakeholders who strongly agreed that these measures had been effective regarding their objectives. However, some stakeholders noted that a lack of technicians who can handle climate-friendly alternatives was a barrier to a more widespread use in some Member States.

Stakeholders reported a range of additional actions in Member States that were going beyond the requirements of the Regulation in particular with respect to producer responsibility schemes, which have been implemented in some, but not all Member States. Where these have been implemented, they are considered to be working well by most stakeholder groups. However, NGOs are more sceptical as to whether these schemes have been effective or not. This comment may however relate to the fact that some Member States did not have any scheme at all. With respect to emissions reporting systems, stakeholders provided evidence on the existence of such systems through interviews: Only few of the interviewed Member States currently have such a reporting system in place (BG, EE, FI, DE, IT, MT, PO, PT). Overall, stakeholders were generally neutral on whether these had or had not been effective. Competent authorities were marginally more inclined to suggest these had been effective, but NGOs and industry stakeholders were slightly inclined to believe they had not.

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

There was an overwhelming agreement amongst all respondents that the Regulation has been effective in achieving this objective. In particular, all competent authorities emphasised this positive role. The fact that the EU had an HFC phase-down in place was considered to have greatly contributed to the development of the global HFC phase-down proposal: it helped the EU Member States to adopt a common position and it served as a convincing example of best practice for non-EU countries and encouraged others to adopt binding obligations at the global level. In addition, the fact that key provisions of the Kigali Amendment were already reflected in the Regulation subsequently helped EU industry to better understand the new requirements of the international regulation.

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

Overall, stakeholders believed that the Regulation has had a positive impact with respect to stimulating innovation and developing green technologies. It was noted the Regulation has provided certainty for companies, has stimulated the development of green and more energy-efficient technologies and has improved market opportunities for lower or zero GWP alternatives whose prices have decreased over time. Indeed, some industry and NGO stakeholders suggested that EU manufacturers are now world-leaders in the development and manufacture of several technologies (e.g. use of natural refrigerants). Stakeholders highlighted that low numbers of personnel trained on alternatives remains a major challenge for the introduction of alternatives to F-gases (noted by all stakeholder types, but this was stressed in particular by service personnel and NGOs). Furthermore, stakeholders (all-types, but particularly NGOs) reaffirmed that unjustified barriers in safety standards and codes still present a very serious challenge to the implementation of the Regulation.

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

In general, stakeholders (all-types) considered illegal imports were the most serious challenge to implementation. An industry stakeholder noted that illegal imports may have been one of the drivers behind the reductions in HFC prices observed following the peak in 2018. Stakeholders, notably industry and NGOs, noted that enforcement was hampered by: a lack of coherence between the Regulation and customs rules; transit procedures being vulnerable to misuse; diverse and too low penalties in Member States); online sales subject to insufficient checks by authorities; and insufficient market surveillance activities.

The fact that the number of HFC importers has increased by 20 times and that some entities appear to be getting several quota shares from the reserve (as some new entrants may have close links to existing quota holders) was seen as a significant issue by NGOs and Member States, as it makes effective enforcement more difficult. Industry views were more mixed on this issue. Quota holders (gas producers and importers) found it to be a serious issue, whereas other industry stakeholders were less concerned.

Some stakeholders also highlighted in the early years of the quota system that stockpiling of gases and price fluctuations (‘low’ prices for two years followed by a subsequent sharp rise in prices to very high levels, before prices then fell again in 2018) had been an issue.

Some stakeholders, in particular NGOs, suggested focusing on natural alternatives to F-gases and avoiding promotion of synthetic alternatives to F-gases because the latter are being analysed together with a large group of chemicals (including F-gases) under REACH for their potentially harmful effects on the environment. On the other hand, several industry stakeholders recalled that the analysis was not yet concluded and that they had invested very large amounts of money in research, innovation and production capacity and that it would be premature to exclude the use of these climate friendly substances. Instead, as a precautionary measure, more could be done to prevent emissions of such substances.

A2.4.2 Efficiency

As noted above, stakeholders believe that the Regulation has achieved substantial environmental benefits through reducing the use of F-gases and increasing the uptake of alternatives. Stakeholders also highlighted wider benefits of the Regulation such as energy efficiency gains (see above).

Although stakeholders did not present much detail regarding the overall costs of compliance, they did comment on how these had been distributed across different stakeholder types and supply chains. Industry stakeholders explained that costs had not fallen proportionately across industry sectors nor company size, and that this variance had predominantly been driven by the price increases observed over the period. Indeed, some industry stakeholders offered a mixed opinion as to whether the Regulation had created a level playing field or not, pointing out that the costs were borne by equipment importers/manufacturers (need to acquire quota authorisations or pay higher gas prices) and the equipment end-users, while others profited from the quota system, in particular the bulk gas producers and importers as well as service companies.

Stakeholders also offered insights to the relative costs imposed by different measures. Respondents suggested: 'Restrictions on use and equipment' and 'HFC quota system', which are the most effective measures in reducing emissions, had presented the highest costs for business, while training and certification also incurred high or very high costs, but similarly was considered useful on balance (see above under leakage reductions). Labelling rules were perceived as the lowest cost measure. Stakeholders did not signal that the costs outweighed the benefits for any of the individual measures.

Stakeholders provided some information on estimating administrative costs associated with the Regulation (although often in qualitative terms). A total of 13 industry stakeholders provided some level of information on the working days required to ensure compliance with the Regulation. In total 12 competent authorities provided information on administrative burdens, with three noting upfront costs.

Stakeholders also highlighted wider potential effects. One industry representative noted the Regulation could have increased the volume of waste as a consequence of incentives that resulted in early replacement of equipment.

Overall, stakeholders generally reported that the Regulation was cost-effective. Stakeholders added that the Regulation has had a neutral impact on competitiveness, although some industry stakeholders noted a slightly negative impact on exports to third countries due to higher EU HFC prices affecting the price of exported equipment.

A2.4.3 Relevance

Stakeholders were asked to consider the ambition level of the Regulation in light of the new EU climate targets in the European Green Deal and the inclusion of obligations on hydrofluorocarbons under the Montreal Protocol. Most Member States authorities, all NGOs and some business associations signalled that more ambition would be required, whereas other industry stakeholders found that the current level up until 2030 was sufficient.

Furthermore, the majority of industry and NGO stakeholders signalled that adaptations are needed to ensure compliance with the Montreal Protocol, in particular post 2030.

Although many stakeholders believe that the current Regulation covers all relevant sectors using F-gases and substances (in particular amongst industry), others do not believe this is the case (in particular NGOs and competent authorities) and they identified substances and applications that are not currently covered by the Regulation nor by specific measures. For example there are no measures incentivising climate friendly propellants in Medical Dose Inhalers (MDIs) although pharmaceutical companies are already exploring such solutions. NGOs highlighted the need for stricter requirements for certain sectors currently exempted, such as medical applications, military applications, transport and SF_6 use in switchgear. Other examples of proposals included requirements beyond reporting for gases listed in Annex II of the Regulation (e.g. HFOs, SO_2F_2), for instance; expanding obligations related to reclamation, certification and training to such gases.

A2.4.4 Coherence

Stakeholders believed there is a need for stronger coherence with customs activities. The lack of which was viewed by industry, in particular, as a key facilitator of illegal imports. Stakeholders proposed a range of options to tackle illegal trade, including: a clearer link between the Regulation and the Union Customs Code Regulation (EU) No 952/2013, more harmonised and dissuasive penalties, tackling online trade and enforcement by local authorities as well as improved market surveillance activities.

Many industry stakeholders also affirmed the persistence of the barriers posed by national safety standards to the uptake of alternatives. That said, stakeholders did note that progress has been made recently, citing the examples of Italy and Spain who, since 2015 have been working on amending their national building codes and fire prevention rules in buildings to allow installation of some flammable refrigerants (especially A2L) in certain types of public buildings. However, the situation in France was reported to still pose a barrier to the use of any flammable F-gas alternatives (e.g. targeted interview with industry). The current national laws covering public buildings (CH35) and covering high-rise buildings (GH37) prevent the installation of equipment with A2L and A3 refrigerants.

There are synergies regarding energy efficiency and the Eco-design Directive, in particular through Article 11(2) of the Regulation that includes an exemption from the placing on the market bans (set out in Annex III) if the equipment with HFCs would achieve lower overall lifecycle GHG emissions. Despite this alignment, there is a perception among a number of stakeholders that there is a lack of coherence with the Eco-design Directive. Some highlighted that there are examples where there is trade-off relationship between reducing the level of GWP and energy efficiency, e.g. in the category of R410A alternatives. However, when prompted, these stakeholders struggled to find good examples of applications of where such trade-offs actually occurred.

One industry stakeholder highlighted that, whilst the Regulation pushed to reduce the HFC charge size of heat pumps, the Eco-design 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, which disadvantages the use of some natural alternatives. Similar concerns have been raised in the F-gas Consultation Forum by industry players with hydrocarbon technologies in the past. Eco-design requirements continue to be refined as technologies develop. In this way, Eco-design requirements have an impact on the charge amount needed, with higher efficiencies typically needing more refrigerant. Since hydrocarbon 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 in standards are addressed.

Although not directly conflicting, it appears that the complexities of the interaction of the Regulation with waste legislation have created uncertainty for market players. This is particularly the case around the classification of what is waste: e.g. should an F-gas recovered from old equipment be treated as waste? This uncertainty has resulted in cases of sub-optimal outcomes highlighted by industry and competent authorities. This presents a case where further consistency or guidance could be useful. Legislation around the transboundary shipments of waste is viewed by some competent authorities and industry stakeholders (but not all – some industry stakeholders disagreed) to present a barrier to reclamation.

The general perception amongst stakeholders is that coherence with REACH is high, but that there are a number of issues that warrant further consideration. REACH registration for importers needs to be better enforced and current lack of enforcement creates a disadvantage for EU-based F-gas businesses. Several industry stakeholders pointed out that there is currently a REACH PFAS[127] restriction proposal being prepared by some EU Member States that could potentially lead to a number of synthetic, low GWP alternatives being prohibited (with potential exemptions). On the same issue, other stakeholders, especially NGOs, felt that the Regulation and REACH has failed so far to systematically identify and manage the potential harmful effects of some F-gas alternatives.

Concerning internal coherence overall, stakeholders generally agreed that the Regulation is clear and consistent. That said, several minor areas were identified for further consideration and adaptation, including: the clarification of some definitions as well as making new definitions, in addition to a number of clarifications in individual provisions.

A2.4.5 EU-added value

Stakeholders of all types generally agree that the Regulation has delivered EU value-added, however opinions are mixed between stakeholders as regards the value provided. The greatest value added provided by the Regulation perceived amongst stakeholders is that it has achieved a higher level of ambition than what would have occurred at individual Member State level. Competent authorities consistently stated that the EU approach of the Regulation has been clearly advantageous compared to action at Member State level. One competent authority stakeholder noted specifically that common elements such as definitions, labelling, etc. would be complicated to agree at national level. Another competent authority also stressed the low administrative burden at Member State level, as the F-gas Portal is managed

[127] Poly- and perfluorinated alkyl substances

exclusively by the Commission. The EU-wide quota system also ensures a fair and equal quota distribution between applicants. Furthermore, common legislation has also enhanced the market for new alternatives. NGOs and competent authorities also believe that the Regulation has provided a level playing field across the EU, whereas the sentiment among industry players was more mixed.

A2.4.6 Impact of COVID-19

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 had had a negative impact. It was signalled that the majority of sectors may have been negatively affected. Closer inspection revealed that this perception also varied by sector, indicating that some sectors had been affected more negatively than others. Those most frequently noted by stakeholders as being negatively affected were: the mobile AC sector, transport refrigeration, fire protection and electronics manufacture. In addition, servicing and maintenance as well as leak checks at installed equipment and installation of new air conditioning systems in hotels and offices were also negatively impacted by the pandemic. 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, business has increased during the pandemic (food production and retail sector, cold storage sectors – including for cooling of vaccines, and increased demand for air circulation in public and commercial buildings) and/or remained consistent (use in the medical sector). From these responses, it is unclear what the impact on use and emissions of F-gases (and hence on the effectiveness of the Regulation) has been.

Business associations also elaborated on the type of impacts the COVID-19 pandemic has placed on the EU F-gas supply and equipment 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, limitations in access for service technicians, and delayed compliance testing of products in test labs due to limited capacities and unavailable prototypes. Again although the overall effect on the impact of the Regulation is difficult to deduce, certainly the curtailment of R&D and slow-down in training run contrary to the objective of the Regulation.

A2.5 Results of consultation activities - Impact Assessment

A2.5.1 Objectives for the amended F-Gas Regulation

Stakeholders generally agreed with all three review objectives specified in the Inception Impact Assessment[128]: to ensure EU long-term compliance with the Montreal Protocol; raise ambition in light of the Green Deal and technological progress; and improve implementation and enforcement including monitoring, with the latter objective gaining the most support. Given that the use of F-gases in new equipment and applications locks away or 'embeds' emissions for the future (when the lifetime of that equipment or application comes to an end), NGOs stressed the importance to act now.

Furthermore, the majority of stakeholders reaffirmed that the objectives of the F-gas Regulation would ***not*** be best achieved by action at Member State level (rather than EU-level). That said, the response was mixed, with industry stakeholders in particular less unanimous in their response that EU-level legislation would deliver value added.

A2.5.2 Measures proposed for the amended F-Gas Regulation

Objective A: Raising ambition in line with the EU Green Deal

The responses on HFC phase-down and prohibitions are strongly linked to the stakeholder type and the sector concerned. However, NGOs and all industry expressed that there is a need to take into account differences and specific limitations of the different types of equipment.

While many industry and businesses stakeholders commonly working with F-gases in the RACHP sector did not want to raise the ambition level of the current F-gas Regulation further, manufacturers of equipment using alternative refrigerants and NGOs strongly supported higher ambition. It was confirmed that a switch to low-GWP alternative refrigerants is ongoing and one industry stakeholder highlighted the important role that the HFC phase-down had played, given it provides flexibility and clarity whilst also driving efficient change. One NGO stakeholder highlighted that the phase-down alone would not be sufficiently effective, and further bans would be needed to provide stronger signals to market players.

It was also pointed out that new solutions need to be fully in line with the Eco-design and energy labelling rules and studies. Furthermore, GWP limitations should not result in the marketing of less efficient products and that differences related to the same category of equipment, e.g. different types of heat pumps, would have to be taken into account. An association of manufacturers of natural refrigerant alternatives underlined that the highest potential for replacing highly warming gases was in the sector of **stationary AC**. Smaller AC systems are already being produced with carbon dioxide [R744] and propane [R290], and larger air conditioning systems can rely on water [R718] chillers. Alternatives, notably R290, are also well established in the case of factory-sealed **small hermetic appliances** (e.g. ice

[128] https://ec.europa.eu/info/law/better-regulation/have-your-say/initiatives/12479-Fluorinated-greenhouse-gases-review-of-EU-rules-2015-20-_en

cream makers, heat pump tumble driers, washer driers, double-duct air conditioning units). As for **refrigeration equipment below the charge of 40 tCO_2e,** a major industry association confirmed that HFC alternatives are widely used so that no exemption would need to be maintained for this range of equipment. One NGO stakeholder highlighted that more emphasis is needed on transport refrigeration given that this is a growing sector and that leakage rates are high.

Concerning **fire protection equipment,** it was highlighted that alternatives such as fluorinated ketones (FK 5-1-12) and inert gases (e.g. CO_2, nitrogen) are commonly used throughout the EU.

For **MDIs**, industry stakeholders such as gas producers and some MDI manufacturers pointed out that lower-GWP alternatives are being developed and will be introduced to the market from 2025 onwards. Other manufacturers and patient organisations pointed to the fact that sufficient time is needed to introduce the alternatives, also due to the need of following the regulatory processes, and that the interest of the patient should be kept in mind.

As for **inhalation anaesthetics**, medical experts confirmed that the emissive use of certain high-GWP gases could be avoided by increased use of lower-GWP options and/or special recovery technology which, however, is not yet widely introduced. Also, the emissive use of **SO_2F_2** as a fumigation agent could be avoided by alternative methods and/or containment measures.

With respect to **electrical switchgear,** industry stakeholders highlighted that their significant investments in SF_6 alternatives had been fruitful. However a clear regulatory framework would be needed to market these solutions, promote continued R&D and maintain EU technological leadership in this area. Switchgear users such as network operators highlighted that the key factor would be to allow sufficient time to ensure a smooth transition and to not disrupt ongoing processes. This was underlined by a consensual scenario developed by German switchgear stakeholders[129].

Among competent authorities, mixed opinions were found: Most supported the notion of raising ambition in line with the EU Green Deal, while certain concerns were raised that further raising of ambition of the HFC phase-down could lead to adverse effects, such as stimulating illegal trade and smuggling.

Objective B: Seeking alignment with the Montreal Protocol

Most competent authorities stated that the Regulation needs to be aligned with the Montreal Protocol after 2030 to ensure future coherence and compliance. However, one competent authority saw no need for further alignment as additional restrictions on industry should be avoided. Of those competent authorities that generally highlighted the need for greater

[129] VDE, FNN, Verband der Industriellen Energie- und Kraftwirtschaft, ZVEI 2020: Scenario for reducing SF6 operating emissions from electrical equipment through the use of alternative insulating gases, March 2020. https://www.zvei.org/fileadmin/user_upload/Presse_und_Medien/Publikationen/2020/April/SF_6_Reduktion/Szenario-zur-Reduktion-von-SF6-Betriebsemissionen-final-eng.pdf

alignment, two went further to emphasize that alignment of exemptions and thresholds would also be required and expected at international level (e.g. threshold for HFC POM), as the Montreal Protocol is above the Regulation in the hierarchy of legislation. A third competent authority stated that the general exemptions for military equipment, semiconductors and MDIs (Article 15 (2)(d)-(f)) should be removed, but exemptions for specific uses should be maintained if no alternatives are available (e.g. medical sector, military sector, possibly switchgear), as it has been done for critical uses of halons under the Ozone Regulation).

One industry association was concerned that the removal of phase-down exemptions would result in more acute shortages of HFCs for the industries already covered by the phase-down. Also, registration procedures would become more complex due to the increased number of actors that use smaller quantities. Reducing the scope of the exemptions rather than completely removing them may be an alternative option for bulk gases.

On the potential removal of the MDI exemption, one industry association representing MDI manufactures pointed out that it could lead to shortages and thus supply disruptions of MDIs, as companies have little flexibility in choosing their suppliers. With the first lower GWP MDIs expected to enter the market in 2025, the current exemption should remain in place for at least another five years.

On the possible removal of the exemption for semiconductor manufacturing, one industry association of semiconductor manufacturers noted that the financial impact would depend upon the extent to which the price of HFCs would increase. This in turn would depend on the extent to which additional quantities of HFCs would be included under the phase-down to take into account future demand for HFCs for MDIs. A significant increase in the price of inputs to the semiconductor manufacturing process will be detrimental to the overall competitiveness of the EU industry.

As regards the possible removal of the phase-down exemption for placing on the market below 100 tonnes of CO_2 equivalents, ten competent authorities confirmed that this minimum threshold may have been exploited for illegal activities. Although it was introduced primarily to reduce the administrative burden especially for private individuals, some competent authorities stated that this threshold should clearly be abolished to avoid illegal activities in the future and to ensure full compliance with the Montreal Protocol.

On the need to include a separate HFC production phase-down to mirror the separate production phase-down under the Montreal Protocol, one competent authority explicitly supported its inclusion to ensure compliance with the Protocol. According to the feedback from an industry stakeholder (gas producer), it is essential that any HFC production phase-down replicates the timetable of the Kigali Amendment. Implementing faster phase-down schedules could potentially prevent the manufacture of new lower GWP alternatives within the EU and create an economic disadvantage for EU companies.

Objective C: Improving implementation and enforcement

Across all consultation activities, stakeholders showed a high level of support for additional training and certification of technicians on F-gas alternatives, mirroring opinions expressed through the questions related to the evaluation that this is a key barrier to the uptake of alternatives. The extension of the current training and certification programmes to low GWP alternatives was considered useful by all competent authorities. One competent authority stated that it would be rather beneficial to have all information and requirements on F-gases and their alternatives in one single piece of legislation, otherwise authorities and companies might lose track of the different requirements. That said, some stakeholders also highlighted some concerns with this measure. While the general consensus was that an extension of the current minimum requirements of the existing certification scheme to alternatives could be useful, one competent authority raised concerns that such requirements might go beyond the scope of the Regulation. Another competent authority stated that this requirement could lead to an increase in training costs that were considered to be very high already (especially for SMEs), and that there is a wide range of different alternatives which would be difficult to cover.

Stakeholders also showed high support for various measures aimed at tackling illegal trade, reflecting that they consider this a key challenge to the Regulation. However, different measures received different levels of support. Stakeholders expressed greatest support for: strengthening the role of customs and facilitate the link with the EU Single Window Environment for Customs; to strengthen obligations of economic operators to prevent illegal trade; and setting minimum requirements for penalties at Member State level. An industry stakeholder and an NGO also specifically asked whether revisions to the T1 transit custom procedure were being considered. Although overall positive, support for measures limiting the market to legitimate participants and more comprehensive monitoring was less vocal. As for obligations on economic operators, some competent authorities pointed out that the Regulation should not only focus on the placing on the market (i.e. making available for the first time), but should also cover subsequent sales along the supply chain, while referring to the approach used in the Ozone Regulation.

Several industry stakeholders stressed the importance that any changes to the Regulation should be made coherently with wider EU legislation. In particular, industry stakeholders noted that some applications (e.g. heat pumps in households and industry) using F-gases will be critical for meeting broader climate change targets and that energy consumption from such appliances is the main source of GHG emissions not F-gases.

As for evidence on destruction of HFC-23 by-production, one NGO noted that Article 7(2) could be operationalised based on a technical advice paper prepared by Öko-Recherche on behalf of the EU Commission. It was considered that this paper already contained a clear approach on traceability of evidence, which could then be strengthened by third-party verification and a reporting obligation. In addition, reference was made to the EU Renewable Energy Directive II and EU Timber Regulation, which provide for a product certification scheme with rather low administrative burden, which could also be considered for application to the HFC-23 by-production issue. According to one industry association (representing gas manufacturers), a template for a declaration of conformity could be useful. However, third-party verification would be difficult and could be disproportionate, especially for buyers of small quantities.

Objective D: Monitoring

Mixed opinions were found among competent authorities regarding an extension of the labelling requirements to Annex II gases. While eight competent authorities generally supported the measure, two competent authorities questioned the purpose of this measure, stating that the majority of F-gases were already covered by Annex I of the Regulation. According to one customs authority, a template for labelling of bulk gases and pre-charged products and equipment would add value as there is significant non-compliance.

The role of further data collection, monitoring and reporting for better understanding of environmental impacts was underlined as regards production, containment, recovery, recycling, reclamation and destruction of F-gases and end-of-life treatment of equipment, as well as in view of alternatives to conventional F-gases, which might also feature high GWP values and are being introduced to the EU market in various applications (e.g. electrical switchgear).

An auditing company suggested the introduction of an electronic verification process of the annual reports to facilitate checking compliance with the verification obligation and thereby reducing costs. On the company side, stakeholders had some doubts if the administrative burden would actually decrease, as the underlying verification processes would remain unchanged.

On extending Annex II, adding fluorinated gases with very low GWP (<10) to the list was criticized by stakeholders, especially from the switchgear sector.

A2.5.3 Impacts of the amended F-Gas Regulation

A2.5.3.1 Environmental impacts

Stakeholders agreed that some measures could reduce emissions further, in particular increasing the HFC phase-down ambition in line with technological development and prohibiting F-gas use in applications, where they are no longer needed. Links to energy efficiency requirements and the need for continued alignment with decarbonisation targets were emphasized, especially by industry and with respect to the important role heat pumps are expected to play to meet broader climate targets. A business organisation for natural alternatives to F-gases pointed out that the current phase-down schedule does not take into account the demand reduction resulting from the 2020 ban for servicing of existing refrigeration installations. This association also noted that further alignment with recent IPCC mitigation scenarios should result in a reduction of HFC phase-down steps already before 2030 and that the GWP20 metrics should be included to present more accurate information in terms of climate-friendly refrigerants.

Industry stakeholders underlined the need to consider energy efficiency requirements and impacts on indirect emissions from energy use. The future energy efficiency provisions set out by the Eco-design Directive and under the Energy Performance of Buildings Directive (EPBD) should not be compromised. Stakeholders, in particular NGOs but also some competent authorities and certain industry, reiterated the need to consider the potential for wider environmental effects beyond the reduction of F-gas use and emissions. This referred especially to by-products during manufacture as well as persistent degradation products of fluorinated chemicals.

A2.5.3.2 Economic impacts

As regards administrative costs, stakeholders, in particular industry and competent authorities noted that some measures would result in an increase. However, the perceived level of increase varied across measures and many stakeholders noted that it is difficult to gauge more precise impacts without a detailed description of the measures. Higher administrative costs were expected by a larger number of stakeholders for the options of: more comprehensive monitoring (e.g. adding new substances, filling gaps in obligations), strengthening obligations to prevent illegal trade, increasing HFC phase-down ambition and technicians training on non-F-gas alternatives. Generally, higher costs were more often expected by industrial stakeholders compared to other stakeholders. For three measures, the response was more mixed, with stakeholders unable to agree whether there would be an increase or decrease in administrative costs: adding flexibility to align with future Montreal Protocol decisions, removing some exemptions and thresholds not foreseen by the Montreal Protocol, and limiting the market players to legitimate participants.

As regards technical adjustment costs, stakeholders (again industry and competent authorities) also recognised a potential for increase in costs for some of the proposed measures. Most stakeholders saw increased costs for the options: increasing HFC phase-down ambition, technicians training on non-F-gas alternatives, adding new HFC phase-down steps beyond 2030, more comprehensive monitoring and a separate HFC production phase-down. Increased adjustment costs were linked to deploying alternatives to SF_6, increased training requirements and increased R&D specifically. The adaption and development of facilities is expected to lead to a particularly high initial cost. Higher end user costs could result from the flammability of alternative refrigerants in the cooling sector and from using more costly alternatives in energy transmission.

More broadly, stakeholders have also reflected that the measures proposed could have wide-ranging economic effects, particularly on R&D and innovation, but also on EU competitiveness, trade with non-EU countries and consumer prices. Stakeholders highlighted they would expect an increase in R&D and higher EU competitiveness, not least in the field of SF_6 alternative technologies. A concern expressed was that non-EU markets were not mature enough to absorb alternative technologies, so that EU companies would not be able to market their innovative equipment and may have to design different products for different markets. There were differing opinions on the impact on SMEs, as some expected higher staff and training costs due to the need for skilled personnel, while others increased business opportunities for providers of green technologies.

Concerning increased HFC phase-down ambition, one end-user association would expect significant additional costs. The stakeholder believed that this could in turn lead to end-users taking additional risks with regards to technical choices, switching to alternative technologies which may not be sufficiently mature. It is also generally expected that there would be a price increase associated with the development of new solutions, alongside an eventual increase in the general energy consumption of the facilities. It was suggested that any additional prohibitions and restrictions should consider not only the GWP but evolve to an analysis based on the Total Equivalent Warming Impact (TEWI) or possibly the Life Cycle Climate Performance (LCCP).

For training of technicians, additional costs to industry, especially for SMEs, were highlighted by individual companies and also include the required absence from work to undergo training.

Industries currently covered by exemptions pointed out cost increases in case these exemptions would not be maintained. As for semiconductor manufacture, concerns related to the competitiveness of the EU market were stated.

A2.5.3.3 Social impacts

Stakeholders generally observed that any social effects of proposed measures would be less significant than the potential economic and environmental effects. Some noted the potential for impacts on public health and safety, although it was deemed to be small.

Several industry stakeholders pointed out increased safety risks related to flammable refrigerant use during installation, service and at end-of life. This risk was perceived to be elevated due to a lack of technician certification, which could also encourage do-it-yourself installations by unqualified individuals.

Concerning employment, one industry association related to natural alternatives to F-gases highlighted the opportunities for market growth within the EU in manufacturing, design, R&D, customer service, marketing etc. but also regarding exports to the North American market. Without the move to natural refrigerants, the EU market would face significant competition from outside the EU, in particular from Southeast Asia.

A3 Who is affected and how?

A3.1 Practical implications of the initiative

A number of different industry stakeholders are affected by changes to the Regulation.

(i) **EU bulk gas producers and gas importers** are, as quota holders, affected by changes to the quota system (ambition levels, quota price) as well as stricter measures on economic operators to achieve better custom controls and enforcement. Compliant companies are pushing strongly for the latter even though these measures would increase their burden, since they feel disadvantaged towards entities involved in illegal activities such as imports without quota. Gas producers and importers are also affected by the prohibitions reducing the use of F-gases, but have business opportunities in importing the higher-value climate-friendly alternatives. They are affected by changes to the reporting and verification measures, but would also profit from many of the efficiency measures made in that area.

(ii) **Gas distributors** are affected by higher gas prices (due to the quota system), but the last six years have shown that the full price increase is passed on to their buyers. Gas distributors will also increasingly use more climate-friendly gases as a result of the quota system and the prohibitions. Today's best practice of handling F-gases is also reinforced for distributors with the need to reduce emissions during storage, transfer and transport.

(iii) **EU equipment manufacturers and importers** are affected by the ambition of the quota system, as gases inside this equipment must be covered by quota, and prohibitions leading to the use of more friendly gases inside the equipment. The modelling has shown that equipment manufacturing and related sectors will profit from the policy-driven technology conversion. Equipment importers will benefit from some of the efficiency measures on the reporting and verification rules, in particular a relaxation of the minimum threshold for independent verification.

(iv) **Gas and equipment exporters**. There are no direct restrictions on exports until 2028 when trade with Parties that have not ratified the Kigali Amendment will be prohibited. HFCs filled into products and equipment in the Union may be more expensive than on the world market. In order to be able to provide a quota balance in real time in the future via CERTEX/Single Environment for Customs, exporters will be asked to provide the CO2e of HFCs exported in equipment in their export declaration. Exporters are mostly unaffected by the changes to the reporting rules, except for a few substances added that could also be exported in small amounts.

(v) **Equipment and product operators (end users)**. A number of different products and equipment use F-gases in addition to RAC appliances. The most relevant of the former in terms of remaining emissions are switchgear (electricity providers, utilities and network operators) and MDIs (patients). End users experience higher prices due to the quota system or replacement of the gases (technology conversion). These costs are very low compared to baseline costs in most cases and are distributed over a large number of end users. In addition end-users often profit from savings in running costs due to e.g. energy efficiencies (RAC sector) so that abatement costs are negative in the long run (i.e. cost savings).

(vi) **Service companies**. Service companies perform activities such as installation, maintenance, leak checking or decommissioning of equipment. Higher prices due to the quota system are routinely passed on to end users. Service companies and their personnel will be required to have more comprehensive certification to include skills on the climate-friendly alternatives and energy efficiency, which is something that their representatives have strongly advocated for.

(vii) **Gas reclamation and destruction companies** should have good business opportunities due to a stricter quota system and the incentive to reclaim gases (no quota needed!) or replace older equipment and the need to avoid emissions. Reclamation companies will be asked to report in the future, so that this monitoring gap can be closed.

(viii) **Private persons**. Some private persons can be operators in the case of e.g. AC used in cars or homes and may experience higher gas prices in the future, but could benefit from lower operating costs in the long run. Home owners that are renovating houses may have to ensure that old foams installed in their houses are appropriately treated to avoid losses of F-gases. Patients using MDIs will not experience any noteworthy cost increases as the cost component of the HFC in the MDI is less than 1%. Citizens are of course benefiting from fewer climate change effects as the emission of these highly warming greenhouse gases will be reduced.

A3.2 Summary of costs and benefits

Table 13. Summary of costs and benefits of the preferred option (Option 2)

I. Overview of Benefits (total for all provisions) – Preferred Option		
Description	***Amount***	***Comments***
Direct benefits		
Reduced climate emissions	Additional savings of direct emissions: 40 MCO2e by 2030 308 MtCO2e by 2050 Indirect emissions: Energy savings 2.5 GWh/year (2024-2036 average; ~0.3% of baseline energy use), 2050: 8.2 GWh/year savings (~0.5% of baseline energy use)	Emission savings mostly come from the quota system and the accompanying prohibitions as well as the emission avoidance measure (A3); many other measures contribute small savings. The technology conversion also leads to small energy savings

	Saved indirect CO_2 emissions 2030 ~ 0.3 Mt CO_2/a ; 2050: ~0.3 Mt CO_2/year	
Reduction of administrative costs for businesses	Savings of €4.5m per year	Delivered by *inter alia* relaxing thresholds for placing on the market of products and equipment, quota application in 3-year cycle rather than annually and an electronic verification process
Reduction of administrative costs for authorities	Savings of ca 2,850 days per year across Member State competent authorities, DG CLIMA and EEA.	Driven by savings to MS competent authorities from aligning reporting and verification thresholds and requirement for specification of 'NIL' reporting.
Reduction of adjustment costs to end-users (mostly businesses)	~-835 Mio € per year by 2050	Cost savings in adjustment costs to end-users (sum of capex & opex) in the long-term perspective, (in 2024-2036 time horizon additional costs primarily due to higher investment expenditures)
Revenue from quota allocation price	~125 Mio € per year initially	The quota allocation price reduces profits in HFC supply chain without increasing cost to end-users. To cover admin cost at EU level and residual amount to be transferred to the EU budget.
Indirect benefits		
Job creation	~400 by 2030, ~6,800 by 2050	In particular in the EU manufacture of equipment and supplying industries
Research and development	+	Incentive in R&D in the EU equipment manufacturing sector
Competitiveness	+	Strengthened competitiveness of EU equipment manufacturing sector; however: drawback for export-oriented equipment manufacturing

GDP increase	+ 0.005 vs baseline by 2050	GDP increase in the long-term perspective. In 2030 horizon: GDP loss of ~0.001% of baseline

II. Overview of costs – Preferred option						
	Citizens/Private Consumers		Businesses		Administrations	
	One-off	Recurrent	One-off	Recurrent	One-off	Recurrent
Direct costs		Adjustment costs: Increased HFC refill cost until ~2030 for EU car owners of ACs in old vehicles (new cars not affected due to MAC Directive)	Admin burden: €3 million	Admin burden: €12.1 million per year (plus €20.8 million for training costs) (the cost savings of €4.5 million [130] are not subtracted here, see benefits above) *Thereof:* €1.9 million relate to alignment with international rules and/or improving enforcement to reduce illegal activities. Adjustment costs to business end-users (sum of capex & opex) ~421 Mio € per year (2024-2036 average),	Admin burden: 2,600 days	Admin burden: 13,500 days per year (does not include savings of 2,850, see benefits above)

[130] According to Annex A14.2 the individual measures result in total gross savings of €4.5 million and additional gross burden of €12.1 million. These numbers cancel each other out when deriving summary costs and are therefore not apparent in the summary tables in e.g. section 6.2.2

				turning into cost savings of ~835 Mio € per year by 2050. Also, distributional costs linked to HFC gas prices		
Indirect costs		Adjustment costs: Potential pass-through to consumers (e.g. ACs, heat pumps) of higher compliance cost for businesses not significant in most sectors as additional cost <1% of total operating cost (including for MDIs where the HFC propellant gas costs a very small fraction of the total price)				

A4 Analytical methods

A4.1 Data sources

Data sources included

- Referenced literature as per the support study;
- EEA's yearly reports on fluorinated gases[131];
- Recent technical reports published by the EC (see footnote 128);
- The extensive stakeholder consultations carried out for this study;
- Previous expertise including past and current projects of the external consultants.

The following impacts were examined making use of the above information as well as modelling based on AnaFgas and the JRC's GEM-E3 model (see below for information on these modelling activities).

Table 14. List of impacts examined

Environmental impacts
Direct F-gas emissions
Energy use / indirect emissions
Ecotoxicity
Economic impacts
Operative adjustment costs of F-gas using industries
Administrative costs
- to businesses
- to Member State competent authorities
- to the EU Commission and the European Environmental Agency (EEA)
Distribution of costs
- across business size
- across EU regions
Macroeconomic impacts on the EU
Distributional effects between equipment operators and undertakings of the HFC supply chain
Impact on consumer prices
Impact on trade flows (imports and exports)
Impact on R&D and innovation
Impact on competitiveness
Social impacts
Employment effects
Public health & safety and health systems

131 https://www.eea.europa.eu/publications/fluorinated-greenhouse-gases-2020

A4.2 AnaFgas: Modelling F-gas demand and emissions

A4.2.1 Overview of the model

AnaFgas calculates demand and emissions of fluorinated greenhouse gases (F-gases) in the EU27+UK in the period of 2000 to 2050, based on a bottom-up stock model. An attached cost module allows quantification of related costs to the operators of equipment relying on F-gases or their alternatives.

The model AnaFgas was designed as a detailed bottom-up stock model to derive demand and emission scenarios for F-gases used in the most relevant sectors and sub-sectors (Figure 8) for the EU Member States. The original model set up for the 2011 preparatory study for the impact assessment of the current Regulation includes the UK, while Croatia was not yet a Member State of the EU and thus not included. However, Croatia was added in a later update of the model in the period 2017 to 2020. The current model represents a thoroughly updated version of the original model, with the latest available data and assumptions as described further below.

The AnaFgas model is designed to calculate demand and emissions of F-gas gases under different scenarios and was used to derive a baseline, as well as a counterfactual scenario for relevant sectors in the EU. Demand is the sum of quantities of F-gases used in the initial first filling of equipment and the re-filling in the servicing of equipment during the lifetime. Emissions are the sum of emissions of F-gases during the lifetime of equipment (lifetime emissions) and F-gases that are released to the atmosphere during disposal of old equipment (disposal emissions). In AnaFgas, all emission and demand estimates are derived from bottom-up approaches, i.e. by estimating demand and emissions per sector through the use of underlying driving factors. These include annual changes in equipment stock, composition and charge of the equipment, leakage during equipment lifetime and during disposal. Some of these components are driven by other factors such as population development, GDP growth or technological changes. Based on these drivers, annual emissions and banks as well as use can be calculated for each year, sub-sector and EU Member State.

AnaFgas makes use of market information to build an inventory of the in-use stocks of the equipment in each of the end-uses in each country. This includes the percentage of the equipment stock that contains each F-gas. These modelled stock inventories are maintained through the annual addition of new equipment/new F-gas quantities and the retirement of equipment after an appropriate number of years. Annual leak rates, servicing emissions, and disposal emissions are estimated for each of the end-uses. The AnaFgas cost module is based on model installations per sector and respective assumptions investment and operating expenditures for available options of used F-gases or F-gas alternatives. Specific cost at model installation level can be recalculated into total sectoral cost in the EU27+UK AnaFgas scope by means of AnaFgas data on equipment stocks. AnaFgas can be used to quantify the effects and costs of policy interventions to reduce emissions of fluorinated greenhouse gases by comparing different scenarios (e.g. policy options, baseline and counterfactual).

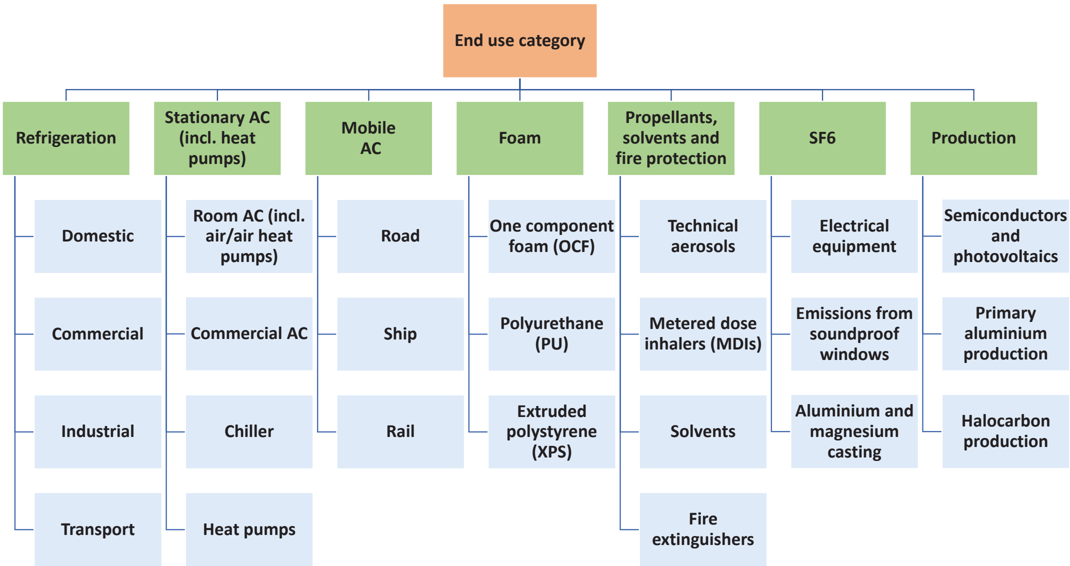

Figure 8: Overview of the sectors and subsectors covered by the AnaFgas model

Source: *OekoRecherche et al. (2021), based on Schwarz et al. (2011)*

Certain sub-sectors in Figure are represented in more detail in the model:

- **Commercial refrigeration**
  - Central systems
  - Condensing units
  - Hermetic units
- **Industrial refrigeration**
  - Food industry
    - Beer production
    - Wine production
    - Meat production
    - Dairy industry
    - Chocolate production
    - Frozen food
    - Fruit juice / Gaseous drinks
    - Milk farms
  - Other industry
    - Cold storage
    - Ice rinks
    - Other industry (50 % chemical)
- **Transport refrigeration**
  - Vans
  - Trucks and trailers
  - Fishing vessels
- **Room air conditioning**
  - Moveable (portable) units
  - Small split units including reversible air-to-air heat pumps (average charge of 1.5 kg)
- **Commercial air conditioning**
  - Large split and variable refrigerant flow (VRF) systems
  - Packaged equipment (incl. rooftop units)
- **Chiller**
  - Displacement compressor type
    - Mini-chiller
    - <100 kW chiller
    - >100 kW chiller
  - Centrifugal compressor type

- **Heat pumps**
  - Small (average charge of 2.6 kg) and medium (average charge of 26 kg) heat pumps (95% small and 5% medium units)
    - Air/water (heating only and reversible)
    - Water/water (heating only)
    - Brine/water (heating only and reversible)
    - Direct exchange
    - Exhaust air
    - Sanitary hot water
  - Large commercial heat pumps (average charge of 750 kg)
    - District heating
    - Industrial
- **Road mobile air conditioning**
  - Passenger cars
  - Commercial transport vehicles
    - Trucks N1
    - Trucks N2
    - Trucks N3
  - Buses
  - Ships
    - Cruise ships
    - Passenger ships
    - Container ships
    - Cargo ships
  - Rail
    - Trams
    - Metros
    - Trains

In the current model, the heat pumps sector was extended to cover medium and large equipment. All sales data for heat pumps were gathered from data provided by the European Heat Pumps Association (EHPA[132]) and the German Bundesverband Wärmepumpe (bwp[133]). For small and medium heat pumps, the sales data was identical, since data grouped by charge size was not available. A share of 95 % of sold units for small heat pumps and 5 % for medium heat pumps was assumed. For all heat pumps, an annual increase in sales of 5 % was assumed from 2020 to 2050.

For electrical equipment (including switchgear), the assumed saturation of the growth in the market in Schwarz et al. (2011) for Western and Eastern European countries in 2015 and 2020, respectively, was replaced by an assumed growth rate of 2 % per year until 2050 for all EU countries based on ZVEI (2020)[134] and expert opinion.

The latest model version features AnaFgas calculates demand and emissions individually for 33 different F-gases and 12 different blends, including HFCs, H(C)FOs, PFCs and SF_6, for the period 2010 to 2050 based on market data and estimates of the quantity of equipment or products sold each year containing these substances, and the quantity of substances required in the EU to manufacture and/or maintain equipment and products over time.

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132 https://www.ehpa.org/

133 https://www.waermepumpe.de/

134 https://www.zvei.org/fileadmin/user_upload/Presse_und_Medien/Publikationen/2020/April/SF_6_Reduktion/Szenario-zur-Reduktion-von-SF6-Betriebsemissionen-final-eng.pdf

Projections by EU Member States and IPCC/TEAP SROC Report 8 and the recent TEAP reports are included in the growth assumptions for the model scenarios until 2050. For the projections of activity data including charges and F-gas split, and emission factors until 2050, AnaFgas generally distinguishes between three different time periods:

- Near past (5-10 years) is calculated by adjusting the stock model using data reported under Article 19 of the F-gas Regulation (reporting on supply of F-gases) and the National Inventory Reports (NIRs) submitted by the EU under the United Nations Framework Convention on Climate Change (UNFCCC, reporting on emissions and partially on first fill quantities). It must be noted, however, that the reported data is not equivalent to the modelled metrics. Under the F-gas Regulation, supply of F-gases is reported, which does not directly translate to demand. Further, the NIRs only contain data based on estimates that are not frequently changed to reflect market developments. Thus, deviations between the reported and modelled data are to be expected.
- Near future (5-10 years) is modelled on known policies and measures, technological changes, substitution patterns and expected changes in use patterns.
- Distant future (until 2050) is based on a continuation of trends observed, external projections of driving forces such as GDP and population and follows a business-as-usual trend as the model does not consider changes in technologies which are likely to happen within such a long timeframe.

Underlying assumptions for each sector in the model AnaFgas are outlined in detail in the model description in Annex III to the preparatory study (Schwarz et al. 2011). The model is limited by the fact that (i) it assumes yearly re-fillings of emitted quantities not necessarily reflecting common practice, which may cause deviations from actual demand in the short term (i.e. at annual level) while accurately predicting medium and longer term trends, (ii) each modelled sector is represented by one typical installation size to represent the whole sector, and (iii) assumptions on parameters affecting investment and operating costs rely on expert judgement and industry input. Specific information on each sector for the EU is summarized in the Annex to the support study.[135] These sector sheets cover economic assessments of standard and F-gas substitution technologies and allow the calculation of abatement cost for substitution technologies and thus the generation of cost curves and cost-driven abatement scenarios, for example in response to economic interventions like the EU HFC phase-down. These data were updated as relevant in the current version of the model.

Figure 9 gives a simplified overview of the general logic behind AnaFgas. In the model, each sector has unique adaptations that add to the logic outlined below. The result, however, is always the calculation of the demand and emissions in metric tonnes for each gas in each sector/subsector for each year. Based on the GWP of the different gases, the demand and emissions can then be easily converted into tCO_2e. In its latest version, 33 different gases and 12 blends are covered by the model. Those include the most relevant HFCs, PFCs and SF_6 and blends of HFCs.

[135] Oeko-Recherche (2021)

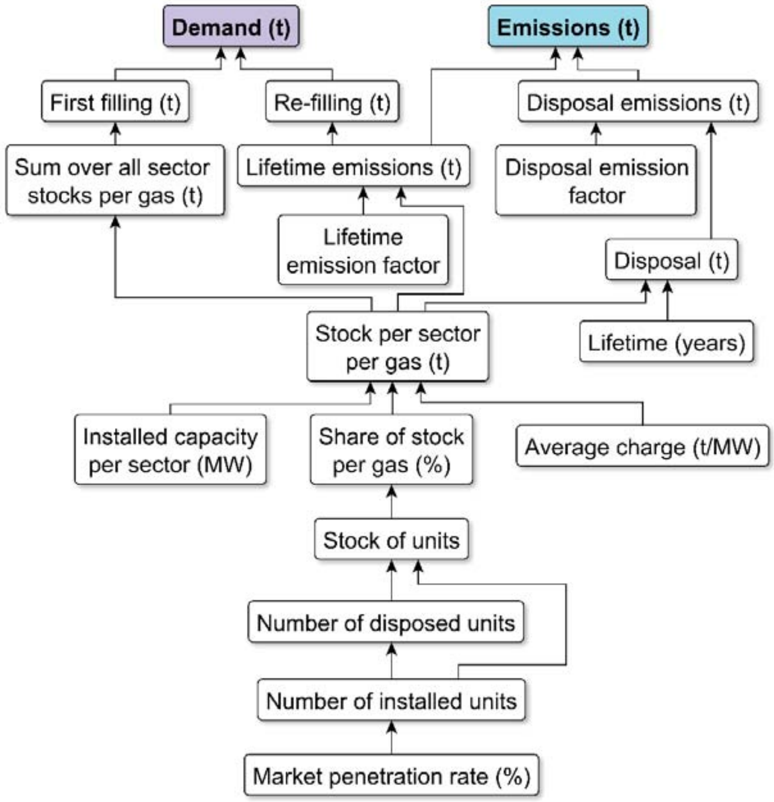

Figure 9: Simplified overview of the AnaFgas logic to project demand and emissions of F-gases in the EU

Source: *Oeko-Recherche et al., 2021*

In the model structure of AnaFgas, it is assumed that emissions from leakage during a year are replaced in the same year, irrespective of the age of the equipment. In reality, it can be assumed that leakage rates increase over the course of the lifetime of equipment. AnaFgas uses the average leakage rate over the entire lifetime of equipment for each year. This can lead to deviations from observed emissions for specific years but should even out when looking at longer time periods.

The AnaFgas cost module is based on model installations per sector and respective assumptions investment and operating expenditures for available options of used F-gases or F-gas alternatives. Specific cost at model installation level can be recalculated into total sectoral cost in the EU27+UK AnaFgas scope by means of AnaFgas data on equipment stocks.

Input and parametrization

Key inputs used for the model.

- Lifetime emission rates
- Disposal emission rates
- Sales of equipment
- Disposal of equipment
- Market penetration rate of F-gases and blends in new equipment

- Prices for F-gases and their alternatives
- Investment cost for model installations
- Operating cost for model installations (energy and servicing)

Main output

Key outputs produced by the model.

- Yearly demand for 33 different F-gases in the EU27/EU27+UK from 2000 to 2050
- Yearly emissions of 33 different F-gases in the EU27/EU27+UK from 2000 to 2050
- Equipment operators' total expenditures under different scenarios / policy options

Spatial - temporal extent

Parameter	Description
Spatial Extent / Country Coverage	EU Member states 27 and UK
(Spatial) resolution	National
Temporal extent	Long-term (more than 15 years)
Temporal resolution	Years

A4.2.2 Emission rates used in the AnaFgas model

Although leakage rates can be used to estimate the emissions over time, lifetime emissions go beyond leakage rates since they also include emissions that are not covered by refill, e.g. during recovery and decommissioning at end of life. The table below shows the annual emission factors applied in the AnaFgas model for the period since 2010 for lifetime, disposal and manufacturing emissions by sector and sub-sector. Lifetime emission rates decreased for many, but not all, sectors following the application of the Regulation in 2015. Disposal emission factors have also decreased since 2015 in several applications since collection and recycling of both bulk and equipment containing F-gases has been improved. For many sectors, a reduction in emission rates is also expected under the counterfactual scenario, albeit not always as pronounced. This is because technological developments are also expected to occur in the absence of the Regulation.

The assumptions provided in Table 14 have been developed based on previous modelling as well as national emission reporting to the UNFCCC, literature and input from industry experts. There are no emission rates assumed for the sector “PFC and other halocarbons”. For this sector, emissions are directly taken from the UNFCCC data (National Inventory Reports, NIRs). The table shows annual emission factors for lifetime (LE), disposal (DE) and manufacturing (ME) for the baseline and the counterfactual scenario in 2015 and 2019 used in the model, while differences between scenarios are highlighted.

Table 15: Annual lifetime, disposal and manufacturing emission factors for all scenarios from 2020 used in the model

Sectors and subsectors	Emission rates from 2020 LE = lifetime emissions, DE = disposal emissions, ME = manufacturing emissions		
	LE (%)	DE (%)	ME (%)
Refrigeration			
Domestic	0.3	29	
Central systems	9	18	
Condensing units	6	25	
Hermetic units	1	35	
Industrial (food)	4	30	
Industrial (other)	5	30	
Vans	25	30	
Trucks and trailers	18	30	
Fishing vessels	30	30	
Stationary air conditioning (incl. heat pumps)			
Moveable units	3	35	
Small split units incl. air/air heat pumps	5	35	
Large split and VRF units	5	20	
Packaged equipment (incl. rooftop units)	3	20	
Chillers	2.4	20	
Heat pumps (small)	3.5	35	
Heat pumps (medium)	4.5	35	
Heat pumps (large)	6	20	
Mobile air conditioning			
Passenger cars	10	40	
Buses	15	30	
Trucks (N1)	10	70	
Trucks (N2, N3)	15	70	
Rail (trams, metros and trains)	7	30	
Ships	40	30	
Foams			
One-component	100		
Extruded polystyrene (XPS)			
HFC-134a, HFC-1234ze(E)	0.75		30
HFC-125	25		100
Polyurethane (spray and non-spray)	1		10
Other HFC			
Aerosols and solvents	100		
Fire extinguishers			
HFC-227ea, HFC-125, HFC-23	2	9	
HFC-134a	4	9	
HFC-236fa	5	9	
SF_6			
Electrical equipment	1	5	4
Soundproof windows	1	100	33
Aluminium and magnesium casting			3

A4.2.3 Validation of the AnaFgas model

Validating the results from the AnaFgas baseline model is crucial but there only exist very limited data for comparison. In the following, demand and emissions are contrasted with supply, as calculated by the EEA based on reporting data under the Regulation, and emissions data extracted from the National Inventory Reports (NIR) for the EU under UNFCCC. However, some systematic differences between the compared data set should be noted:

- Supply as defined and calculated by the EEA [EEA 2020 public report] is not the same metric as demand used in the AnaFgas modelling. The AnaFgas demand covers the gases which are needed for the operation of equipment in the EU. In the supply metric, additionally, those gas amounts are accounted for which are charged into equipment in the EU and subsequently exported for use outside the EU. Furthermore, some interannual discrepancies may occur due to stocks. The EEA supply metric is cleared of amounts stockpiled at the end of the year by producers or importers of gas. However, gases stockpiled further downstream e.g. by distributors and also gases contained in stockpiled imported equipment are contained in the supply of the year of import rather than for the year of actual use.
- UNFCCC data on emissions of F-gases are estimated values only, and Member States use very different methods to obtain this data, from databases of actual emissions, to surveys or the use of very generalised emission factors as per UNFCCC methodology. This data therefore also carries an inherent amount of uncertainty.

When comparing demand and supply, the metrics align closely for certain years but deviate for others (Figure 10 and Table 15). Especially in 2014, the supply is substantially higher than the modelled demand, while in 2019 the reverse is the case. In 2014, large quantities of F-gas supply were reported that most certainly were not actually used in equipment in that year. These quantities were very likely stockpiled in anticipation of shortages anticipated because of the phase-down that started the following year. Stocks are not part of the derivation of demand, however, and this is the reason why 2014 shows no increase in the modelling. Some of the differences can also be explained by yearly carry-over effects. The modelling is not designed to accurately predict single years, or outliers, but rather the general development over time.

In general, a very good fit is obtained between model and reported data, with the exception of the special year 2014 (see explanation on stock building above).

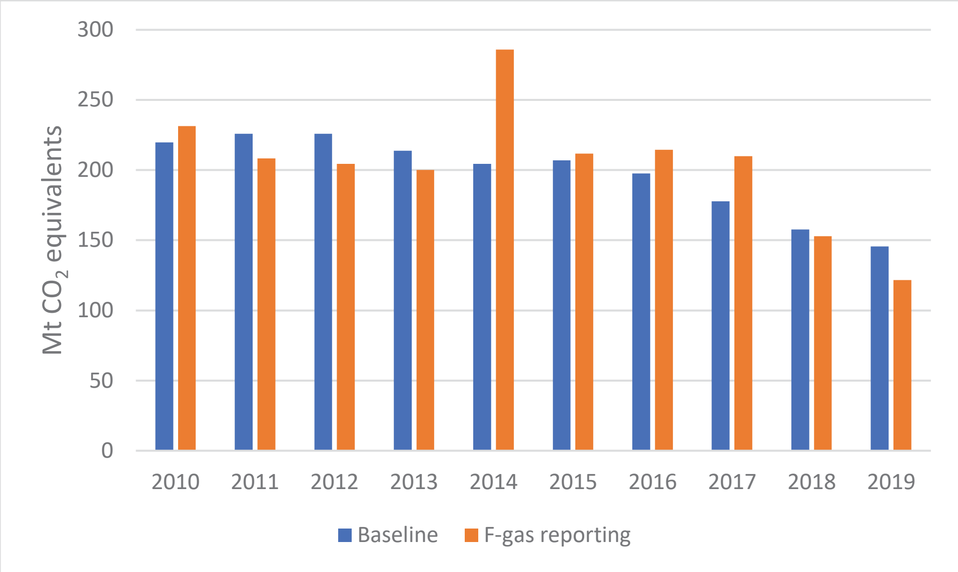

Figure 10: Comparison between the reported F-gas supply for the EU-28 and the results from the AnaFgas baseline modelling for F-gas demand

Sources: *AnaFgas modelling, Data from EEA 2020*

Table 16: Comparison of the modelled baseline F-gas demand and the reported F-gas supply in the EU-28

Mt CO_2 eq	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
F-gas supply (F-gas reporting)	231	208	204	200	286	212	214	210	153	122
F-gas demand (AnaFgas)	221	224	227	216	206	206	198	176	157	145
Difference	5%	-7%	-10%	-7%	39%	3%	8%	19%	-2%	-16%

Source: *AnaFgas modelling, EEA 2020*

Regarding emissions, the AnaFgas model consistently calculates higher quantities in tCO_2e than stated in the UNFCCC NIR (Figure 11 and Table 16), but the deviations are very small (on average 3 %). Since the UNFCCC data is based on estimations, the methodology of collecting this data is very different for different member States (surveys, estimations, actual emissions databases). Possible explanations could be differences in the assumed emission rates for different sectors and subsectors or charge sizes for different equipment where these are used to determine the emissions reported to the UNFCCC. In any case, the deviations are small and are likely within the uncertainties.

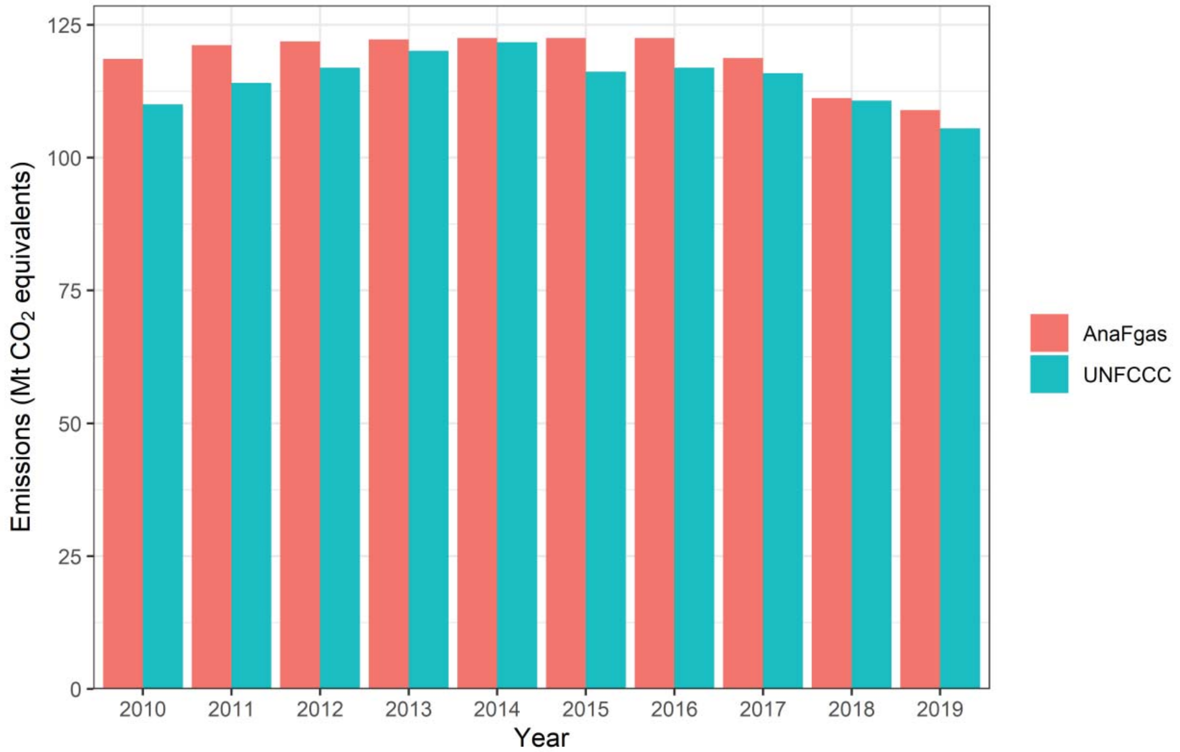

Figure 11: Comparison between the results from the AnaFgas baseline modelling and the reported emissions under UNFCCC (NIR) for the EU-28

Source: *AnaFgas modelling, UNFCCC (https://unfccc.int/documents/275968)*

Table 17: Comparison of AnaFgas baseline modelling output with the NIR reported EU-28 F-gas emissions

Mt CO_2 eq	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
UNFCCC	110	114	117	120	122	116	117	116	111	106
AnaFgas	119	121	122	122	122	123	122	120	112	109
Difference	8%	6%	4%	2%	0%	6%	4%	3%	1%	4%

Source: *AnaFgas modelling, UNFCCC (https://unfccc.int/documents/275968)*

For single gases or gas groups, the modelled emissions show similar trends to the UNFCCC data (Figure 12). Both data sources show a decline in emissions of high-GWP gases in recent years, especially for HFC-134a, HFC-125 and HFC-143a. The UNFCCC data shows an increase in emissions until the F-gas Regulation took effect in 2014, followed by a rather sharp drop with a second stronger decline from 2017 to 2019. The AnaFgas model, at first, shows a more gradual effect of the F-gas Regulation that picks up speed from 2017 to 2018, due to the second phase-down step starting in 2018, cutting the placing on the market quantities by 30 %. From 2018 to 2019, the decline in emissions shows a more moderate reduction compared to the previous years.

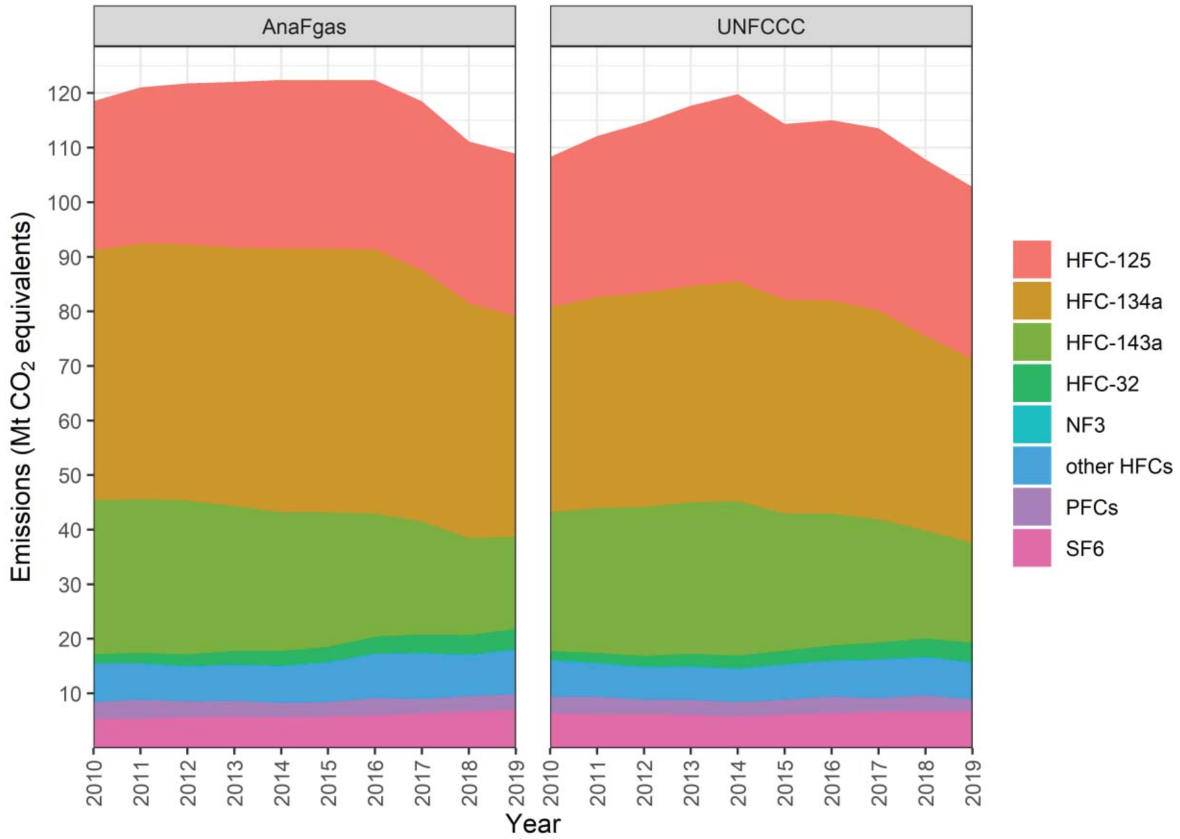

Figure 12: Comparison of the AnaFgas baseline modelling output with the UNFCCC reported EU-28 F-gas emissions by gas/gas group

Source: *AnaFgas modelling, UNFCCC (https://unfccc.int/documents/194921)*

A4.2.4 Continuation of baseline scenario until 2050

To assess any impact on demand and emissions of F-gases due to further policy action, a hypothetical reference scenario must be constructed that describes the unchanged continuation of current policy. In the Evaluation report (Annex A5), the baseline scenario from the AnaFgas modelling represents the effect of the current Regulation until and including 2019. For assessment of the impact of further policy action, this baseline scenario was projected until 2050, under the assumption that there are no future policy changes. As such, compliance with the HFC phase-down schedule is assumed and the final 2030 phase-down step to 21 % maximum quantity of HFCs on the market, compared to the reference period of 2009 to 2012, is continued until 2050 (even though not regulated).

A4.2.5 Assumed reclamation of HFCs

For the modelling exercise, future potential reclamation rates are being assumed for relevant HFCs with the help of expert input. The goal is to project reasonable rates per gas that are informed by the modelled quantities of available HFCs in end-of-life (EoL) equipment in any given year.

Table 17 shows the assumed reclamation rates of HFCs for the EU-27 that were used in the modelling for the different scenarios. Further, the share of reclaimed gas from the available quantities from EoL equipment and the share of the demand for the respective year are shown. While the baseline and Policy Option 1 show the highest absolute reclamation quantities in Mt CO_2 eq, the more ambitious scenarios (Option 2 and Option 3) show a higher share of reclamation in relation to the demand. Higher ambition leads to a quicker replacement of high GWP gases in new equipment, which in turn limits the available quantities for reclamation at end of life. This is why the share of reclamation of the demand decreases also for the more ambitious scenarios in the long run.

Table 18. Assumed reclamation quantities of HFCs in the EU-27

	Mt CO_2 eq				% of gas in EoL equipment				% of demand			
Year	BL	O1	O2	O3	BL	O1	O2	O3	BL	O1	O2	O3
2015	3	3	3	3	10%	10%	10%	10%	2%	2%	2%	2%
2020	8	8	8	8	16%	16%	16%	16%	10%	10%	10%	10%
2025	8	8	8	8	19%	19%	19%	19%	15%	14%	19%	21%
2030	6	6	5	6	22%	22%	21%	22%	20%	16%	31%	40%
2035	6	6	3	3	32%	31%	17%	24%	20%	20%	23%	40%
2040	4	4	2	2	40%	28%	37%	43%	20%	19%	21%	25%
2045	3	3	1	1	38%	28%	39%	42%	14%	17%	18%	20%
2050	3	3	1	1	33%	35%	34%	45%	12%	16%	16%	21%

Generally, an estimation of future reclamation rates is difficult and deviations from the assumed rates are possible, especially in the long-term. However, reclamation plays a pivotal role for the restriction of placing on the market (POM) quantities. Since reclaimed quantities are exempted from the phase-down, an increase in reclamation allows for an increase in virgin HFCs on the market. Following market logic, in the model it is assumed that with increasing non-virgin HFC quantities (reclamation), more virgin HFCs are placed on the market.

A4.2.6 Validation of the baseline HFC phase-down scenario

To ensure that the HFC demand (excluding MDIs and semiconductors), calculated under the baseline scenario, does not exceed the placing on the market restrictions set out by the Regulation, the demand was adjusted to conform as closely as possible to the POM metric. Since the modelled demand includes reclaimed quantities that are not covered by the HFC phase-down, the reclamation quantities listed for specific years in Table 17 were subtracted from the demand. Figure 13 shows the adjusted baseline HFC demand in comparison to the HFC POM limit under the Regulation. From 2020 to 2050, the area under the curve for the adjusted demand (or the sum over all yearly values) exceeds the area for the POM limit by 38 Mt CO_2 eq. This difference can be flexibly compensated by the approximately 69 Mt CO_2 eq of authorisations that are still available as of 2020 (EEA 2021).

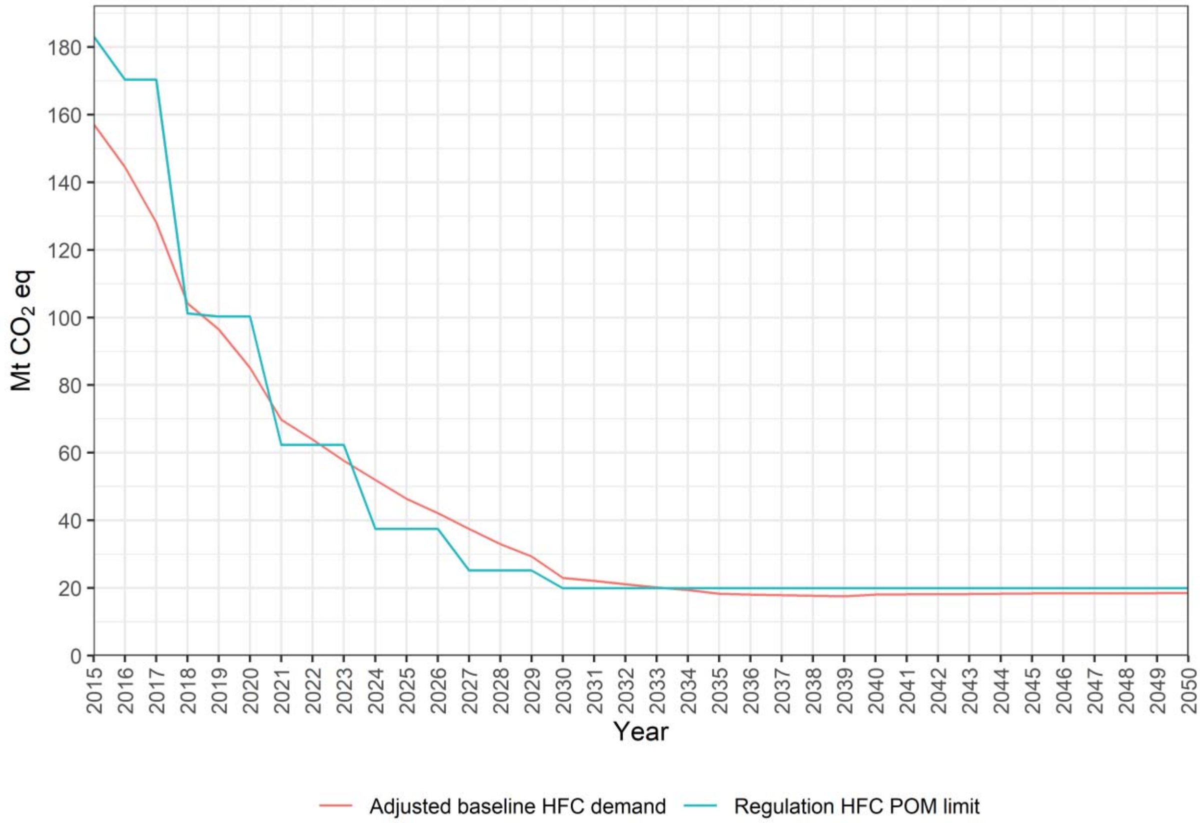

Figure 13. Adjusted HFC demand under the baseline and HFC POM limit under the Regulation

Source: *AnaFgas modelling*

A4.2.7 Modelling scenario definitions

Policy option 1: Montreal Protocol alignment

The Protocol defines consumption and production limits for HFCs that differ from the HFC POM restrictions set out in the Regulation and extend beyond the year 2030. This scenario has the goal to ensure the long-term EU-compliance under the Protocol under all circumstances.

The ambition level of the POM phase-down of the current Regulation is not sufficient to ensure EU compliance with the Protocol's HFC consumption phase-down after 2033 in the case that EU HFC consumption of HFCs outside the scope of the Regulation's POM phase-down remains high. This relates in particular to the HFC demand for use in the quota-exempted MDI sector. To address this issue, Option 1 removes the MDI exemption from the phase-down (as do the other two options).

Like the baseline, Option 1 has been modelled in AnaFgas so that the HFC demand meets an externally set limitation of HFC POM (placing on the market), considering corrections for quota-exempted HFC use, HFC reclamation, and use of banked quota authorisations. The POM schedule for Option 1 was calculated by adding a high estimate of HFC demand for MDIs to account for lifting the MDI exemption and introducing additional POM reduction steps for 2033 and for 2036 (to keep the 3 year cycle) and allow meeting the consumption ceilings set by the Protocol for the EU for 2034 and 2036.

As HFC demand for MDIs may be lower than the 'worst case' HFC demand for MDIs considered in Option 1 (to ensure compliance under all circumstances), the pressure to reduce HFC use by other sectors may be lower in the years 2024-2032 under this scenario if HFC need for MDIs is less than the "worst case". In consequence, overall EU HFC demand 2024-2030 in Option 1 is modelled as higher than in the baseline, leading to sustained higher emissions. After 2033, however, overall HFC demand in Option 1 is below the baseline and safely meets the MP HFC consumption limits from 2034 onwards which were found to be at risk under the baseline scenario.

Policy option 2: Proportionate costs

For the design of the phase-down all sub-sectors were included to replace highly warming HFCs as soon as technically feasible, as long as their marginal abatement costs at sub-sectoral level remained lower than €390/CO2e up to 2050. This excludes the sectors AC in trains, metro and buses.

Policy option 3: Maximum feasibility

For the design of the phase-down all sub-sectors were included to replace highly warming HFCs as soon as technically feasible, without considering the abatement costs.

A4.2.8 Assumptions on regional distribution of equipment in sectors that use F-gases

There may be differences how policy measures on F-gases affect the EU North and EU South. This may be the case because

- Natural refrigerants are already used more commonly in northern Europe, so a higher rate of replacement is needed in the South.
- The choice of equipment type may differ, e.g. in the South small shops are more common than it the North and refrigeration and air conditioning systems for small spaces are different to those used in large supermarkets or shopping malls.
- The climatic situation are different. As a result, stationary AC units are more frequently used in the south. For these subsectors adjustment costs or benefits will occur to a larger extent in southern European countries. Conversely, heating-only heat pumps are more frequently used in the northern EU.

These and possibly other factors could potentially lead to a different cost burden between North and South. To examine such possible regional effects between Southern and Northern EU states, the different equipment types were divided for these two regions (EU28 for evaluation (Table 19) and EU27 for the purpose of the impact assessment (Table 18)).

Table 19. Regional distribution of equipment stocks EU27 south vs EU 27 north

AnaFgas sector	**EU 27 south (39% of population)**	**EU 27 north (61% of population)**
Domestic Refrigeration	39%	61%
Commercial refrigeration - Hermetics	60%	40%
Commercial refrigeration - Condensing units	39%	61%
Commercial refrigeration - Central systems	39%	61%
Industrial refrigeration - small	39%	61%
Industrial refrigeration - large	39%	61%
Transport refrigeration - Vans	39%	61%
Transport refrigeration - Trucks & Trailers	39%	61%
Transport refrigeration - Ships	39%	61%
Room AC - Moveables	63%	38%
Room AC - Single split (includes small multi-split <12 kW & reversible air-to-air heat pumps)	60%	40%
Room AC - Packaged systems (rooftop units), cooling only	70%	30%
Room AC - VRF cooling only (includes Single-split >3kg VRF Multi-Split)	39%	61%
Minichillers	39%	61%
Displacement chillers - small	39%	61%
Displacement chillers - large	39%	61%
Centrifugal chillers	39%	61%
Heat pumps - small (<20 kW, excluding small reversible air/air heat pumps covered in the single split subsector)	39%	61%
Heat pumps - medium (20-200kW)	35%	65%
Heat pumps - large (>200kW, district heating & industrial)	28%	73%
Mobile AC - Passenger cars	39%	61%
Mobile AC - Buses	39%	61%
Mobile AC - Trucks N1	39%	61%
Mobile AC - Trucks N2	39%	61%

AnaFgas sector	EU 27 south (39% of population)	EU 27 north (61% of population)
Mobile AC - Trucks N3	39%	61%
Mobile AC - Passenger ships	39%	61%
Mobile AC - Cargo ships	39%	61%
Mobile AC - Tram	39%	61%
Mobile AC - Metro	39%	61%
Mobile AC - Train	39%	61%
Aerosols - technical	35%	65%
Aerosols - MDIs	39%	61%
Fire extinguishers	39%	61%
Solvents	25%	75%
Foam OCF (one component foam)	39%	61%
Foam XPS (extruded polystyrene)	39%	61%
Foam PU (polyurethane) spray	39%	61%
Foam PU (polyurethane) non-spray	39%	61%
Switchgear MV	39%	61%
Switchgear HV	39%	61%

Notes: EU 27 south: Bulgaria, Croatia, Cyprus, southern France (25% of FR population), Greece, Italy, Malta, Portugal, Romania, Spain; EU28 North: other EU 27 MS, including 75% of French population

Table 20. Regional distribution of equipment stocks EU28 south vs EU 28 north 2015-2019

AnaFgas sector	EU 28 south (35% of population)	EU 28 north (65% of population)
Domestic Refrigeration	35%	65%
Commercial refrigeration - Hermetics	55%	45%
Commercial refrigeration - Condensing units	35%	65%
Commercial refrigeration - Central systems	35%	65%
Industrial refrigeration - small	35%	65%
Industrial refrigeration - large	35%	65%
Transport refrigeration - Vans	35%	65%
Transport refrigeration - Trucks & Trailers	35%	65%
Transport refrigeration - Ships	35%	65%
Room AC - Moveables	60%	40%
Room AC - Single split (includes small multi-split <12 kW & reversible air-to-air heat pumps)	55%	45%
Room AC - Packaged systems (rooftop units), cooling	65%	35%

only		
Room AC - VRF cooling only (includes Single-split >3kg VRF Multi-Split)	35%	65%
Minichillers	35%	65%
Displacement chillers - small	35%	65%
Displacement chillers - large	35%	65%
Centrifugal chillers	35%	65%
Heat pumps - small (<20 kW, excluding small reversible air/air heat pumps covered in the single split subsector)	35%	65%
Heat pumps - medium (20-200kW)	25%	75%
Heat pumps - large (>200kW, district heating & industrial)	20%	80%
Mobile AC - Passenger cars	35%	65%
Mobile AC - Buses	35%	65%
Mobile AC - Trucks N1	35%	65%
Mobile AC - Trucks N2	35%	65%
Mobile AC - Trucks N3	35%	65%
Mobile AC - Passenger ships	35%	65%
Mobile AC - Cargo ships	35%	65%
Mobile AC - Tram	35%	65%
Mobile AC - Metro	35%	65%
Mobile AC - Train	35%	65%
Aerosols - technical	25%	75%
Aerosols - MDIs	30%	70%
Fire extinguishers	35%	65%
Solvents	15%	85%
Foam OCF (one component foam)	35%	65%
Foam XPS (extruded polystyrene)	35%	65%
Foam PU (polyurethane) spray	35%	65%
Foam PU (polyurethane) non-spray	35%	65%
Switchgear MV	35%	65%
Switchgear HV	35%	65%

Notes: EU 28 south: Bulgaria, Croatia, Cyprus, southern France (25% of FR population), Greece, Italy, Malta, Portugal, Romania, Spain; EU28 North: other EU 28 MS, including 75% of French population

A4.2.9 Modelling energy use

The revision of 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 RAC sector. In the AnaFgas modelling framework, final energy consumption of RAC equipment was calculated both for the baseline scenario and the three policy options scenarios. The assumptions on energy efficiency characteristics of the different technology options are documented in the support study.

A4.2.10 Determination of technological conversion costs and compliance costs

A4.2.10.1 Cost 2015-2019 (Evaluation)

Businesses directly affected by the 2014 revision of the Regulation and addressed in the cost assessment for the evaluation were:

- EU ***F-gas using industries***, i.e. the ***operators of equipment*** usually relying on F-gases (or low-GWP alternatives), and

- Businesses involved in the ***supply chain of the gases***, i.e.
    - Producers and importers of gases
    - Gas distributors
    - Service companies.

Capital expenditure (capex) and operational expenditure (opex) incurred ***by F-gas using industries*** in the evaluation period 2015 -2019 have been calculated in the AnaFGas modelling framework. Capex and opex can be added to result in total expenditure (totex) and compared between both scenarios for all sectors of F-gases use. The spread between totex calculated for the baseline scenario, the counterfactual scenario (evaluation) and the three policy option scenarios (impact assessment) are the 'operative compliance costs'. These can be averaged over the evaluation period and divided by the average totex of the counterfactual scenario/baseline to provide a relative increase or decrease in totex for F-gas using sectors looking backwards (evaluation) and forwards (impact assessment).

Capex includes the equipment operators' investment in new hardware. In all F-gas application sectors where the gases are not directly emitted on application, the cost of the first fill of F-gases is also considered as capex, e.g. the first fill of refrigerants into a refrigeration equipment. Opex includes the cost of refill of gases into equipment (to balance losses from leakage), the cost for electricity or fuel needed to operate the equipment and maintenance cost affected by the Regulation (i.e. additional cost for leak checks and repairs as imposed for HFC installations by the Regulation, and for installations using CO_2, NH_3 or hydrocarbons as refrigerants instead of HFCs).

For a meaningful assessment of ***F-gas using industries'*** compliance cost it is crucial to differentiate compliance cost between costs related to:

a) **technological change** and
b) **HFC price increases** induced by the HFC phase-down supply limitations.

The cost of technological change is borne by those equipment operators which invest in alternatives to the established HFC-based technologies and thus possibly experience a difference in capex and/or opex.

Cost experienced by equipment operators for the first fill or refill of gases/refrigerants are split into a:

- (Counterfactual) reference price [€/kg] which does not take into account HFC price increases induced by the HFC phase-down, and
- HFC premium [€/t CO_2 eq] induced by the HFC phase-down and as observed on the EU HFC markets. Based on the EU HFC price monitoring conducted by Öko-Recherche, an average HFC premium of 8 €/t CO_2 eq at gas distributor selling price level, or 16 €/t CO_2 eq at service company selling level, is estimated as an average for the 2015-2019 evaluation period. Note that HFC taxes as charged in some EU Member States have not been considered for the analysis as such taxes are not directly related to the 2014 revision.

The counterfactual reference prices of used gases are considered for the calculation of the cost of technological change. The cost for the HFC premium, however, is allocated to the cost for the HFC price increase.

The cost of the HFC price increase is borne by:

- operators of existing (HFC-based) equipment which needs to refilled subject to increased HFC prices,
- operators of new installations still based on established high-GWP HFC-based technologies or on substitution technologies relying on alternative medium-GWP HFC substitution technologies.

The cost for operators of such medium HFC substitution technologies (e.g. AC equipment relying on HFC-32 (GWP 625) instead of the previously established R410A (GWP 2088)) is thus partly allocated to cost of technological change and partly to cost of increased HFC prices.

It should be noted that the HFC price increase borne by the equipment operators and F-gas users is being 'offset' (in cost-benefit analysis terms) by equivalent additional profits in the ***businesses in the supply chain of HFCs***:

- On one hand, it is the producers and importers[136] of HFCs that can sell the gases to the gas distributors at considerably higher prices than they could have done without the Regulation. Given the free allocation of quota under the Regulation, these additional revenues come without associated cost[137].
- On the other hand, service companies usually charge their customers (i.e. operators of equipment in need of refill) a levy in proportion to bulk prices (e.g. a fixed mark-up on bulk prices) and thus fully hand down and additionally add to any upstream price increase. The same principle holds for gas distributors, situated between producers/ importers in the HFC supply chain. On average, prices per kg of gas sold at service level are approximately twice the price of gases sold by distributors at bulk level[138].

Thus, when considering both the ***equipment operators*** and the ***gas supply chain*** as the affected industries in the cost assessment, equipment operators' cost for the HFC price increases is fully offset by respective profits in the HFC supply chain, and the overall **net** compliance costs are limited to the equipment operators' cost of technological change. Only cost of technological change, i.e. the net cost, are directly linked emission reductions. Emission reduction costs for the evaluation (and the impact assessment) are therefore limited to the cost of technological change.

[136] Importers of bulk HFCs receive quota for free. However, importers of pre-charged RAC equipment do have to acquire quota authorisation from quota holders. Thus, equipment importers are basically in the same situation as the EU original equipment manufacturers (OEMs): Both have to pay GWP-based a premium on the HFCs charged / to be charged into equipment. Findings of the Öko-Recherche HFC prices management support that authorisation cost have been approximately at the same level as HFC prices increases experienced by EU OEMs.

[137] Except for small admin cost related to quota management.

[138] Source: EU HFC price monitoring conducted by Öko-Recherche

For a meaningful comparison of the change in operative cost to equipment operators against reductions in the demand and/or emissions of F-gases the involved data sets have to be recalculated to comparable annual amounts: In most of the F-gas sectors, a switch from an established (HFC-based) technology to a low-GWP substitution technology for a new installation implies that the demand of F-gases (measured in tCO_2e) is strongly reduced in the first year of operation due to the avoided or reduced first fill. In subsequent operation years of such a new installation the annual demand reduction is much lower as only the refill to compensate for leakage losses is reduced. For actual emissions avoided from such a new installation the distribution over the operation lifetime is different: Emission (and thus emission reductions) occur first in usually low quantities during the first fill of the equipment, and then as leakage emissions during the whole lifetime. The largest single emission event over the equipment lifetime, however, occurs with the disposal of the equipment as usually not the complete remaining charge of F-gases is recovered at that point in time. For a thorough assessment of emission reduction cost, the emission reductions of a single model installation (compared to a counterfactual reference installation) thus needs to be averaged over the complete equipment lifetime.

The observed emission reductions in the 2015-2019 evaluation period cover the reductions observed in the first few operational years of new equipment installed in 2015-2019. The observed emission reductions thus logically cannot cover the emission reductions to be expected in the future for the remaining years of use and at the time of disposal. Therefore, the ***average annual emission reductions observed for 2015-2019 are significantly below the 'implied' annual emission reductions*** from those new installations if averaged over the complete lifetime of the installations. Typical lifetimes in the RAC sector are 10-15 years, for other equipment such as foams this may be up to 50 years. For demand reduction it is the other way around: Due to the avoided/reduced first fill, the average annual demand reductions observed for 2015-2019 are disproportionally high compared to 'implied' annual demand reductions from those same new installation if averaged over the complete lifetime of the installations. Recalculations from observed 2015-2019 emission reductions to **implied lifetime-averaged lifetime-integrated annual emission reductions** from equipment installed in 2015-2019 were made in the AnaFgas modelling framework. Recalculation factors are sector-specific and are influenced mostly by assumptions for equipment lifetime, lifetime emission factors and emission factors at disposal.

Next to emissions, costs also need to be recalculated to annual amounts in order to merge Capex and Opex in a meaningful way for a calculation of emission or demand reduction cost: For that purpose, Capex are annualised over equipment lifetime using a discount factor of 4%[139]. Annualised Capex and average Opex are then added to derive average annualised compliance cost for the installations operated in the 2015-2019 evaluation period.

Based on this approach, operators' ***emission reduction cost for technological change*** are calculated by dividing the annualised cost for technological change of new equipment installed in the 2015-2019 evaluation period by the implied average annual emission

[139] A value of 4% is suggested in the EU Better Regulation Guidelines.

reductions of that new equipment installed in the 2015-2019 evaluation period. In order to allow for aggregation across sectors, lifetime-integrals of emission reductions and cost are used rather than annual averages. The emission reduction cost for technological change are methodologically comparable to GHG abatement cost usually calculated for GHG emission reduction measures in other sectors.

A4.2.10.2 Costs for the baseline and options (2024-2036 and 2050)

In analogy to the analytic approach taken for the evaluation of the Regulation (see immediately above), operative compliance cost of the users (= operating equipment relying on F-gases or alternatives) are separately analysed for cost of technological change and cost incurred due to HFC price increases induced by the HFC-phasedown: Cost of technological change are based on investment and operating expenditures of equipment, assuming pre-phase-down price levels (2014). The impact of HFC prices on F-gas users, that has risen in the past and may be expected to further rise in the future due to the quota system, are captured as HFC-price related cost increases. Future HFC prices are discussed in 6.2.1.2.

Total compliance costs are expressed € per year and as percentages of total equipment operators' expenditures in the baseline scenario, and are further differentiated into

- costs of additional HFC price increases to be expected under respectively modified HFC reduction schedules, to be borne by those users which continue to operate or invest in equipment relying on HFCs, (such costs are reflected as profits in the HFC supply chain, or as state income related to revenues from the sale of quota);
- costs of technological change for investment in and operation equipment relying on low-GWP alternatives.

Emission reduction costs compare the cost of technological change for investment in and operation of equipment based on low-GWP alternatives to the emissions saved during the lifetime of the respective equipment. In line with the methodology applied for the evaluation, equipment operators' cost for increased HFC prices are not considered for the calculation of emission reduction cost as those HFC-price related costs are borne by those operators which do not (fully) replace high-GWP HFCs and thus do not contribute to emission savings. Cost due to further increases of the HFC-price are thus not directly linked to actual emission reductions and lead to distributional effects (see 6.2.1.4). As for operators' total compliance cost, the time horizon is on equipment installed in the 2024-2036 timeframe, as well as an outlook to 2050.

A4.3 Macroeconomic modelling (JRC-GEM-E3 model)

A4.3.1 JRC-GEM-E3 Model Overview

JRC-GEM-E3[140] (General Equilibrium Model for Economy-Energy-Environment) is a recursive dynamic Computable General Equilibrium model operated at the European Commission's Joint Research Centre. It is a global model, covering the 27 EU Member

[140] https://joint-research-centre.ec.europa.eu/gem-e3/gem-e3-model_en

States, alongside 15 other major countries or world regions. With a detailed sectoral disaggregation of energy activities (from extraction to production to distribution sectors) as well as endogenous mechanisms to meet emission constraints, the JRC-GEM-E3 model has been extensively used for the economic analysis of climate and energy policy impacts.

Divided into 35 sectors of activity, firms are cost-minimizing with Constant Elasticity of Substitution (CES) production functions. Sectors are interlinked by providing goods and services as intermediate production inputs to other sectors. Households are the owner of the factors of production (skilled and unskilled labour and capital) and thereby receive income, used to maximize utility through consumption. Household consumption follows a linear expenditure demand system, translating production outputs by industry into 14 final consumption categories via a consumption matrix, while government consumption is considered exogenous. Bilateral trade-flows are allowed between countries and regions using the Armington trade formulation where goods from different goods are imperfect substitutes. In 5-year steps, an equilibrium is achieved at goods and services markets, and for factors of production through adjustments in prices.

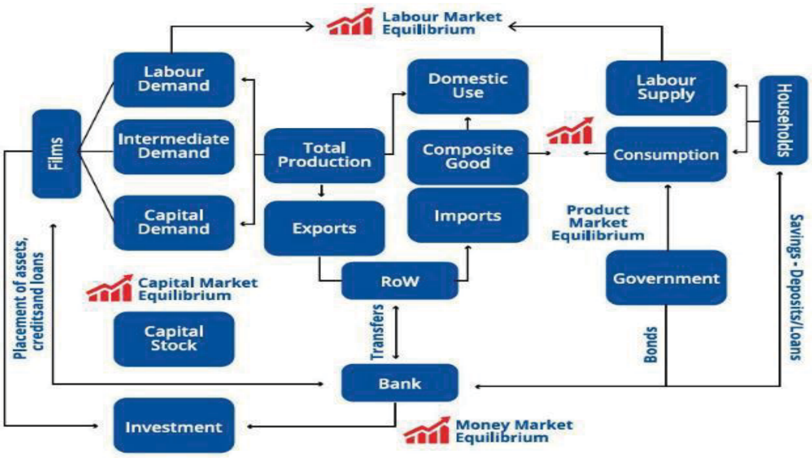

Figure 14. A schematic representation of the JRC-GEM-E3 model
Source: *JRC-GEM-E3 model*

The JRC-GEM-E3 model is normally applied to compare (various) policy options against a baseline scenario, representing the evolution of the global economy under current energy and climate policies. The model can be used to assess the impacts of the energy and climate policies on macroeconomic aggregates such as GDP and employment. Further relevant results by JRC-GEM-E3 include sectoral output, investment, employment, exports, imports, and GHG emissions.

A4.3.2 Description of the baseline

The starting point of the analysis is the EU Reference Scenario 2020, the common baseline developed for the Fit for 55 impact assessments. It provides projections for energy demand and supply, as well as GHG emissions in all sectors of the European economy under the current EU and national policy framework. It embeds in particular the EU legislation in place to reach the 2030 climate target of at least 40 % compared to 1990, as well as national contributions captured in the National Energy and Climate Plans to reaching the EU 2030 energy targets on energy efficiency and renewables under the Governance of the Energy

Union. Projections for GDP, population and fossil fuel prices take into account the impact of the COVID-19 crisis and are aligned with the 2021 Ageing Report[141]. A more detailed description can be found in the impact assessment covering the revision of the ETS Directive[142].

The JRC-GEM-E3 baseline integrates inputs from energy system models (generally PRIMES for EU Member States and POLES-JRC for the rest of the world) on a number of variables of interest, such as a detailed use of energy products by consumers, global fuel prices, etc. The implementation of the EU Reference scenario into JRC-GEM-E3 is using the Piramid methodology[143], reproducing the energy balances of the PRIMES model for the EU Reference scenario and being fully harmonized with the macro data used to drive PRIMES for the EU (and UK). For non-EU regions (except UK), energy balances were taken from POLES-JRC, in particular the model runs produced for the Global Energy and Climate Outlook 2020[144]. These also take into account the macroeconomic consequences of COVID-19 and likely (persistent) changes in the transportation sector.

A4.3.3 Implementation of the F-gas reduction scenarios in JRC-GEM-E3

The JRC-GEM-E3 model is used in this impact assessment to determine the macroeconomic implications of the three scenarios, incorporating the cost implications derived from the AnaFgas model as an input. Under this set-up, the JRC-GEM-E3 model's own representation of f-gases is not used, instead only the economic consequences arising from additional abatement cost, cost savings (e.g. from lower energy use or reduced equipment expenditure) and increased user cost (due to cost increases in end user cost due to the value of the HFC quota) are represented in the model.

In this impact assessment (and contrary to the set-up chosen in the 2012 impact assessment[145]), an end user perspective is taken. The modelling allocates the burden of abatement and the changes in costs on end users. Compared to an upstream modelling approach which models the cost of f-gas abatement on the chemical sector, this approach better targets the limited number of specific downstream sectors that are affected.[146] Further, this approach better represents the situation with respect to trade of f-gases.[147] The end user

141 Potentially need to add a reference: The 2021 Ageing Report: Underlying assumptions and projection methodologies https://ec.europa.eu/info/publications/2021-ageing-report-underlying-assumptions-and-projection-methodologies_en

142 SWD(2021)601

143 See https://joint-research-centre.ec.europa.eu/global-and-eu-macroeconomic-baselines-policy-assessments_en

144 Keramidas, K., Fosse, F., Diaz-Vazquez, A., Schade, B., Tchung-Ming, S., Weitzel, M., Vandyck, T., Wojtowicz, K. Global Energy and Climate Outlook 2020: A New Normal Beyond Covid-19, doi: 10.2760/608429, JRC123203.

145 SWD(2012) 364

146 The chemical sector in JRC-GEM-E3 is relatively broad and chemicals leading to F-gas emissions only contribute a small fraction of the sector. However, in the upstream approach, all users of chemicals are equally affected; the effects are concentrated in the chemical industry sector. Other implications, e.g. energy savings on end users are difficult to implement under the upstream approach.

147 In the upstream approach, imported chemicals are a substitute to domestic chemicals. However, both imports and domestic products are covered by the F-gas regulation.

approach sheds light on the effects of various industries and households, taking advantage of the endogenous demand adjustments of the JRC-GEM-E3 model, which determine changes to demand for intermediate and final products. The JRC-GEM-E3 top-down modelling therefore complements the bottom-up analysis carried out in the AnaFgas model by providing a macroeconomic view, calculating effects on GDP, employment etc. Through the interlinkages between sectors, JRC-GEM-E3 further reports results on upstream sectors, such as supplies to the equipment sectors. Consistent with this approach, changes in the user cost due to a change in the value of the HFC quota are also modelled at the level of the end user, assuming a full pass through of the cost to the end user.

The end user approach facilitates the implementation handshake between the AnaFgas model and JRC-GEM-E3 model, as the costs provided by AnaFgas are in categories of end users. The allocation of costs (or savings) to the end users in JRC-GEM-E3 is performed in two steps. First, end-users of the technologies covered by AnaFgas inputs are mapped to the various agents (sectors, households) in the JRC-GEM-E3 model. Second, the costs are allocated across the EU-27 Member States using population, or alternative indicators when available. This downscaling of EU aggregate numbers allows reporting impacts for the EU North and South regions. Cost increases (or decreases) for each category are reported by AnaFgas in five categories (chemicals, equipment, services, energy, and user cost due to the HFC quota) which are mapped to the corresponding JRC-GEM-E3 sectors.[148] The additional purchases (savings) required for abatement are then available in a two-dimensional variable capturing the provider and end user of abatement, which can be readily used in the JRC-GEM-E3 model equations.[149] Additional purchase requirements increase the demand from sectors providing abatement and increase the cost of the end use products while the opposite holds true for cost reductions.

[148] Energy is allocated to electricity for stationary air conditioning and heat pumps, while for mobile air conditioning, the fuel mix of the commercial transport sector of JRC-GEM-E3 was used (no energy saving was reported for private vehicles). Energy savings for households are allocated to the household consumption category "Fuels and Power". This reflects the modelling of durables and related non-durables purchases in JRC-GEM-E3.

[149] See Weitzel, M., Saveyn, B., & Vandyck, T. (2019). Including bottom-up emission abatement technologies in a large-scale global economic model for policy assessments. *Energy Economics*, 83, 254-263.

Table 21. Mapping of AnaFgas model sectors to JRC-GEM-E3 sectors and regions

AnaFgas sector	Equipment operators / end users	Correspondence with JRC-GEM-E3 end users	Indicator used for allocation to Member States	Source for indicator
Domestic Refrigeration	Private Households	Households (purchase of appliances)	Population	European Commission 2021 Ageing Report
Commercial refrigeration - Hermetics	Commerce: Sale of food to customers	Market Services	Population	European Commission 2021 Ageing Report
Commercial refrigeration - Condensing units		Market Services	Population	European Commission 2021 Ageing Report
Commercial refrigeration - Central systems		Market Services	Population	European Commission 2021 Ageing Report
Industrial refrigeration - small	Cold storage in food industry and by retailers	Consumer goods (50%) & Market Services (50%)	Population	European Commission 2021 Ageing Report
Industrial refrigeration - large		Consumer goods (50%) & Market Services (50%)	Population	European Commission 2021 Ageing Report
Transport refrigeration - Vans	Distribution & delivery of food	Market Services	Population	European Commission 2021 Ageing Report
Transport refrigeration - Trucks & Trailers		Market Services	Population	European Commission 2021 Ageing Report
Transport refrigeration - Ships	Fishing vessels	Livestock	Distribution of fishing vessels by number (weight 50%) and size (weight 50%)	Eurostat [fish_fleet_alt]
Room AC - Moveables	Private homes & offices,	Households (purchase of appliances)	Energy use for cooling in residential buildings	EU Reference 2020
Room AC - Single split	equipment under control of inhabitants	Households (purchase of appliances)	Energy use for cooling in residential buildings	EU Reference 2020
Room AC - Rooftop	Larger residential or commercial buildings, centrally operated equipment	Services (Market and non-market)	Energy use for cooling in commercial buildings	EU Reference 2020
Room AC - VRF		Services (Market and non-market)	Energy use for cooling in commercial buildings	EU Reference 2020
Minichillers	Commercial & industrial buildings, centrally operated equipment	Services (Market and non-market)	Energy use for cooling in commercial buildings	EU Reference 2020
Displacement chillers - small		Services (Market and non-market)	Energy use for cooling in commercial buildings	EU Reference 2020
Displacement chillers - large		Services (Market and non-market)	Energy use for cooling in commercial buildings	EU Reference 2020
Centrifugal chillers	Large commercial & industrial buildings, centrally operated	Services (Market and non-market)	Energy use for cooling in commercial buildings	EU Reference 2020

	equipment			
Heat pumps - small	Private homes, equipment under control of inhabitants	Households (purchase of appliances)	Energy use for heat pumps in residential buildings	EU Reference 2020
Heat-pumps - medium	commercial buildings	Services (Market and non-market)	Energy use for heat pumps in commercial buildings	EU Reference 2020
Heat pumps - large	Larger residential, commercial or industrial buildings, centrally operated equipment	All industrial and services sectors, households through district heat	Use of steam	EU Reference 2020
Mobile AC - Passenger cars	Private & commercial owners of passenger cars	Households (purchase of private vehicles)	Stock of private cars	EU Reference 2020
Mobile AC - Buses	Bus transport undertakings	Land transport	Stock of buses	EU Reference 2020
Mobile AC - Trucks N1	Operators of road vehicles for commercial transport of goods	Land transport	Stock of light-duty vehicles	EU Reference 2020
Mobile AC - Trucks N2		Land transport	Stock of heavy-duty vehicles	EU Reference 2020
Mobile AC - Trucks N3		Land transport	Stock of heavy-duty vehicles	EU Reference 2020
Mobile AC - Passenger ships	Water transport undertakings: Ferries / cruise ships etc	Water transport	Activity (pkm) of passenger ships	EU Reference 2020
Mobile AC - Cargo ships	Water transport undertakings: transport of goods	Water transport	Activity (tkm) of freight ships	EU Reference 2020
Mobile AC - Tram	Public transport operators	Land transport	Activity (pkm) of trams and metro	EU Reference 2020
Mobile AC - Metro		Land transport	Activity (pkm) of trams and metro	EU Reference 2020
Mobile AC - Train		Land transport	Activity (pkm) of trains	EU Reference 2020
Aerosols - technical	Domestic & industrial applications	Chemicals	Output of chemical sector	JRC-GEM-E3 baseline
Aerosols - MDIs	Domestic use (pharmaceutical products)	Households (medical and health expenditures)	Population	European Commission 2021 Ageing Report
Fire extinguishers	Special commercial &	Other equipment manufacturing	Population	European Commission 2021 Ageing Report

	industrial sectors			
Solvents	Special industrial applications	Chemicals	Output of chemical sector	JRC-GEM-E3 baseline
Foam OCF	Insulation of buildings and equipment (fridges, freezers etc)	Market Services	Population	European Commission 2021 Ageing Report
Foam XPS		Market Services	Population	European Commission 2021 Ageing Report
Foam PU spray		Market Services	Population	European Commission 2021 Ageing Report
Foam PU non-spray		Market Services	Population	European Commission 2021 Ageing Report
Switchgear MV	Operators of electrical transmission & distribution grid	Electricity supply	Output of electricity supply sector	JRC-GEM-E3 baseline
Switchgear HV		Electricity supply	Output of electricity supply sector	JRC-GEM-E3 baseline

A4.3.4 Relevant closure rules and key assumptions

Alternative model assumptions can be made about a number of model parameters and closure rules of the JRC-GEM-E3 model. In this assessment, it was assumed the labour market is imperfect, i.e. no full employment is assumed. The implementation is based on a wage curve where increasing real wages lead to increased labour supply while decreasing real wages lead to increased unemployment. The policy scenario can therefore lead to increases or decreases of employment.

The modelling of the increased user cost arising from the value of the HFC quota is implemented as a tax faced by the respective end user. This assumes a full path through of cost to the end user. As government expenditure is held constant in the policy scenarios relative to the baseline, any additional revenue is recycled *lump sum* to households. Therefore, this implementation has an influence on the consumption choices of households and input choices of firms due to altered product prices, but no direct influence on income of the representative household. As there is only one representative household per region, this modelling approach is equivalent to modelling free allocation of quota rights to firms, which in turn would include the value of the quota allocation in the final price of their product, leading to windfall profits. Under both a tax and free allocation with windfall profits, user prices would change in the same way and in both cases the representative household would ultimately obtain the revenues (either via *lump sum* transfers from the government or in the form of capital rents/dividends paid by firms).[150] Obviously, the modelling outcome therefore would also be the same for any combination of a quota allocation price and free allocation to industry.

The main limitation of the GEM-E3 model is the ability of the model to pick up very small impacts on macro-economic parameters, that may result for some variables from F-gas policies, as the latter only affect specific sectors and stakeholders of the overall economy.

A4.4 Determination of administrative costs

For **administrative costs to industry**, industrial stakeholders were asked to provide information on costs for any relevant policy options. The Regulation affects many different types of companies (gas producers, distributors, importers, equipment manufacturers, service companies, end users etc.) and in many different ways (different measures affect different companies (types)). The data collected was therefore necessarily incomplete. This required further analysis based on the data collected taking these issues into account. The cost for each measure is therefore based upon a combination of expert judgement and feedback received from stakeholders. Table 55 in Annex A15 provides the details of the methodology used to calculate the impact upon administrative burden for each policy option. This includes the approach used to determine the number of companies impacted by the proposed measure, and the change

[150] If the modelling would include more than one representative household, the two options would lead to different distributional consequences.

in administrative cost per company as a result. For a number of measures the administrative cost is expected to be consistent across different sized companies. For others an adjustment that had to be made due to the fact that the stakeholder consultation focussed primarily upon interviews and feedback from large business organisations. From the data provided by stakeholders, average days per measure was used in preference to monetary costs per measure since it was considered there was a risk that the monetary estimates could include costs which are rather adjustment costs – e.g. for costs associated with the phase-down. The final number of estimated working days was calculated based upon the aggregated working days for each company. A cost of EUR 230 per day was applied to calculate a total estimated cost (based on an assumed average annual salary of around EUR 50,000, and annual days worked around 220).

At **European level**, the costs were estimated by the DG CLIMA and the EEA. **Table 63.** Detail of the calculation and assumptions for administrative burden of the European Commission and **Table 64.** Detail of calculation and assumptions for administrative burden of the EEA in Annex A14.4.1 give the details of the assessment approach and assumptions made.

For **Member States'** costs, all 27 Member States were asked to fill out a questionnaire related to the administrative costs expected for relevant policy options. Evidence and data regarding the potential costs was somewhat scarce, given the nature of the exercise: future not yet incurred needed to be estimated, and administrative burden typically depends on the detailed implementation of the future measure. The assessment is therefore based on qualitative sentiment provided by the stakeholders, coupled with the administrative burden estimates from the evaluation for related measures and expert evaluation. **Table 65** in Annex A14.4.2 gives the details of the assessment approach and assumptions made.

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PART 2/2

COMMISSION STAFF WORKING DOCUMENT

IMPACT ASSESSMENT REPORT

Accompanying the document

Proposal for a
REGULATION OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL

on fluorinated greenhouse gases, amending Directive (EU) 2019/1937 and repealing Regulation (EU) No 517/2014

{COM(2022) 150 final} - {SEC(2022) 156 final} - {SWD(2022) 95 final} - {SWD(2022) 97 final}

EN EN

A5 Evaluation of Regulation (EU) No 517/2014

A5.1 Introduction

A5.1.1 Purpose and scope

This evaluation assesses if Regulation (EU) No 517/2014 on fluorinated greenhouse gases (hereafter: the Regulation)[151] is fit for purpose by examining its effectiveness, efficiency, coherence, relevance and EU added value. The assessment covers the period of application from 2015 to today (i.e. until most recent available data) and the geographic scope is the EU-28 (including UK).

The Commission has reviewed the Regulation due to the new climate objectives under the European Green Deal as well as in order to better tackle some implementation challenges notably related to illegal imports. In addition, it is also necessary to ensure that the Regulation can safeguard EU compliance with new international obligations under the *Montreal Protocol on substances that deplete the ozone layer* (hereafter: the Montreal Protocol).

This evaluation also responds to Article 21(2) of the Regulation that requires the Commission to publish a comprehensive report on its effects no later than 31 December 2022, including in particular:

- A forecast of the continued demand for hydrofluorocarbons (HFCs[152]) 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 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;

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151 Including its implementing act: Commission Implementing Regulation (EU) 2019/661 of 25 April 2019; Commission Implementing Regulation (EU) 2016/879 of 2 June 2016; Commission Implementing Regulation (EU) 2015/2068 of 17 November 2015; Commission Implementing Regulation (EU) 2015/2067 of 17 November 2015; Commission Implementing Regulation (EU) 2015/2066 of 17 November 2015; Commission Implementing Regulation (EU) 2015/2065 of 17 November 2015; Commission Implementing Regulation (EU) No 1191/2014 of 30 October 2014 amended by Commission Implementing Regulation (EU) 2017/1375 of 25 July 2017, Commission Implementing Regulation (EU) 2018/1992 of 14 December 2018 and Commission Implementing Regulation (EU) 2019/522 of 27 March 2019; Commission Regulation (EC) No 304/2008 of 2 April 2008; Commission Regulation (EC) No 306/2008 of 2 April 2008; Commission Regulation (EC) No 307/2008 of 2 April 2008; Commission Regulation (EC) No 1497/2007 of 18 December 2007; Commission Regulation (EC) No 1497/2007 of 18 December 2007; Commission Regulation (EC) No 1516/2007 of 19 December 2007

152 HFCs (hydrofluorocarbons) are the most common type of fluorinated greenhouse gases, used in particular in cooling appliances (i.e. refrigeration, air conditioning including heat pumps)

- 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 results of this evaluation feed into the impact assessment of the future Regulation. The evaluation and impact assessment have been undertaken "back-to-back", with a joint stakeholder consultation process.

A5.2 Background to the intervention

A5.2.1 Description of the intervention and its objectives

A5.2.1.1 The problem

Fluorinated greenhouse gases (F-gases) are man-made synthetic substances that include hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), sulphur hexafluoride (SF_6) and other fluorinated compounds. They are produced for use in certain products and equipment, e.g. for refrigeration and air conditioning (AC: including heat pumps[153]) equipment, insulation foams, aerosol sprays, fire protection equipment, electricity transmission and can also be used as solvents. **All F-gases contribute to climate change as they often have very high global warming potentials (GWP[154]) once emitted into the atmosphere.** The most commonly used F-gases have a warming effect ("climate forcing") that is several thousand times higher than that of CO2. To be able to compare F-gas emissions with other greenhouse gas emissions, quantities of F-gases are mostly expressed in terms of the impact they would have after 100 years if they were CO_2 emissions. Thus F-gas emissions can be expressed in both tonnes of CO2 equivalent (tCO2e) and their weight in metric tonnes (t).

Emissions can occur at various stages e.g. when F-gases are being produced by the chemical industry, transported, stored, filled into (products and) equipment or when they leak during the lifetime or decommissioning of (products and) equipment. Some uses are also outright emissive in nature, e.g. aerosol sprays and solvents.

Production and consumption of F-gases, specifically HFCs, increased considerably from 1990 because they were widely employed as substitutes for ozone depleting substances (ODS), which needed to be phased out globally under the Montreal Protocol to protect the ozone layer. **As a result, the emissions of F-gases in the EU almost doubled from 1990 to 2014** – in contrast to emissions of all other greenhouse gases, which decreased.

However, **today there are suitable alternatives to the use of F-gases with a very low climate impact in most sectors and applications.** These include the so-called *natural alternatives* such as hydrocarbons (e.g. propane, butane, cyclopentane), ammonia, CO_2 or water. There are also *synthetic alternatives* such as the hydro(chloro)fluoroolefins

[153] In general when air conditioning (AC) is mentioned it should be understood as including heat pumps.

[154] GWP is a metric for determining the relative contribution of a substance to climate warming. The GWP of a substance is set relative to the warming effect of CO2 (GWP=1) over a timeframe of 100 years

(hereafter H(C)FOs)[155]. These are often blended with HFCs in order to lower the overall GWP of the mixture.

A5.2.1.2 The international context

The impact of the F-gas Regulation is relevant for international obligations under both the Paris Agreement on Climate Change and the Montreal Protocol.

The most common F-gas emissions are monitored by the United Nations Framework Convention on Climate Change (UNFCCC) and the Paris Agreement under which **the EU must report on the status of the reduction commitments made and on legislative efforts to achieve greenhouse gas (GHG) emission reductions**. The EU's mechanism for monitoring and reporting the different types of greenhouse gas emissions is laid down in Regulation (EU) No 525/2013 ("Monitoring Mechanism Regulation", MMR).[156]

Due to rising HFC emissions **Parties to the Montreal Protocol decided in 2016 to** implement a **global HFC phase-down** which will reduce HFC production and consumption by more than 80 % over the next 30 years (Kigali Amendment). **This implies that each Party must comply with an HFC consumption and production reduction schedule as well as licensing import/export and reporting on HFCs.** It is estimated that The Kigali Amendment alone will **save up to 0.4°C** of additional warming by the end of the century and thus contribute significantly to the Paris Agreement goal to stay well below 2°C warming of the climate and pursue efforts to limit it to 1.5°C.

A5.2.1.3 EU legislation on fluorinated greenhouse gases

The EU's first legislation aiming at reducing F-gas use and emissions predates the Kigali Amendment by a decade and established the EU as a frontrunner in this policy area. The 2006 F-gas Regulation[157] focused to a large degree on containment or "better management" of F-gases, i.e. avoiding that emissions occur during use of products and equipment and at their end of life. This was reflected in e.g. provisions on certification and training of technicians dealing with F-gases, leakage checking of equipment, company record keeping and F-gas recovery requirements at end of life, labelling of F-gas containers and equipment as well as company reporting. The only major sector addressed by a use prohibition in 2006 was the automobile sector (passenger cars), which is regulated separately by Directive 2006/40 /EC ("MAC Directive") and not subject to this evaluation[158].

The current F-gas Regulation came into force in 2015. It introduced an EU HFC phase-down and has a significantly higher level of ambition than the 2006 Regulation. It was specifically designed to 'make a significant contribution to reducing

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155 H(C)FOs, which chemically are unsaturated H(C)FCs meaning there is an double bond in the molecule making them more prone to degradation, break down rapidly in the atmosphere which lowers their warming effect as compared to HFCs

156 Regulation (EU) No 525/2013 accessible under https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:32013R0525

157 Regulation (EC) No 842/2006

158 Prohibiting the use of HFCs with a GWP > 150 in air conditioning of new passenger cars type approved after 2011 and all new passenger cars after 2017 regardless of type approval date.

GHG emissions in the EU' by 80 to 95% in 2050 compared to 1990 levels though the following specific objectives:

- 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, stimulating innovation and developing green technologies by improving market opportunities for alternative technologies and gases with low GWP.

To ensure a proportionate contribution to the (outdated) climate targets, policy measures that could reduce emissions at abatement costs of less than 50 € per tCO2e abated were included, as this was the cost threshold considered economy wide in the Low Carbon Roadmap for 2050[159] at that time (2011). Modelling showed that the selected measures would result in a reduction of 60% in 2030 compared to 2005, meaning F-gas emissions should decrease by 70 MtCO2e to ca. 35 MtCO2e. Care was also taken to limit undesirable effects on SMEs and employment, the administrative burden for companies and authorities and to preserve the competition in the internal market to the extent possible.

New measures set out in the Regulation included a measure that is gradually reducing the amount (in tCO2e) of HFCs that importers and producers may place on the market every year ("EU HFC phase-down"), and a number of placing on the market bans for products and equipment with F-gases in sectors where alternatives are available. All measures from 2006 were retained and some were slightly extended.

The "HFC phase-down" is implemented through annual quotas to importers and producers of HFCs. The total amount of quota is reduced in 3-yearly steps from 2015 to 2030 and will end up at 21% of the starting point. However, gases used for certain special purposes are not subject to the quota system.[160] Furthermore, since 2017 manufacturers and importers of cooling equipment filled with HFCs, must ensure that the amount of HFCs is accounted for under the quota system. To do so equipment importers can e.g. obtain an equivalent amount of authorisations from a quota holder to use his quota. The scarcity of HFC supply results in higher HFC prices, which in turn promotes:

159 COM (2011) 112 A Roadmap for moving to a competitive low carbon economy in 2050

160 Exemptions exist for imports for destruction, for feedstock use in producing other chemicals, for re-export of bulk gases, for the use in metered dose inhalers (MDIs, e.g. asthma sprays), for use in the semiconductor industry and for use in military applications.

a shift towards climate-friendly alternatives, better leakage prevention to avoid refilling with the expensive gases as well as increased recycling/reclamation of HFCs.

The intervention logic (Figure 15) illustrates the causality of the Regulation in delivering expected results and impacts, by linking them to objectives, actions, and outputs. The intervention logic starts from the **needs** that the Regulation is intended to address and its general objective (to 'make a significant contribution to reducing GHG emissions in the EU' by 80 to 95% in 2050 compared to 1990) and specific and operational objectives. **Inputs** from various actors and a range of **activities** are leading to a number of **outputs,** e.g. a functioning quota system, licensing, labelling, leakage prevention and recovery, training and certification of service personnel. These outputs are expected to deliver the **effects** (e.g. emission reduction and increased use of alternatives) and **impacts** (e.g. climate targets and green growth).

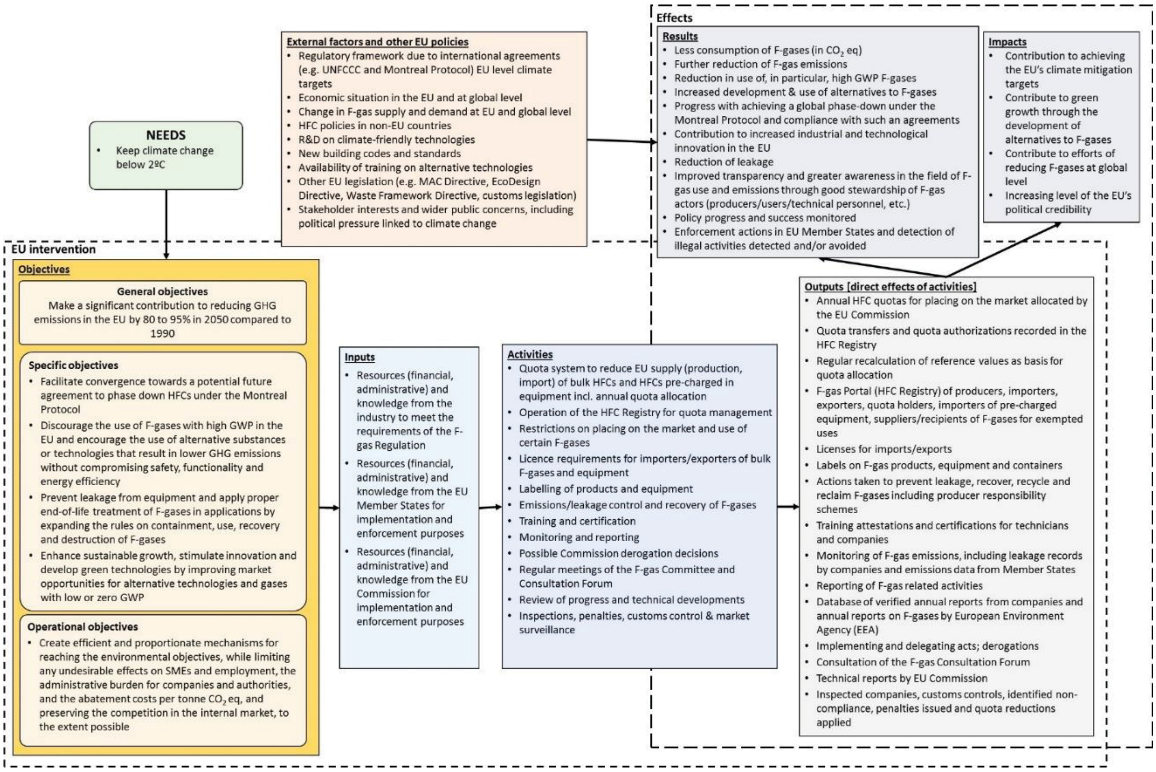

Figure 15. Logical framework of the Regulation

External factors may also influence the delivery of the stated objectives. Such factors include: other regulatory frameworks (both internationally or at EU/national level); 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. a growing online market); R&D on climate-friendly technologies in other markets; broader stakeholder interests and wider public concerns (including political pressure linked to climate change).

Since the Regulation was adopted pursuant to Article 192 (1) of the 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 compatible with the TFEU, provided the Member State notifies the EU Commission of any such measures.

A5.3 Baseline and points of comparison ("Counterfactual scenario")

To determine the effects of the Regulation, the baseline scenario (current Regulation in place) is compared to the counterfactual scenario (old rules preceding the Regulation). The counterfactual scenario takes into account the previous (2006) F-gas Regulation and the (2007) MAC Directive (the latter covering F-gas use in passenger cars). The previous Regulation included comprehensive measures on containment and recovery, which reduce losses of F-gases from products and equipment, both during the use phase of the equipment and its end-of-life, in particular for cooling equipment in the sectors of refrigeration and stationary air conditioning. In addition, it is expected that new equipment would be less leaky due to better technologies and that equipment lifetime emission rates would be declining. On the other hand there would be **only limited reduction in HFC use (new demand) and related future emissions** because the measures having this aim were rather limited in scope[161].

Future F-gas demand and emissions are also influenced by external factors such as population growth, economic and technical developments and lifestyle changes (e.g. increased use of comfort cooling and heating as well as a shift towards heat pumps). A positive correlation between population size and F-gas use is generally assumed. 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 passenger 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. These external factors affect the counterfactual and the baseline in similar ways.

In the counterfactual scenario, the overall F-gas demand in the years from 2015 (i.e. from when the Regulation was in force)[162] would have increased by 4% in metric tonnes, but would have decreased by about 5% in CO_2e (

[161] E.g. use in windows, shoes, tyres, one-component foams, aerosol generators for entertainment purposes, non-refillable containers, direct evaporation systems, fire protection with PFCs; as well as use in larger installations of magnesium die-casting

[162] It is useful to look at the counterfactual from 2010 to see when differences to the baseline scenario start appearing. As many of the envisaged changes, albeit not the detail, became known already from the time of the Commission proposal in 2012, some market players may have already reacted before 2015 to these early signals. This is actually confirmed by a comparison with the baseline where (very) small differences in demand already appear in 2013/2014 (see Annex A11.1.2)

Table 21). This difference between metric vs. CO2e indicates a slight tendency towards an increased use of lower GWP gases. F-gas emissions, which often occur years later after being charged into the equipment[163], would still increase slightly in the same period, from 123 to 126 MtCO2e. The composition of the various F-gases is shown in Figure 16. Hence, **the high quantities of HFCs (and other F-gases) emitted would have continued mostly unabated without the current Regulation.**

[163] As a result, demand reductions do not quickly translate into emission reductions. There is a significant "lag time" of several years

Table 22: 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*

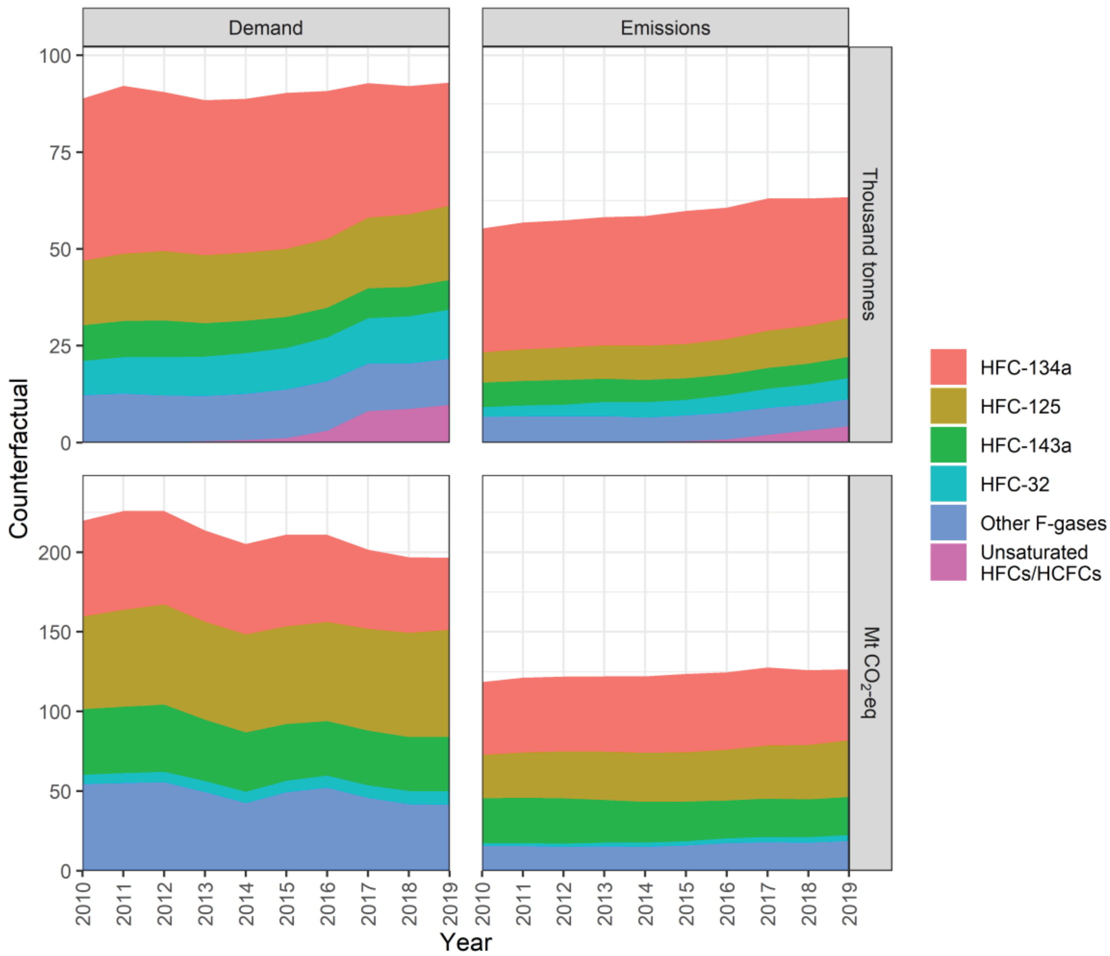

Figure 16: Modelled demand and emissions of F-gases by gas/gas group in the counterfactual scenario between 2010 and 2019 for the EU

Source: *AnaFgas modelling*

A5.4 Implementation / State of Play

A5.4.1 Description of the current situation

A5.4.1.1 Affected stakeholders

The F-gas policy affects a diverse group of stakeholders in different ways, e.g.:

- *Producers and importers of F-gases*: Primarily affected by the HFC phase-down quota mechanism and related provisions including requirements on registration as well as import/export licensing, annual reporting, sectoral prohibitions and labelling of F-gas containers.
- *Exporters of F-gases*: Compliance with licence need for export (registration requirement) and annual reporting requirements.
- *Bulk gas distributors*: Affected by labelling requirements and sectoral prohibitions.
- *Manufacturers and importers of products and equipment*: Primarily affected by quota system and documenting compliance ("declaration of conformity") for import as well as placing on the market restrictions for new equipment, labelling and annual requirements for reporting.
- *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, keeping of records and sectoral prohibitions.
- *Service technicians/companies*: Affected by provisions on containment (i.e. leakage checks and repair) and certification needs 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.
- *Feedstock users*: Must comply with the reporting requirements. Feedstock use[164] is not part of the HFC phase-down but losses need to be minimised (Article 7(1) and evidence needs to be provided that trifluoromethane (HFC-23) generated as a by-product is destroyed or recovered for further use (Article 7(2)) (and not emitted).
- *Reclamation & destruction facilities*: Need to comply with reporting requirements, but reclaimed quantities of F-gases are not covered by the HFC phase-down scheme.
- *Training providers & certification bodies*: Need to offer training and evaluation/certification processes in line with the minimum requirements set by the relevant implementing acts and the national programmes set up on this basis.

[164] Feedstock use means the use of a chemical substance in chemical production processes where the substance is entirely used up to synthesise other substances

A5.4.1.2 EU supply of F-gases

Supply of F-gases to the EU market[165] is likely to result in future emissions when gases leak from equipment during their use or at the end of useful life of the equipment. In climate terms, supply was relatively stable until 2017, at quantities above 200 MtCO2e (Figure 17). The year 2014 was exceptional as it was characterised by very large imports and stock building of HFCs in preparation for the EU phase-down that began in 2015. **The supply of F-gases decreased drastically in the years 2018 (27% reduction from 2017) and once again in 2019 (42% reduction from 2017)**. The relative contribution of the other F-gases (i.e. PFCs, SF_6, NF_3 and other gases listed in Annex II) to supply therefore rose to 24% in 2020, from levels of 15% in 2015 (in tCO_2e). Among the Annex II gases, the supply in tonnes of H(C)FOs (unsaturated HFCs and HCFCs) has increased significantly since 2017, but in terms of climate impact they amounted to less than 0.1 $MtCO_2e$ per year due to their low GWP.

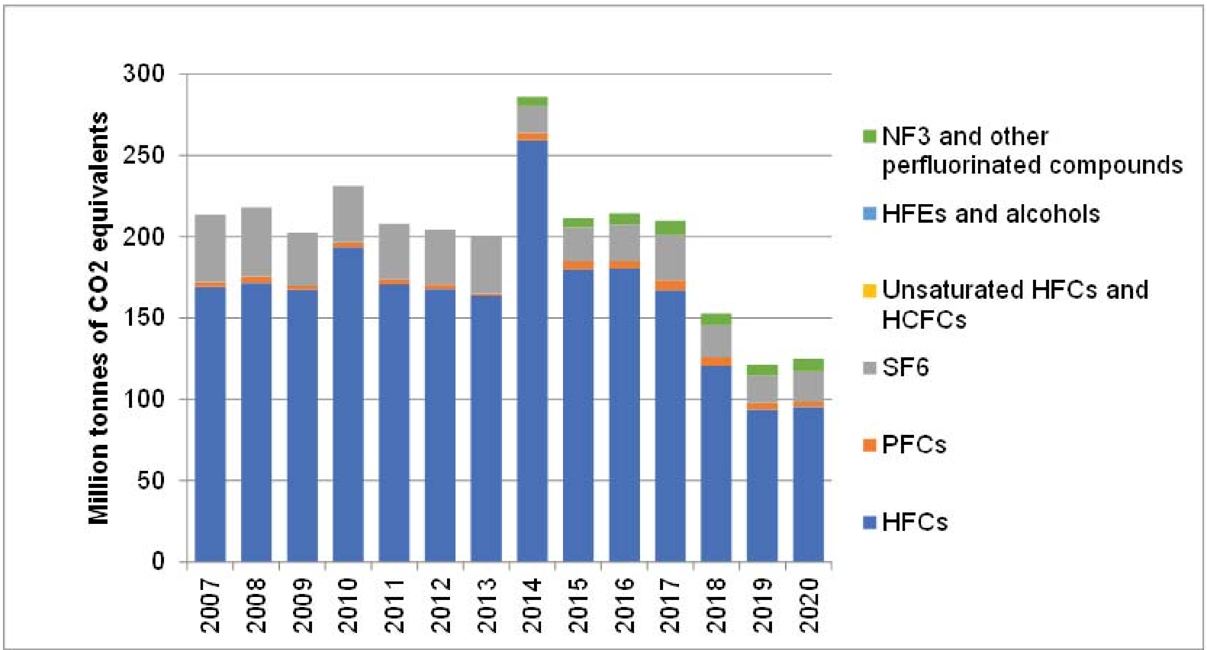

Figure 17. EU supply of F-gases
Note: From 2007 to 2013, only HFCs, PFCs and SF_6 had to be reported on and imports in products and equipment (ca. 11%) were not included.
Source: *[EEA 2021 F-gases reporting data]*

A5.4.1.3 Intended use of F-gases

The most common F-gases are HFCs used in RAC equipment (about two-thirds of F-gases in climate terms). Electrical equipment (SF_6), electronics manufacture (HFC-23,

165 "Supply" is a parameter calculated on the basis of available data on imports, stocks, production etc. that indicates the actual use of F-gases by EU industry. It includes gases imported in products in equipment as well as those exported in products and equipment. It is similar to the "demand" derived from modelling, which is however based rather on the yearly gas "requirements" of filling new and old equipment. "Demand" also does not include gases filled into exported equipment.

PFCs, SF_6, NF_3) and use as aerosol sprays (including MDIs: HFCs) make up most of the remainder of F-gas usage, see Figure 18.

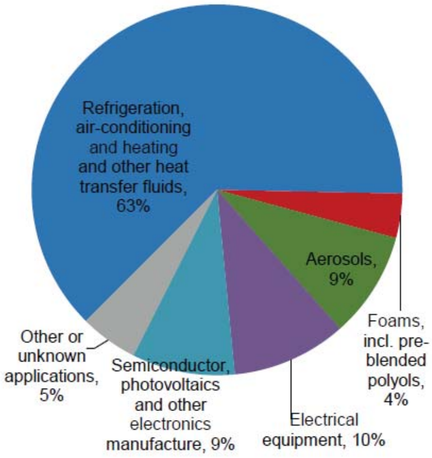

Figure 18: Intended uses of the total EU supply of F-gases in 2019 (in CO2e)
Source: *[EEA 2020 public report]*

A5.4.1.4 EU emissions of F-gases

From 2004 until 2014, F-gas emissions had been increasing year-on-year. Since then, emissions have started to fall, in particular those related to HFCs (which represent ca. 85% of total F-gas emissions), while PFCs and SF_6 emissions appear to have remained relatively stable in recent years, see Figure 19.

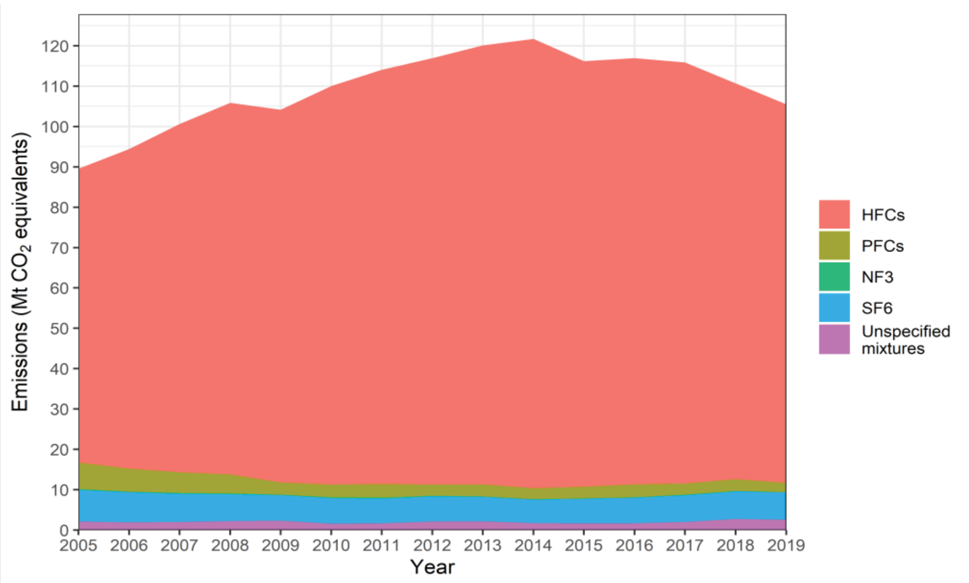

Figure 19: F-gas emissions in the EU-28 by substance group
Source: *AnaFgas modelling (2021)*

A5.4.2 State of Implementation

A5.4.2.1 Implementation at EU level of the HFC phase-down and reporting

The Commission implements the HFC phase-down at EU level. The quotas are based on a formula that ensures that the annual quantity of quota is reduced in accordance with the phase-down schedule and it takes into account three elements:

- An individual **reference value** (incumbent companies only). The Commission must establish new reference values for companies every 3 years, which means that new entrants are gradually becoming incumbents.
- A pro-rata quota share to new entrants and incumbents (from 2018) that have **declared that they need (more) quota from a reserve.** The Commission invites incumbents and new entrants every year to declare if they need quota from the reserve. The share of the total quota allocated from the reserve started out at 11%. The more declarations there are, the lower the individual quota.
- In case a company has exceeded its quota in a given year, the Commission **imposes a penalt**y corresponding to a reduction in quota of 2 times the exceedance for that company the next year(s).

The phase-down steps are expressed in declining percentages of a maximum amount that partly depends on what happened in previous years. Thus the total quota amount cannot be precisely predicted years in advance.

The Commission calculates and allocates annual quotas to HFC bulk importers and producers **for free** by uploading the quotas in the F-gas Portal and Licensing system (the Registry). This **Registry** is open 24-7 and complemented by manuals and a help desk that is answering thousands of requests every year. The Registry includes:

- **Registrations of importers, producers and exporters** of bulk HFCs. The Registry includes their **trade licence** and keeps track of their **annual quota**, their **authorisations** given to equipment importers and potential **quota exceedances** (ex post).
- **Registrations of HFC equipment importers**. It keeps track of their **acquired authorisations to use quota** and includes a **delegation module** for equipment importers that allows them to pool their authorisations and a function to **find quota holders** that may wish to authorise (part of) their quota (match making).
- **Registrations of all companies that have reporting obligations**. The **annual company reporting data** is collected and stored in the European Environment Agency's (EEA) Business Data Repository (BDR). Reporters can find an auditor carrying out independent verification of the yearly (bulk and equipment) reports.
- Member States competent authorities and custom have access to the Registry.

Figure 20 shows the amount of quota allocated each year (blue dot) and the way the quota was used by HFC producers and importers to either place bulk HFCs on the market (green) or to authorise an equipment importer to use the quota (purple). While some quota holders exceeded their quota, the total allowable quota ceiling was respected in all years.

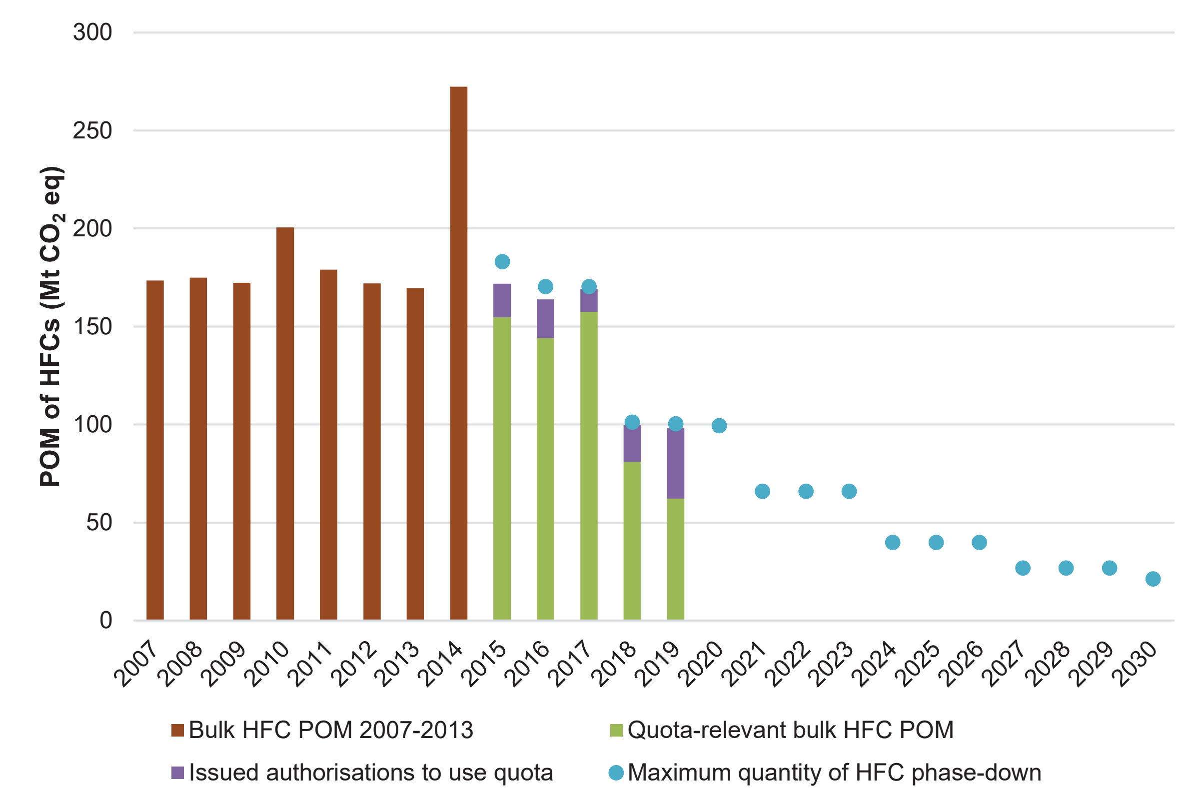

Figure 20: Placing on the market (POM) of HFCs in the EU
Source: *EEA, Annual report on fluorinated greenhouse gases 2020*

There are, however, some issues relating to the implementation of the phase-down which are outlined in the effectiveness section (A5.6.1).

A5.4.2.2 Implementation at MS level

The Member States are in general responsible for enforcing all measures of the Regulation, which includes **custom controls and market surveillance and setting effective, proportionate and dissuasive penalties**. Italy and Romania received a formal notice in July 2019 for failing to establish and notify national penalties as required by 1 July 2017. In response, the two notifications were received in late 2019 and early 2020, respectively. Since HFC prices are high in the EU (due to the phase-down), it is rather profitable to circumvent the quota system and penalties for illegal imports must be relatively high to be dissuasive. Industry and an NGO are questioning the dissuasiveness of penalties in some Member States. The Commission has reminded Member States repeatedly of the need to continue to reassess their penalties in the light of EU HFC price developments and the Commission opened an EU pilot in October 2021 for Romania due to the perceived insufficiency of penalties on quota non-compliance.

Industry and an NGO are also concerned about the different levels and/or insufficiency of controls at customs or market surveillance level. Authorities on the other hand pointed to a lack of clarity of the rules that complicated putting in place efficient controls. To increase clarity, best practice guidelines for enforcing F-gas rules at customs were developed in 2020 by a group of Member States under the Customs 2020 programme.

Member States updated their relevant **training, attestation and certification** bodies for technical personnel. Such programmes already existed as a result of the previous Regulation and needed only to be marginally extended in scope, e.g. to include refrigerated trucks and trailers and information about alternatives to F-gases.

A requirement to **collect emissions data** is done in different ways by Member States. Some rely on inventories and expert studies and some have established equipment registers. Member States are not (yet) commonly using those data for their UNFCCC reporting.

Member States are also encouraged by the Regulation to develop **producer responsibility schemes** for the recovery, recycling, reclamation and destruction of HFCs. There are a number of schemes in place to support HFC recovery at end of life, including take-back schemes (DK, FR, NL), deposit-refund schemes (DK), or refrigerant tax rebates (ES). Further schemes are planned by EE and MT. Where these schemes have been implemented, they are generally considered to be working well by stakeholders, but direct data on their performance is lacking. Some producers felt these schemes create the risk of free-riders. There are also voluntary take-back schemes organised by industry on SF_6 equipment (e.g. DE, ES).

Some Member States have implemented additional measures such as tax schemes (e.g. DK, ES, FR), additional requirements for F-gas related customs controls (e.g. EE) or leakage checks (e.g. FI, PO, SE), additional national reporting requirements and databases (e.g. CZ, EE, HU, IT, PL), better control over the distribution chain of HFCs (DE) or measures to support the market uptake of low GWP alternatives (e.g. FI, DE, SE), and voluntary agreements on SF_6 (DE, ES).

A5.5 Methodology

A5.5.1 Short description

The work was supported by an external study and work by external experts carried out between April 2020 and October 2021 (Oeko-Recherche et al., 2021[166]).

Eleven evaluation questions were developed to guide the analytical work on the five evaluation criteria. The questions and a detailed **evaluation matrix** that includes sub-questions, assessment criteria, indicators and data analysis approach as well as sources and collection methods are given at the end of this annex (A5.8).

An extensive literature review was conducted to inform the assessment based on the evaluation criteria. It involved an in-depth review of a range of sources, including current or previous work being undertaken by project partners; from reports and other evidence at pan-European level 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.

[166] Support contract for an Evaluation and Impact assessment for amending Regulation (EU) No 517/2014 on fluorinated greenhouse gases (CLIMA.A2/ETU/2019/0016): Evaluation Final Report)

The technical input from a series of **Commission reports,** required by Article 21 of the Regulation, were also taken into account.[167]

Another important source for this evaluation is the **annual company reporting data** related to production, imports (including equipment), exports, destruction, and feedstock use of F-gases. These data are compiled and comprehensively analysed in annual reports produced by the EEA.[168]

A5.5.2 Modelling to derive baseline and counterfactual scenario

In order to quantify the effect of the Regulation, a bottom-up stock model at sub-sectoral basis was set up to calculate yearly demand and emissions of F-gases in metric tonnes and CO_2e 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)[169], but was updated with the most recent data available in the course of this work. In the following, AnaFgas refers to the updated model used for this evaluation. A detailed description of the model can be found in Annex A4.

Demand is defined as quantities of gas required for first filling of new equipment and re-filling of existing equipment in a given year.

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 of parameters used to identify these emissions can be found in the external study.

167 REPORT FROM THE COMMISSION on barriers posed by codes, standards and legislation to using climate-friendly technologies in the refrigeration, air conditioning, heat pumps and foam sectors, COM/2016/0749 final (https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:52016DC0749); REPORT FROM THE COMMISSION of assessing the 2022 requirement to avoid highly global warming Hydrofluorocarbons in some commercial refrigeration systems, C(2017) 5230 final (https://ec.europa.eu/clima/sites/default/files/f-gas/legislation/docs/c_2017_5230_en.pdf);
REPORT FROM THE COMMISSION assessing the quota allocation method in accordance with Regulation (EU) No 517/2014, COM(2017) 377 final (https://ec.europa.eu/clima/sites/default/files/f-gas/legislation/docs/com_2017_377_en.pdf);
REPORT FROM THE COMMISSION on the availability of refrigerants for new split air conditioning systems that can replace fluorinated greenhouse gases or result in a lower climate impact, C(2020) 6637 final (https://ec.europa.eu/clima/sites/clima/files/news/docs/c_2020_6637_en.pdf);
REPORT FROM THE COMMISSION assessing the availability of alternatives to fluorinated greenhouse gases in switchgear and related equipment, including medium-voltage secondary switchgear, C(2020) 6635 final (https://ec.europa.eu/clima/sites/clima/files/news/docs/c_2020_6635_en.pdf); and
REPORT FROM THE COMMISSION on the availability of hydrofluorocarbons on the Union market, C(2020) 8842 final (https://ec.europa.eu/clima/sites/clima/files/f-gas/docs/20201216_c_2020_8842_en.pdf)

168 https://www.eea.europa.eu/publications/fluorinated-greenhouse-gases-2020

169 https://ec.europa.eu/clima/sites/default/files/f-gas/docs/2011_study_en.pdf

The baseline and counterfactual scenarios were calculated for the period from 2010 to 2019. This is useful to cover the period before any changes could take an effect and discover when a discrepancy is first discovered[170]. The counterfactual scenario is an update of the "with measures" (WM) scenario from the preparatory study for a review of Regulation (EC) No 842/2006 by Schwarz et al. (2011) which takes into account the actual data on e.g. developments in technology, sales and stocks, population growth and gross domestic product (the WM was forward looking and based on assumptions). Also, it was necessary to include data for Croatia (not included in WM). This update implies that the counterfactual is consistently higher than the WM scenario by 6-8%.

A5.5.3 Macro-economic analysis

An evaluation of economic effects was 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)"[171] over time. This sector is considered as most representative of the EU industry sectors affected by the Regulation, representing approximately 80 % of HFC demand.

A counterfactual scenario is constructed by applying three steps: First, economic development of the sector 28.25 with regard to the development observed for total industry by establishing a time series for the coefficient between sectoral and total development[172]. Second, the trend for this coefficient prior to the revision of the Regulation is derived from a simple linear trend analysis for the years 2010 to 2014[173]. Finally, the pre-revision trend is extrapolated into the future (2015+) to arrive at the counterfactual development for the years 2015 to 2018. Impacts on employment were analysed using an analogous methodology. 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.

A5.5.4 Assessment of adjustment costs to industry

In the assessment of the costs to Businesses a distinction is made between:

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170 As is apparent from Figure 22, first signs of an impact on demand are seen from 2013 and 2014. This is assumed to be due to "early birds" market players that react already to the writing on the wall, i.e. the measures proposed in the Commission proposal in 2012 and the discussions during the negotiations. However, these effects are of course very small.

171 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

172 "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.

173 Any effects before 2015 that may be linked to the Regulation as seen for demand (see section A5.5.2) are so small that cost differences would not be picked up by this analysis.

- ***F-gas using industries***, i.e. the ***operators of equipment*** (end-users) usually relying on F-gases (or low-GWP alternatives), and
- **Businesses involved in the *supply chain of the gases***, i.e. producers and importers of gases; gas distributors and service companies.

Equipment manufacturers are also impacted but any costs incurred are taken into account as higher equipment prices for the F-gas using industry.

The total expenditure (totex) for all F-gas using industries has been calculated for the period 2015 -2019 using the AnaFGas model both for the baseline and counterfactual scenario. It takes into account:

- Capital expenditure (capex), which includes the equipment operators' investment in new hardware. In all F-gas application sectors where the gases are not directly emitted on application, the cost of the first fill of F-gases is also considered as capex, e.g. the first fill of refrigerants into refrigeration equipment
- Operational expenditure (opex), which includes the cost of refill of gases into equipment (to balance losses from leakage), the cost for electricity or fuel needed to operate the equipment and maintenance costs affected by the Regulation (i.e. additional cost for leak checks and repairs as imposed on HFC installations by the Regulation, and for installations using CO_2, NH_3 or hydrocarbons as refrigerants instead of HFCs)..

The difference in total costs between the two scenarios are the 'operative compliance costs' of the Regulation. These have been averaged over the evaluation period and divided by the average totex of the counterfactual scenario to provide a relative increase or decrease in totex for F-gas using sectors.

For a meaningful assessment of F-gas using industries compliance, the adjustment costs are divided into:

- **costs of technological change** which are borne by those equipment operators that invest in alternatives to the established HFC-based technologies; and
- **costs related to HFC price increases**[174] which are borne by operators of existing (HFC-based) equipment which need to be refilled subject to increased HFC prices as well as operators of new installations that still buy HFC-based technologies.

However, the costs for users related to any increase in the price of HFCs are 'offset' (in cost-benefit analysis terms) by equivalent additional benefits to ***businesses in the supply chain of HFCs,*** *i.e.*:

- producers and importers[175] of HFCs that can sell the gases to the gas distributors at considerably higher prices than they could have done without the Regulation.

[174] Based on the EU HFC price monitoring an average HFC premium of 8 €/t CO_2e at gas distributor selling price level, or 16 €/t CO_2e at service company selling level for the 2015-2019.

[175] Importers of bulk HFCs receive quota for free. However, importers of pre-charged RAC equipment do have to acquire quota authorisation from quota holders. Thus, equipment importers are

Given the free allocation of quota under the Regulation, these additional revenues come without[176] associated costs.

- service companies that usually charge their customers (i.e. operators of equipment in need of refill) a levy in proportion to bulk prices (e.g. a fixed mark-up on bulk prices) and thus pass on and add to any upstream price increase. The same principle applies for gas distributors, situated between producers/importers and e.g. service companies in the HFC supply chain. On average, prices per kg of gas sold at service level are approximately twice the price of gases sold by distributors[177].

Consequently, the **gas price increase is having distributional effects** and the overall net cost to business is zero. Total adjustment costs are therefore limited to the changes in investment and operating costs related to technological changes.

A5.5.5 Administrative costs

Industrial stakeholders were asked to provide information on administrative costs that are additional to those that were already incurred as a consequence of the 2006 Regulation. The Regulation affects many different types of companies (gas producers, distributors, importers, equipment manufacturers, service companies, end users etc.) and in many different ways (different measures affect different companies (types)). Thus, the data collected needed to be complemented by further analysis. This detailed analysis, assumptions made and data considered are given in Annex A14. By way of example, one adjustment that had to be made was due to the fact that the stakeholder consultation focussed primarily on interviews and feedback from large business organisations. Costs were therefore adjusted for small and medium firms based on levels of activity. For some measures, the costs for large companies were expected to be equivalent to the costs borne by small and medium companies. The final number of estimated working days was calculated based on the aggregated working days for each company. A cost of EUR 230 per day was applied to calculate a total estimated cost (based on an assumed average annual salary of around EUR 50,000, and annual days worked - around 220).

For the **EU Commission** the costs were estimated by DG CLIMA. The data for the **EEA** are based on EEA time recording and invoice information from EEA's contractors.

All 27 **Member States** were asked to fill out a questionnaire related to the administrative costs associated with the implementation and enforcement of the Regulation. The questionnaire provided the option of reporting either time or financial expenses (average number of annual working days or average annual cost in €) and invited information on the certainty of estimates. The respondents were not able to provide answers to all the

basically in the same situation like EU original equipment manufacturers (OEMs): Both have to pay GWP-based a premium on the HFCs charged / to be charged into equipment. Findings of the Öko-recherche HFC prices management support that authorisation cost have been approximately at the same level as HFC prices increases experienced by EU OEMs.

176 Except for small admin cost related to quota management.

177 Source: EU HFC price monitoring conducted by Öko-Recherche

questions and the figures obtained include a combination of time effort and monetary expenditure estimates. The level of certainty ranges from ‘definitive’ to ‘rough estimates.’ Nonetheless, a good base of data was collected from the competent authorities on which an estimate of administrative costs could be made. In total 13 Member States provided information on administrative burden[178], with six noting upfront costs. To arrive at total costs, the data from those Member States that provided cost data were aggregated and extrapolated to an overall total using the number of reporting companies in each Member State[179]. This approach, considering the total number of reporting companies, has been applied to the majority of measures as this was considered to provide the most accurate basis for extrapolating the costs. However, where appropriate, in some cases the extrapolation has been based upon the number of reporting importers within Member States.

A5.5.6 Consultations

The consultation exercise was carried out in parallel with those for the impact assessment of potential changes to the Regulation. The main consultation activities were the following:

- Stakeholder feedback received on the Initial Impact Assessment.
- Public consultation from 15 September to 29 December 2020. A total of 241 responses and 44 attachments were provided which are available on ‘Have your say’[180].
- 34 additional semi-structured targeted stakeholder interviews (16 Member States competent authorities, 2 customs authorities, 1 NGO and 16 EU business associations/companies). In addition, two competent authorities and two customs authorities provided written responses to the interview questions.
- A full-day stakeholder workshop (virtual) on 6 May 2021 with 355 participants, primarily industry stakeholders representing relevant business organisations and associations, but also NGOs and public authorities were represented. Additional written feedback could be provided until 24 May (69 submissions received).

A summary of the stakeholder consultation activities and findings is presented in the Consultation Synopsis report (Annex A2).

A5.5.7 Limitations and robustness of findings

A5.5.7.1 Limitations related to the data available

The following limitations on data were detected:

- Reporting data used to examine the effectiveness of **placing on the market restrictions** only covers imports (not EU produced equipment) and does not

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178 13 Member States provided data based on time effort required, and 9 Member States provided data on financial costs.

179 EEA report - 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

180 https://ec.europa.eu/info/law/better-regulation/have-your-say

provide a precise sector split. Also, reporting data for placing on the market restrictions only goes up to 2020, so one cannot judge the impact of prohibitions which fall after this date.

- No comprehensive data is available on **labelling compliance**, which is difficult to separate from related obligations e.g. under the Classification, Labelling and Packaging (CLP) and the Registration, Evaluation, Authorisation and Restriction of Chemicals (REACH) Regulations.
- No comprehensive data is available on **recycled and reclaimed F-gas quantities**. 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 and existing databases are not publicly available or are confidential. No consistent data set tracking leakage rates pre-implementation are available.
- It is not feasible to make an accurate estimate of the **level of illegal imports**.[181] As a consequence, the levels of demand and emissions presented throughout the reporting and modelling analysis on demand and emissions do not capture any quantities from illegal imports.

A5.5.7.2 Limitations related to the AnaFgas model

The following limitations of the AnaFgas model should be noted:

- 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* (i.e. on an annual basis) from actual demand while accurately predicting the longer term trends (i.e. multi-annual).
- For the assessment of the 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 costs rely on expert judgement and industry input.
- A clear separation of the **impacts of the different individual measures** of the Regulation on e.g. the demand for HFCs or F-gas emissions is not always possible. By way of example, observed reduction effects on HFC demand and emissions in the model cannot be cleanly ascribed to specific prohibitions, the overall phase-reductions or smaller leakage rates due to the containment provisions. Generally, specific effects of measures can only be extracted from the model when no confounding effects of other measures are present. For other F-gases that are not HFCs, on the other hand, direct effects of prohibitions can be more easily extracted from the model results (as they are not covered by the phase-down and containment measures mostly do not apply).

[181] https://ec.europa.eu/clima/sites/default/files/f-gas/legislation/docs/report_illegal_trade_hcf_en.pdf

A5.5.7.3 Macroeconomic and cost analysis

Finally, the following approximations were made in the analysis:

- **Stakeholder costs** cannot be split by business size, Member State or measure with any degree of confidence. Technical compliance costs were assessed by application sub-sectors, which hardly correlate with business sizes
- There is little published data or studies on the **administrative burden** placed on different stakeholders by the Regulation. To close this gap, data was requested from stakeholders repeatedly but data collected remained limited, in particular regarding costs to industry, both due to limitations in the evidence available on costs per undertaking, the number of undertakings affected and the type of companies affected by different measures and in different ways. These gaps were filled by expert judgement to provide quantitative estimations. In addition, cost data collected was predominantly provided by larger firms and as a proxy, the costs for small and medium firms were scaled down.
- The analysis of **macro-economic effects** is based on a simple analysis of trade flows, production and employment in the most relevant F-gas sectors used as a proxy for the rest of the market. This approach was deemed appropriate as effects at this level and over the relatively short timeframe (2015-2020) are small and very difficult to detect at the economy-wide level. The results are in line with the main conclusions on efficiency that were based on the analysis of compliance and administrative costs.

A5.6 Analysis and answers to the evaluation questions

A5.6.1 Effectiveness

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% reduction in emissions by 2030. The modelling exercise confirms that the demand and resulting emissions savings are a result of the Regulation, as compared to the counterfactual scenario (compare Figure 22). The drop in demand (13% in CO2e) is more striking than that of emissions (6% in CO2e), because emissions occur years after gases are put into equipment (from leakage, losses at end-of-life etc.). The largest changes are observed in refrigeration (62% of emission reductions), and to some degree in air conditioning, while a transition is also going on in other HFC using sectors. Forward modelling indicates that **emissions will continue to fall significantly but the 2030 emission goal set for the Regulation may not be fully reached** (see efficiency). **Still it can be concluded that overall the measures in the Regulation have worked rather effectively**.

The degree to which the four specific objectives are being met is summarised below.

A5.6.1.1 Objective 1: Discourage the use of F-gases with high GWP in the EU and encourage the use of alternative substances or technologies

The development of the F-gas supply to the EU market is an indication of the extent to which the Regulation managed to discourage the use of F-gases. **For HFCs, the supply**

declined by 37% in metric tonnes and 47% in terms of CO2 equivalents between 2015 and 2019. A significant share of the decline in HFC supply was due to a lower use of a few types of high GWP HFCs and HFC mixtures (R134a[182], R404A and R410A) **and a shift to natural alternatives and the synthetic alternatives, H(C)FOs**. Users of natural refrigerants have the advantage that they are not restricted in any way under the Regulation, but this also means that data on their consumption is not collected. The supply of the synthetic alternatives, H(C)FOs, has grown to about 18,000 tonnes (2019 data; from 1,300 tonnes in 2014). In addition, while the amounts of **HFCs imported inside of products and equipment** have remained rather constant in metric tons since 2016, the **GWP of these HFCs dropped by 33 % from 2015 to 2019** (see Figure 21). This is a clear indication that this sector has shifted from using higher warming HFCs (e.g. R410A) to HFCs with a medium-high GWP (e.g. R32). These findings indicate that **the HFC phase-down (i.e. the quota system) combined with placing on the market (POM) and use prohibitions worked rather well.**

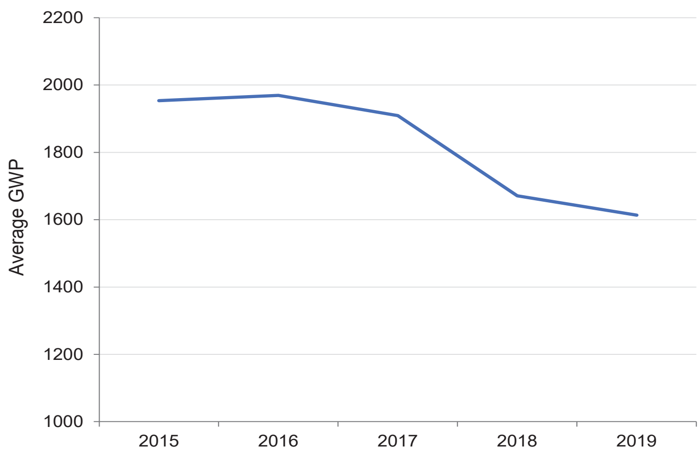

Figure 21. Development of average GWP in HFC supply

By design, the HFC phase-down restricts supply in CO2 equivalents. Prices of high GWP HFCs increased significantly in mid-2017 and early 2018 reaching a peak of 6 to 13 times higher than the original price in 2015[183]. The observed price increases for the different HFCs roughly reflected their GWP[184] and were passed on from the upper to the lower levels of the refrigerant supply chain. Prices of high GWP HFCs in the 3rd quarter of 2021 continue to be two to seven times higher (compared to 2014) depending on the supply chain level and **therefore continue to be an incentive for innovation**. Since, **prices for HFC alternatives have remained rather stable** climate-friendly technologies have become more competitive. Stakeholders agreed that the HFC phase-down in combination with prohibitions has proven to be an effective measure. Some

182 The ability to reduce supply for HFC-134a is partly due to a lower need for this gas in the production of new passenger cars from 2017. This is an effect of the MAC Directive which is both taken into account in the counterfactual and the baseline scenario.

183 https://ec.europa.eu/clima/document/download/11f89677-c97e-420d-97b7-97b9ad14618a_en

184 The higher the GWP of the HFC the more quota is needed for the same metric quantity. Thus the higher the GWP of the HFC the higher is the price increase for the gas.

stakeholders suggested that the phase-down has been the most important measure of the Regulation as it provides flexibility and clarity and is driving change.

The phase-down also **incentivised the reclamation of F-gases in the EU, resulting in a low, but steady increase of these activities**. Based on the reported data under the Regulation[185], reclaimed HFCs made up 8 % of the amount produced in 2019, equalling 3 % of the EU supply of virgin HFCs (or 9 % and 4 % respectively in CO_2e). This means that quantities reclaimed have roughly tripled since 2014. This is assumed to be a direct consequence of gases having a higher value as a result of the quota system, making reclamation activities more attractive. A reclaimed gas is of the same quality as virgin gas but does not require any quota to be placed on the EU market. HFCs make up the vast majority of reclaimed F-gases in metric tonnes (97 %), with SF_6 contributing approximately 20 % in tCO2e of reclaimed gas. As not all reclamation facilities are required to report today, the real numbers are expected to be higher.

The placing on the market and use prohibitions were implemented successfully as seen by the reporting data, and were considered to be effective by stakeholders. Prohibitions related to F-gas products and equipment appear to be mostly complied with (on the basis of Article 19 reporting data). The successful technological transition reflects that prohibitions were introduced where suitable alternatives were available. This is supported by the fact that no derogations on the basis of Articles 11(2) and 11(3) were made. The prohibitions efficiently avoided the use of HFCs in certain applications where this was easy and economical to do, while facilitating the availability of HFCs where finding alternatives is more difficult or costly in the context of scarce overall 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. Still, there appears to be further **potential to reduce HFCs, in particular in the area of AC. Furthermore, some emissive types of uses that could be avoided are currently not restricted**, e.g. uses of HFCs for cooling skin in beauty clinics and some inhalation anaesthetics in hospitals.

Moreover, the Regulation has not promoted a transition for uses that are not covered by the phase-down (exempted or non-HFC) **and/or prohibitions**. As regards the exempted uses, HFCs amounts (in CO2e) for **metered dose inhalers (MDIs) has even increased by about 45% since 2015.** Feedstock use (for which there are normally no alternatives) was rather constant in that period and amounts related to export exemptions have been fluctuating. Semiconductor and military uses remained moderate and accounted for only 3 % of total quota exemptions in 2019. Some stakeholders noted that the quota exempted uses were a cause for concern. Others signalled that pharmaceutical undertakings are moving to lower GWP propellants (the first undertakings have announced their intention to commercialise the first lower GWP MDIs by the end of 2025).

[185] Currently only producers, importers, and exporters are reporting on reclamation activities. Any company that does not fall into any of these company types but carries out reclamation is currently not obliged to report. The data is therefore incomplete.

As regards other gases, SF_6 and PFCs represented 18 % of F-gas emissions in terms of CO2e due to their very high GWP (ranging from 7 000 to 23 000), but there are few restrictions on their current use. In particular, in the case of **SF_6 for use in electrical transmission, suitable alternatives have been developed, intensively researched or even placed on the market in the past years, but the Regulation is not sufficiently promoting the deployment of these new alternatives**. Also, there is **concern that use of SO_2F_2** in pest control of timber for export, is not **currently covered by the Regulation**,

Consequently, the Regulation has been **less effective in promoting a transition to climate friendly alternatives for quota exempted uses, some special HFC uses and for F-gases other than HFCs**.

A5.6.1.2 Objective 2: Prevent leakage from equipment and proper end of life treatment of F-gases in applications

Because there is still a large bank of existing equipment and products that contain F-gases, prevention of leakages remains key to achieving significant emission reductions. To this end, the Regulation is building on the rules put into place by the previous F-gas Regulation as they had already proven to be effective. Data available from surveys in a number of Member States has shown the importance of regular leakage checks and associated servicing activities, especially in the commercial refrigeration sector, as **HFC leakage rates from cooling equipment have declined (further) in recent years**. Data from a comprehensive Polish database shows that leakage rates have declined in all cooling equipment (refrigeration, air conditioning) from 12.6% average in 2016 to 3.0 % in 2020. This trend also appears to have been generally observed in Germany and Slovakia. Such reductions result in both savings on adding new (expensive) gas and better energy efficiency of the equipment. Similarly, some data suggests that recovery rates may also have gone up in recent years.[186] Roughly two-thirds of quantities were reported to have been recovered from maintenance activity and one-third from equipment at end-of-life in France. In Poland about 30% of recovered refrigerant was reclaimed in 2019, which increased to 44% in 2020. These levels are thought to rank highest within the EU. Reclamation activities are strongly linked to the availability of facilities within the country, as cross-border shipments are difficult to organise. High shares of reclamation are thus expected in France, Belgium, Czech Republic, Germany, the Netherlands and (looking back) the UK.

The Regulation was less effective in preventing leaking emissions of other uses and substances other than HFCs. Firstly, SF_6 emissions will continue unabated and for many years to come due to the long lifetimes of the equipment in place (40-50 years). Secondly, a requirement to prevent emissions during production, transport and storage applies only to producers and not to other relevant actors. Thirdly, the Regulation will stop the additional use of HFCs in foams by 2023, but does not ensure the safe disposal and recovery of HFCs already used in insulation material. The Regulation states that

[186] Reported quantities of reclaimed gas have been going up 4 times between 2014 and today, but these data are not complete as not all companies are required to report currently.

recovery of F-gases is required at end-of-life from foams where it is "technically feasible and does not entail disproportionate cost". However, in practice costs, whatever they are, are often used as an excuse for not recovering the gas and it is difficult for authorities to enforce this provision strictly. As a result, HFCs in insulation foams are likely to be released into the atmosphere in the future. Finally, current emission prevention requirements only concern F-gases listed in Annex I of the Regulation. Thus such requirements do not apply to other fluorinated gases listed in Annex II (or relevant gases not listed in the Regulation), such as NF_3, H(C)FOs, fluorinated ethers and alcohols and other perfluorinated compounds.

A5.6.1.3 Objective 3: Facilitate convergence towards a potential future agreement to phase down HFCs under the Montreal Protocol

The Regulation clearly demonstrated to other countries that ambitious action on HFCs is possible and enabled a joint EU negotiation position and the tabling of an EU amendment proposal to the Montreal Protocol that provided crucial impetus for the negotiations. The Commission and the EU Member States were vocal supporters and advocates of the proposed Kigali Amendment during its negotiation, on the basis of the established best-practice rules of the Regulation. Prior to the implementation of the Regulation, there was no international agreement tackling the growing use of HFCs and there were little effective HFC measures elsewhere in the world[187]. Some industry and NGO stakeholders have labelled the Regulation 'the world's gold standard' and there is consensus that the F-gas Regulation had a positive impact on reaching an agreement internationally.

A5.6.1.4 Objective 4: Enhance sustainable growth, stimulate innovation and develop green technologies by improving market opportunities for alternative technologies and gases with low GWP

The Regulation has been a strong trigger for innovation in the relevant sectors. Dozens of new, more climate-friendly blends, especially mixtures consisting of HFCs and H(C)FOs, have entered the EU market since 2015. In addition, the number of companies working with natural refrigerants increased from 400 to 650 in the period 2013 to 2016 and, for example, in the commercial refrigeration sector, over 80% of companies increased their levels of investment in R&D between 2011 and 2016.[188] The same source 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, and that Europe is now a global leader in the adoption of low-GWP alternatives, not least due to the favourable policy environment. By way of example, by 2019:

- Europe had adopted around 2,200 low-charge ammonia systems, relative to a global total of 4,000.

[187] With the exception of Switzerland and the EEA countries. Japan introduced legislation on HFCs shortly after the EU.

[188] Shecco (2016): F-Gas Regulation Shaking up the HVAC&R Industry.

- Europe had installed over 40,000 transcritical CO2 systems, considerably more than the rest of the world combined.
- Hydrocarbons (in particular propane) in plug-in display cases has emerged as a viable refrigerant for supermarkets and smaller convenience stores. By early 2017, it was reported that there were around 700,000 hydrocarbon integral units in European supermarkets.

The report also observed that the large number of (new) suppliers has helped to increase the efficiency of the alternative technologies. These findings are fully reflected in the responses of stakeholders. 84 % of the respondents in the OPC reported that the Regulation has had a positive or very positive impact on the stimulation of innovation and development of green technologies. Further to this, stakeholders have noted the Regulation has provided certainty for undertakings although, initially considerable awareness raising on the rules of the Regulation and their meaning for stakeholders and the use of technologies proved to be necessary to support the uptake of the new technologies.

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.

Stakeholders largely agree that the Regulation has been quite effective. The vast majority of OPC 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.

A5.6.1.5 Identified Challenges to an effective implementation

Despite the relatively high effectiveness, there are also a number of challenges:

- There remain **barriers** to the use of climate-friendly alternatives due to **safety codes that have not been updated in line with technological progress**. They therefore inhibit a more widespread use of alternatives even though this is not warranted on safety grounds (see also A5.6.4.3.4).
- An **insufficient number of service personnel qualified to install equipment with climate-friendly alternatives** may have reduced the uptake of such technologies. This was pointed out already in a report by the Commission in 2016.[189] The European installers association AREA confirmed that this problem persists: Only 3.5-7% of certified F-gas personnel was trained on the alternatives (ammonia, CO2, hydrocarbons, HFOs). This is better than the situation in 2016 (0-2.3%) but still very far from sufficient. Only half of the current training centres in the EU offering any training on alternative refrigerants and they are unevenly

[189] http://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:52016DC0748

spread throughout the Union.[190] Industrial stakeholders including the service personnel strongly advised to remedy the lack of training and certification for alternatives.

- 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 Commission study confirmed that there are discrepancies between Chinese export data labelled as intended for the EU market and the actual EUROSTAT import data. [191] There are also increasing imports to EU neighbourhood countries that could, illegally, be diverted to enter the Union market. Based on these findings, and assuming that all unexplained quantities would indeed become HFC illegally sold in the EU (while there are also other factors that could explain at least some of these discrepancies such as trade re-routing and higher growth rates in neighbouring states), stakeholders such as the large chemical producers claim that illegal gases could be up to 30% of the total allowed quota. While the exact extent cannot be determined as numbers on smuggling is not available, it is apparent from increasing illegal HFC quantities discovered through border controls that this is happening. OLAF has investigated a number of illegal smuggling activities and identified a number of modus operandi of illegal traders as well as shortcomings in the Fgas Regulation. The industry has set up a noticeboard where illegal activities can be reported and a private investigation firm has been following up, and discovering wrongdoing. Industrial stakeholders (gas producers, importers, distributors, service companies and endusers) confirm the existence of illegal gases on the market. The refilling of ACs in passenger cars, where smaller bottles are usually used, is experiencing high quantities of HFCs from dubious origins. Internet sales are also often cited. A number of actions to prevent the latter activities are ongoing, including by industry itself, but the current legal situation due to the Regulation (e.g. lack of detail on custom and market surveillance role, lack of detail on obligations of economic operators) is limiting an effective enforcement and border controls.
- Some **company owners with several affiliates** (including single actors setting up and registering multiple mailbox companies), **benefit disproportionately from the reserve** 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 (data from DG CLIMA's HFC registry). The Commission adopted an Implementing Regulation in 2019 that clarified the rules and this 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, including mailbox firms and multiple companies registered under the same address (data from DG CLIMA's HFC registry). This results in **very low quota shares from the reserve to the real F-gas traders. It also makes it more challenging to prevent illegal imports.**

[190] All data from OekoRecherche, 2021

[191] https://ec.europa.eu/clima/document/download/8b970e78-c5c3-41fd-b846-c75c1b6b045b_en

- While substances replacing HFCs generally have negligible climate impacts, some of them **could potentially have undesirable eco-toxicological effects that require further monitoring**. It concerns the generation of environmentally persistent and accumulative trifluoroacetic acid (TFA) as a breakdown product of H(C)FOs in the atmosphere and its subsequent accumulation in the aqueous environment (see Quadrennial Report of the Scientific Advisory Panel to the Montreal Protocol[192]). **The H(C)FOs are listed in Annex II of the Regulation, and are currently not covered by measures aiming at preventing their emissions.** Given that they are common substitutes for many RAC equipment including ACs in passenger cars, their emissions are rising strongly (see A11.2).
- All Member States have introduced **penalties for non-compliance** with the Regulation. However, **penalties are quite heterogeneous and their level may not be dissuasive enough considering the possible economic gains achievable through 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. To industrial stakeholders and NGOs, low penalties is one of the major issues facilitating the illegal trade, as rogue traders could pay the low fines and still make a profit off selling the illegal gases. Also, European-wide operating networks could direct their activities towards Member States where penalties are minor. Based on information provided by Member States, DG CLIMA has collected available information on penalties. While that is a less than straightforward exercise, in particular in Member States with a federal organisation, the collected data confirms the large differences in penalties applied, both from an administrative view and, where relevant, the applicability of criminal sanctions.
- **A large share of quota holders are not subject to independent verification of reported data. Independent and appropriate verification is crucial** for effective enforcement of the phase-down. However, the amount of quota allocated per company from the reserve in 2019 dropped below the mandatory verification threshold of 10,000 tonnes of CO2e (because of the high number of quota declarations). This meant that 78% of the quota holders in 2021 (12.6% of amounts reported) did not need to have the reported amounts verified independently (data from CLIMA's HFC registry). Thus under-reporting is less likely to be caught as it would normally require individual inspections to establish. Furthermore, the mandatory verification obligation is not very prescriptive, thus the quality of reports provided by companies varies. This is apparent from reports submitted to DG CLIMA during the yearly compliance

[192] https://csl.noaa.gov/assessments/ozone/2018/downloads/2018OzoneAssessment.pdf

checking exercise. A study by the Dutch enforcement agency has come to similar results.

A5.6.2 Efficiency

A5.6.2.1 Benefits

The Regulation has provided benefits in terms of F-gas emissions saved and better energy efficiency. Some economic and social benefits also appear likely.

A5.6.2.1.1 Emissions saved

The Regulation has **saved F-gas emissions in the order of 44 million tonnes of CO2e *cumulatively* up to and including 2019 (EU-28).** In the baseline scenario, emissions started to fall from 2015 onwards, and demand shows even earlier effects in anticipation of the new rules (Figure 22). In contrast, in the counterfactual scenario emissions continue to increase slightly until 2017 and remain stable thereafter. Until 2030, significant decreases in emissions are expected under the baseline scenario (430 MtCO2e emissions less than counterfactual scenario[193]). Still they are expected to fall short of the emission savings anticipated originally (60% in the 2012 impact assessment). The highest absolute emission savings were achieved in the refrigeration sector, but the highest relative reductions were achieved in the foam sector[194].

[193] By 2050, emission savings by the Regulation is estimated to be 1991 MtCO2e vs. the counterfactual

[194] In the foam sector the industry has moved rapidly to alternatives from 2017, thus anticipating the 2020 and 2023 prohibitions.

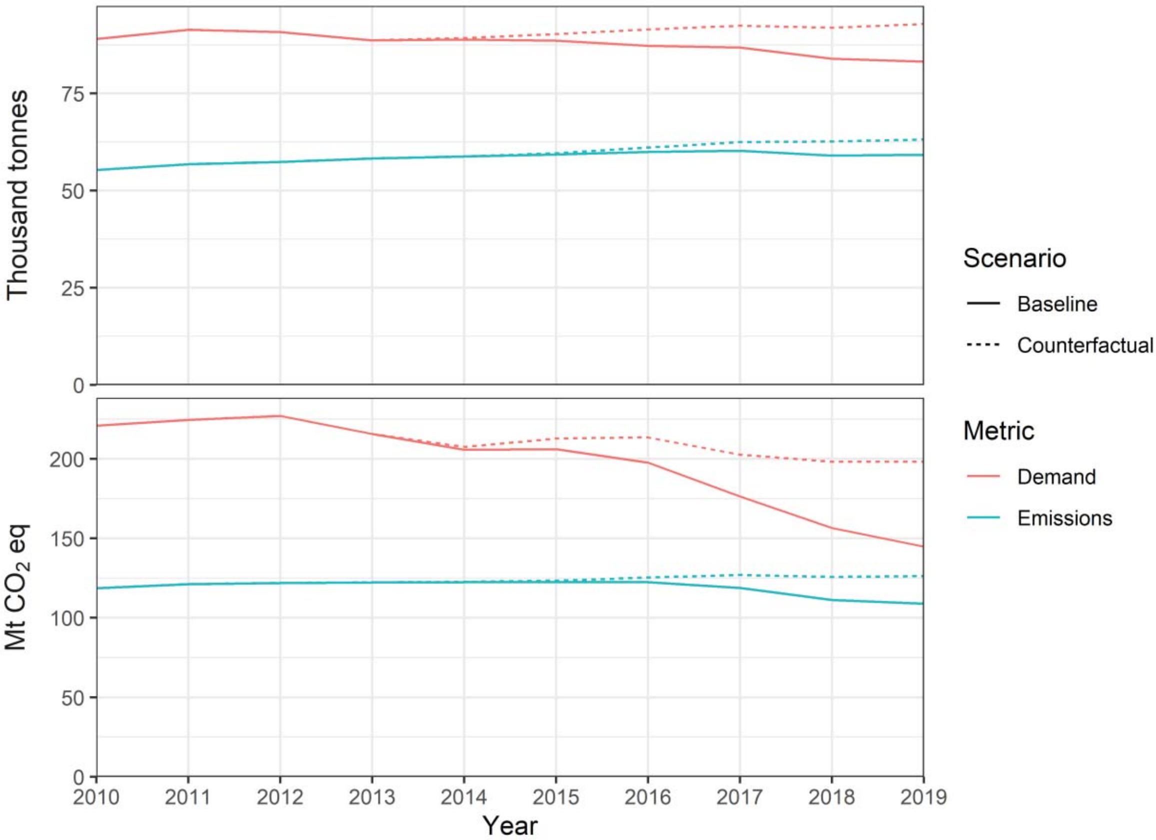

Figure 22. Total demand and emissions of F gases in the period of 2010 to 2019 in the baseline and the counterfactual scenario in metric tonnes and CO2e

A5.6.2.1.2 Energy use

Based on research on the technology employed, detailed documentation for the sub-sectors was compiled on energy efficiency assumption for the alternative technologies. 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.[195] 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 an alternative to HFCs, to achieve the same insulating efficiency.

At sectoral level **small energy savings in the refrigeration and air-conditioning (RAC) sector in the evaluation period 2015 to 2019** can be attributed to technological changes brought about by the Regulation. Given the low intensity of energy savings (about 0.1 %) of final energy use, no quantification of linked indirect emission reductions was attempted. Stakeholders corroborated these calculated energy savings: Some highlighted that energy-efficiency of home appliances for heating, ventilation, and air conditioning equipment has indeed improved over the implementation period (although this is also attributable to synergies with other EU legislation, e.g. Eco-design and Energy Labelling). In summary, **reductions of direct emissions (F-gases) and indirect**

[195] Shecco report "Toward energy - efficient refrigeration with natural refrigerants" and the 2015 Gluckman Consulting UNEP Ozone Secretariat Fact Sheets

emissions (energy efficiency) were achieved in parallel and synergies with e.g. eco-design rules have been exploited.

A5.6.2.1.3 Economic benefits

The **effects of the Regulation on production and gross value added (GVA) are more likely to have been positive than negative**. 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 and the introduction of the Regulation appears to align with a period of expansion for the sector above the trend observed for industry as a whole. Furthermore, compared to the counterfactual scenario, actual value added (baseline) appears to have grown faster in the RAC sector since 2014, see Figure 23. The need for replacement due to high leakages, the phase-down and prohibitions under the Regulation may have contributed to additional investment supporting that trend.

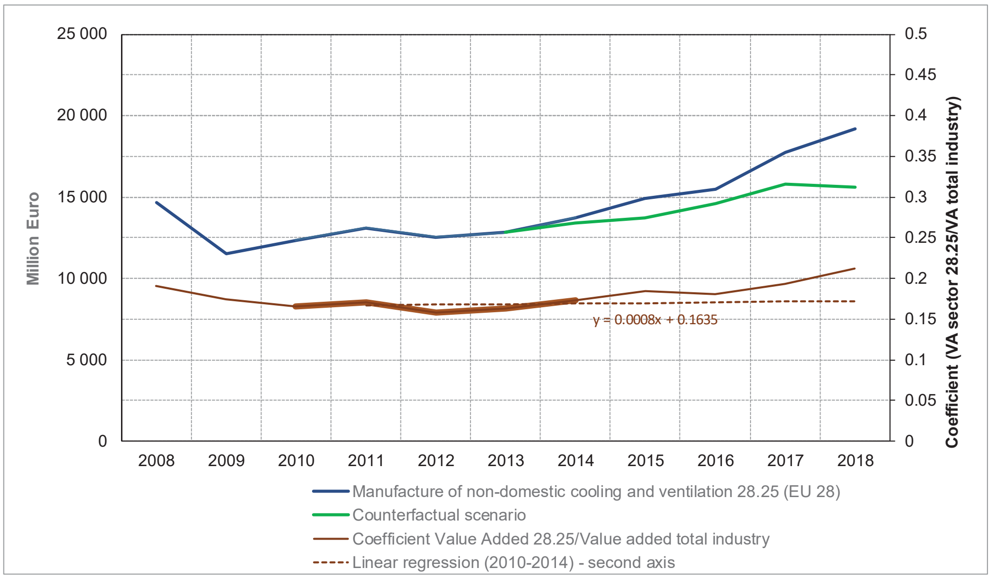

Figure 23: Value Added (VA) manufacturing of non-domestic cooling and ventilation equipment – actual development and counterfactual scenario (EU 28)

Other variables may have influenced the sector over this period, such as demand for heat pumps due to energy efficiency policies in the building sectors, general growth in demand for climate cooling, rising living standards or other climate change or energy efficiency policies that lead to demand and investment responses. As described above, there are however clear indications that the Regulation has increased R&D and investment by industry and developed a wide range of new alternatives which can promote economic growth (see effectiveness).

With **respect to trade**, the Regulation did **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 H(C)FOs, measured in tonnes of gas, were about 7% lower than they would have been without the Regulation. Given the higher cost for H(C)FOs, however, the value of HFCs and H(C)FOs imports was about 16% higher.

These limited (if any) economic impacts were corroborated by respondents to the OPC, the majority of whom suggested the Regulation has had a **neutral effect on EU competitiveness**.

A5.6.2.1.4 Social benefits

Sectoral employment has performed better than total industry with higher growth rates since 2014 (see rising red (coefficient) trendline in Figure 24). 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. Although it appears that the Regulation may have had a positive effect on employment, the precise effect is highly uncertain as it has also been affected by other (external) factors (see preceding section).

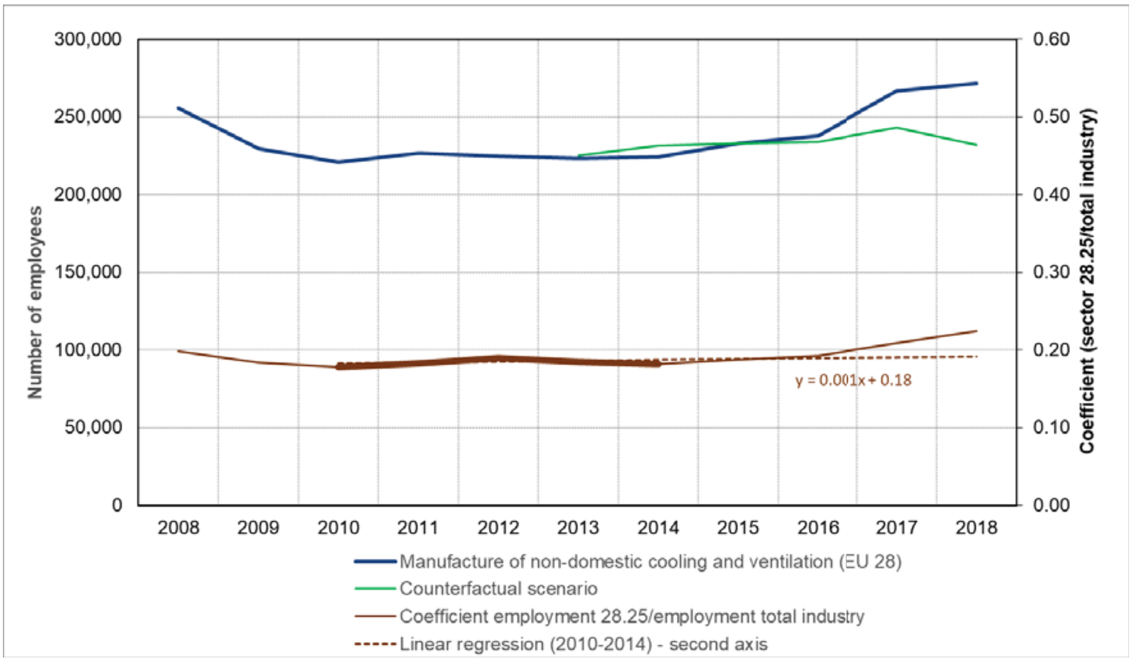

Figure 24: Employment - Manufacturing of non-domestic cooling and ventilation equipment – actual development and counterfactual scenario (EU 28)

Employment impacts were not directly raised by stakeholders but some noted that there is a lack of qualified technicians that can handle climate-friendly equipment. Out of the certified personnel, who have been trained in line with the minimum requirements for handling F-gases, only a minority are competent and experienced in handling the F-gas alternatives that are often characterised by being either flammable, toxic or require higher pressures.

A5.6.2.2 Costs

A5.6.2.2.1 Adjustment costs for end-users

The estimated annual net adjustment cost for end-users related to technological change was 461 million € per year (Table 22) and covers additional investment and operating cost for using low(er) GWP technologies in comparison to established high-GWP HFC technologies. The refrigeration users bore over 75% of total cost, stationary air-conditioning 11 % and mobile air-conditioning about 1%. Foam and propellants, solvents and fire protection take on 5-6 % each. Data at sub-sector level are given in Annex A12.1.

However, the majority of the costs to end-users were linked to higher HFC prices for those users that did not (or not yet) fully switch to low-GWP alternatives[196]. That share was gradually reduced over the years as climate friendly alternatives were increasingly being introduced. Moreover, the expenses were distributed over a large number of users (still) buying new HFC equipment or topping up existing equipment (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 older vehicles). Moreover, similar higher benefits occurred in the HFC supply chain when they were selling the gas (distributional effect).

The RAC sector accounted for approximately 94 % of the total adjustment costs in 2015-2019. That is equivalent to about 0.3 % - 2.3 % of total expenditure (totex). In the foam sector, the cost increase was substantially higher at about 18 %.[197] For the HFC use as propellant, solvent or fire suppression agent, the cost increase is about 0.01 %.[198]

There were also other types of costs effects of Regulation due to the requirement of reducing emissions on production (Article 7) and recovery of F-gases (Article 8; only refrigerated trucks and trailers were added with the Regulation). The linked estimated costs are €0.4 million and €5.9 million, respectively (see Annex A14.1).

Table 23: Average annual compliance cost of Regulation to industry 2015-2019 (costs difference between counterfactual and baseline)

	Gross equipment operators compliance cost Mio € / a	**thereof:** cost of HFC price increases Mio € / a	**thereof:** Cost of technological change Mio € / a	**Share of compliance cost in total costs** % 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%

196 The HFC-price related share of the compliance cost at F-gas user level is based on an average 2015-2019 HFC premium 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.

197 It should be noted that in the present analysis only focus on a rather small part of the overall EU foam sector and if the cost increases were seen in relation to the complete EU foam sector the percentage would be far lower.

198 The cost of HFCs is very low in relation to total product cost. This is partly because there are no additional costs for propellants used in MDIs (exempted from the HFC phase-down). If product costs for MDIs are not considered, an average price increase of about 13 % is calculated for the few applications in those sectors that still use HFCs.

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*

A5.6.2.2.2 Cost efficiency of the emission reductions

Abatement costs compared to the emissions saved were lower than expected in the 2012 Impact Assessment. As HFC price increases lead to distributional effects rather than overall costs, a meaningful comparison of total cost to industry vs the achieved emission reductions takes into account cost of technological change only.

The average emission reduction costs calculated as the ratio of the annualised technological cost relative to the lifetime averaged emissions savings observed until 2019 were on average about **6.4 €/tCO2e** and are thus far below the 16 €/tCO2e that was estimated for the 2030 time-horizon in the 2012 Impact Assessment.

At sectoral level, the low-GWP alternative technologies in stationary air-conditioning equipment were on average less costly than the traditional HFC-based options (negative costs). For refrigeration, the average emission reduction cost was 10 €/ tCO_2e. For mobile air conditioning the average emission reduction cost was 94 € /tCO_2e[199]. This relatively high number is due to the fact that there were very few emission savings observed so far (mostly for air conditioning systems for trucks and buses). For the foam and propellant / solvents / fire protection sectors, technological emission reduction costs are calculated as 8 and 10 €/ tCO_2 e, respectively. Data for the calculation of emission reduction cost at sub-sector level are presented in Annex A12.2. For those sub-sectors that did not reduce emissions at all compared to the counterfactual scenario, a calculation of emission reduction cost is not possible.

Table 24: Average emission reduction cost 2015-2019

[199] These costs would represent ca. 0.6% on average of total expenditure of mobile AC (excluding passenger cars)

	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*

A5.6.2.2.3 Distribution of costs across business size

A high share of SMEs is likely to be found among equipment importers and service companies. For both, however, no particular strong disadvantage is assumed: Equipment importers basically face the same premium on HFCs in equipment as EU manufacturers. On the other hand service companies benefit from higher margins on HFC prices and, with the increasing use of alternatives, they are needing more skilled personnel to work with H(C)FOs and natural refrigerants. Since 2006 they have been required to obtain certifications for installations of F-gas equipment.

A5.6.2.2.4 Distribution of costs across EU regions

In the sub-sectors of domestic refrigeration, commercial refrigeration, transport refrigeration, mobile air-conditioning as well as for aerosols, a large number of installations have been affected by the 2014 revision and the type of equipment is relatively equally distributed among Member States. Investments in replacement technologies will, however, 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.

Stationary air conditioning units as well as air conditioning systems in buses and trams are more frequently used in southern Member States than in temperate climates 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.

The assessment shows that the southern EU region, representing approximately 35% of EU28 population has borne about 37.5% of total end-users' compliance cost. The northern EU region, representing about 65% of the EU 28 population, has borne about 62.5% of total cost. Hence, even if some regional effects may have taken place due to the reasons above, **the overall economic impacts are not that different between North and South, with the latter bearing just a marginally larger share of the cost burden.**

A5.6.2.2.5 Split of costs by measure

Business on average did not perceive the costs of the measures as exceedingly high. Stakeholders clearly identified the 'Restrictions on use and equipment' and 'HFC quota system' as the measures with the highest costs on industry (Table 24) while also recognising that these are most effective measures in terms of saving emissions and that their costs were justified on the basis of their benefits (e.g. OPC). Most other measures (training/certification, producer responsibility, reporting) were seen to represent at most medium-level costs, while costs for labelling were considered less important. Responses on the basis of company size did not differ very strongly. A majority of business associations and companies agreed that the costs of the individual measures were justified to achieve the objectives, i.e. that the benefits of action had outweighed the costs (a result which matched overall responses across all stakeholder groups).

Table 25 : Costs for businesses as determined on the basis of answers to the OPC rating costs from 1 (marginal costs) to 5 (very high costs))

	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)	2.39	3.13	2.89	2.03	3.31	3.37	3.06
Small (10 to 49 employees)	2.89	3.00	3.13	2.20	3.17	3.50	3.00
Medium (50 to 249 employees)	2.83	2.97	3.04	2.27	3.00	3.41	2.85
Large (250 or more)	3.17	2.95	3.02	2.16	3.40	3.76	2.73
All Business	2.89	3.00	3.01	2.16	3.25	3.54	2.87
All	2.88	3.01	2.96	2.13	3.23	3.38	2.84

A5.6.2.2.6 Administrative costs to undertakings

Additional[200] administrative costs arise from the need (i) to keep records on refrigerants and for certification of service personnel in cooling equipment of trucks and trailers, (ii) for extended labelling requirements, (iii) to prove compliance with the quota system for new cooling equipment using HFCs, (iv) to comply with the quota system for bulk HFCs, and (v) for reporting and verification of annual company data. Different measures apply to different company types, and the range of costs can vary, e.g. between large and small

[200] On top of those costs already incurred from measures of the previous 2006 Regulation.

companies. In Annex A14.1 the rationale and assumptions made for the estimation of cost related to each measure are given. The highest total administrative costs are related to ensuring that HFCs filled in new HFC cooling equipment are being counted under the quota system (4.8 million € in total), followed by record keeping (3 million €; due to a relatively high number of companies affected), and reporting and verification (2.4 million €). Note that adjustment costs related to equipment and bulk gas under the quota system (e.g. quota (authorisation) purchasing) are not included in these numbers. The smallest total costs are incurred for extended labelling requirements (0.3 million €). **In total, 14.1 million € are recurrent additional annual administrative costs for industry.**

Table 26. Additional administrative costs for industry resulting from the different measures

Measure	**Companies impacted** ca.	**Average burden** (person days)	**Total Costs** (million €)
Keeping records	25,750	0.5*	**3.0**
Obtain certification	9,400	1*	**2.2**
Label equipment	4,700	L:1, M: 0.5, S: 0.25	**0.3**
Ensure HFC equipment under quota system	2,900	L:27, M:13.5, S 6.75	**4.8**
Ensure HFC gas under quota system	1,700	L:15, M:7.5, S: 3.75	**1.5**
Reporting & verification	3,000	L:13, M:6.5, S:3.25	**2.4**
TOTAL			**14.1**

L: large companies; M: medium-sized companies; S: small companies

*: As it is more difficult for smaller companies to comply, the burden was not scaled down from that established for larger companies

A5.6.2.2.7 Administrative costs to Member State competent authorities

The total yearly costs across all Member State competent authorities and across all measures is estimated to be a total of ca. 58,000 person days p.a. to ensure enforcement or compliance with the Regulation. The Member States provided quantitative feedback on a number of measures, but the costs associated vary widely not least due to the different number of stakeholders affected. A detailed overview is provided in Annex A14.3.1. These figures may not fully include the most significant cost item of 'conducting national inspections or checks' (e.g. linked to emission prevention and leakage). The latter is difficult to determine since these controls are jointly carried out with other general environmental inspection activities (e.g. Industrial Emissions Directive, Ozone Regulation), and checks are coordinated and carried out at local or regional level. National authorities also report a wide range of costs when it comes to the efforts linked to guidance and awareness raising, which may have represented the highest costs besides compliance related actions.

In addition, one-off costs are incurred for establishing training and certification schemes (truck and trailers[201]), and producer responsibility schemes (encouraged in Article 9) where these are set up (only encouraged by the Regulation). A further cost is associated

[201] Member State responses were likely not limited to truck and trailers, but refer to all certification programmes put in place by the 2006 F-gas Regulation

with the storing of company refrigerant management records (Article 6) in a national database to determine emissions (Article 20). This action is not required under the Regulation, but is the way some Member States chose to implement these articles. The cost effort varies strongly depending on how these actions were implemented, see Annex A14.3.1.

A5.6.2.2.8 Administrative costs to the European Commission

Five full-time equivalents (person days) are needed to run the quota system and other central elements of the Regulation (DG CLIMA). An overview of the administrative costs incurred is provided in Annex A14.3.2. The most significant number of working days are associated with IT related aspects of the HFC Registry (an additional 1.5 person days), implementing the quota system and its registry, as well as providing information on the implementation of the Regulation (including compliance) to stakeholders. External support to DG CLIMA for implementing the Regulation amounted to ca €185,000 per year on average from 2014 to 2019. The costs incurred by other services in the Commission, e.g. in DG TAXUD and OLAF are estimated to be up to 2 person days in total. The staff resources required under the old Regulation was 2 person days.

A5.6.2.2.9 Administrative costs to the European Environment Agency (EEA)

The EEA has up to **1 person days internal staff** for the collection, analysis and publication of company reporting data. There has been a gradual increase in administrative costs since 2012, which is linked to the big increase in quota holders. In addition, **409 person days of external support** are needed (2019). The greatest number of workdays are linked to external IT consultancy supporting the F-gas webform, see Annex A14.3.2.

A5.6.2.2.10 Areas of unnecessary burden or excessive costs

Many stakeholders agreed that the Regulation is efficient. Only very few mentioned areas that were not including: that (i) the threshold for mandatory independently verified reporting is too high; the (ii) verification requirements are unclear (especially for smaller undertakings) and leave too much room for interpretation which is resulting in a low/ variable quality; there is (iii) no obligation for registered undertakings to submit a 'NIL'[202] report if they have nothing to report, thus it is unclear if they have nothing to report or if their report is missing.

At a more general level, equipment manufacturers, importers and operators expressed dismay that they were footing the bill, while others benefitted from the quota system (distributional effects). An analysis showed that about 60 % of the HFC-price increases 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 of HFCs and the gas distributors. About 40 % of the equipment operators' costs due to HFC price

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

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.

A5.6.2.2.11 Trade, competitiveness and consumer prices

The intended decline of EU HFC supply will evidently impact on amounts imported and produced in the EU. In the beginning this decline was primarily a result of lower EU HFC production for domestic use, but after 2017 HFC imports also declined more significantly. The decline of domestic production is however largely due to an expansion of production in China, and not strongly related to the Regulation. Furthermore, the decline in HFC imports is partly compensated (by mass) by strongly rising imports of H(C)FOs that are normally more expensive. Thus the value of imported HFCs and H(C)FOs 2015-2019 was approximately 15 % (90 Mio €/year) higher than it would have been without the revision of the Regulation. Imports of HFCs in equipment (measured in tonnes of gas) have been stable since 2016. About 70% of HFC imports into the EU come from China and about 30 % from Japan and the United States.

Total EU HFC exports remained relatively stable. The ratio of bulk HFC exports to HFC production has been moving from about 50 % in the years before 2014 to more than 100 % in 2018 and 2019. The exported HFCs are mainly sourced from EU production and from HFC imports for inward processing and re-export (e.g. blending of mixtures). Those export-related trade patterns are hardly affected by the Regulation.

Thus the Regulation has had at most a limited impact on trade and competitiveness. This was 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).

As regards consumer prices it can be concluded that the overall effect of the revised Regulation was insignificant since (i) most sub-sectors have negative or very low relative compliance costs, (ii) compliance costs can be balanced within sectors (or applications), (iii) equipment operators have always had to cope with highly fluctuating input costs and that (iv) the cost of the F-gas using equipment often constitutes only a marginal share of overall system costs of the users.

A5.6.2.2.12 COVID-19 Pandemic

The COVID-19 pandemic is expected to have an impact on trade of products and equipment containing F-gases. Cooling systems and their use were scrutinized closely 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[203]. As the pandemic is still ongoing, the full effects are not yet known. A recently published study explored the impact of COVID on the EU heating, ventilation and air-conditioning market (Eurovent, 2020). The report, which surveyed more than 100 manufacturers across 16 countries,

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[203] European Centre for Disease Prevention and Control (2020).https://www.ecdc.europa.eu/en

suggested that within the EU, Spain, Italy and the Czech Republic appear to have been most negatively impacted. In contrast, Germany and Austria 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: While products such as dry coolers, CO2 gas coolers, cooling towers and air filters fared better, rooftop units saw the biggest drop in demand. In addition, suppliers to hospitals, data centres and the food industry have 'profited' from the crisis (especially with regard to additional refrigeration requirements), whereas the worst affected were suppliers of equipment for offices and shopping centres and for niche applications in cruises and air travel.

Another study by BSRIA[204], based on interviews with air conditioning manufacturers in 20 major world markets, concluded that the six months to September 2020 following the onset of the pandemic had been 'challenging' to the sector. As a result of the surveys, BSRIA revised down its predictions for global air conditioning sales in 2020 and 2021. The study reported falls in sales across the board, with different air conditioning equipment types down 4-12%. That said, the report also suggests that there have been growth opportunities in some sectors, with the shift to home working and a resulting increase in demand for residential air conditioning.

Complementing these reports, several major equipment (parts) manufacturers reported declines in sales over the period of the pandemic (noting the detrimental impact of the pandemic as a key driver). However, following the peak of the pandemic many undertakings are seeing a bounce-back in sales. 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. Those most strongly affected according to stakeholders included the mobile air conditioning sector, transport refrigeration, fire protection and the manufacture of electronics. Other sectors identified by stakeholders as being detrimentally affected included activities such as servicing and maintenance, leak checks of installed equipment, and installation of new air conditioning systems in hotels and offices. Short-term impacts mentioned included the 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. On the positive side, the outlook for 2021 and beyond appears to be brighter with a backlog in orders coming through and a stabilization of spending. Recent press articles[205] suggest there has been a strong recovery in some sectors, e.g. Germany and France have seen double-digit growth in the split air conditioning market.

204 Building Services Research and Information Association (2020).https://www.bsria.com/uk/
205 www.coolingpost.com

In addition, in the switchgear and related equipment sector, the majority of respondents felt that this sector as critical infrastructure was not negatively impacted by COVID-19. Other sectors seeing an increase according to stakeholders are the food production and retail sector, cold storage sectors – including for cooling of vaccines (overall demand in the medical sector was apparently stable), and increased demand for air circulation in public and commercial buildings.

A5.6.2.3 Benefits vs. Costs

The Regulation has delivered a range of benefits since its revision in 2014. It has changed an increasing trend of EU F-gas emissions (until 2014) to a decreasing trend (every year since). The decrease of F-Gas emissions from 2015 to 2019 amounted to a total of 44 $MtCO_2e$ saved. Also, the average GWP value of F-gases supplied to the market was significantly lowered due to the increase in more climate-friendly alternatives (- 32 % in 2018 compared to 2014). This was achieved while the level of energy efficiency was maintained (or even slightly increased). In terms of wider economic effects, the Regulation has not had any negative effects on EU F-gas production or exports and gross value added or employment and may even have slightly increased these parameters. The imports of F-gases into the EU was reduced while imports of synthetic alternatives increased. Industry has increased R&D investment and the wide range of new alternatives is indicative of the high levels of innovation driven by the Regulation.

As the 2015-2019 evaluation period is characterised by remaining high shares of installed equipment relying on established HFC technologies, there are still relatively high total HFC price-related cost for users that are slow in shifting to climate-friendly alternatives. These HFC price-related costs were however borne by many millions of users and in addition they were offset by benefits in the HFC supply chain, thus for the economy as a whole the cost is zero (distributional effects). In terms of overall value-for-money, the calculated averaged ratio of the technological cost relative to emissions savings is about 6 €/t CO2e. Emission reduction costs observed for the first years of the phase-down are thus below the average of 16 €/t CO2e calculated for the 2030 time horizon in the 2012 Impact Assessment. As such, it is concluded that **the Regulation has resulted in significant emission savings at very low abatement costs linked to technological change**. The cost-effectiveness of the Regulation is generally supported by stakeholders.

Most measures also place some administrative costs on different actors (industry, competent authorities and at European level). The total administrative costs are however much smaller than the cost of technological change.

Finally, very few areas of the Regulation were found to be unnecessarily burdensome. An issue where improvements can be made is the area of reporting and verification obligations. Some stakeholders also noted that equipment operators are mostly paying for the technological transition, while others are profiting e.g. from higher HFC selling prices. In addition, a number of important challenges to implementation have been identified.

A5.6.3 Relevance

In light of the more ambitious climate targets enshrined in the European Climate Law, **the objective of the Regulation to mitigate F-gas emissions to prevent climate change has never been more relevant.** F-gas emissions contribute ca. 2.5 % to the EU's total GHG emissions. The continued supply and use of F-gases contributes to a 'bank' of potential emissions (e.g. in equipment in use) in the future. The model output underlines that relevant emission volumes will continue to occur in the coming decades, which would, without the Regulation, be much higher (counterfactual scenario). Thus t**he underlying problem clearly persists** and ambitious action is required to ensure that F-gas emissions are being reduced in line with the new climate targets.

Furthermore, it remains essential that the EU can comply with **its international commitments related to the Montreal Protocol**. The Regulation is the most appropriate instrument to safeguard compliance given its EU added value compared to national rules. In this respect there is a need to regulate the phase-down for the period after 2030 and adjust reporting, quota exemption rules and minimum thresholds to ensure long-term compliance.

The Regulation has been effective notably on reducing HFC emissions, but even **more could still be done cost-effectively for some HFC appliances and notably for other types of F-gases**. Stakeholders identified e.g. the potential for reducing F-gas emissions from skin-cooling equipment and anaesthetics as well as SF_6 in switchgear. Research on alternatives to HFCs for the (hitherto) more complicated uses shows that technical feasibility has progressed in many areas, but is not sufficiently supported by the current scope of restrictions in the case of all applications.

The scope of some measures (actors, activities, gases) was found to be somewhat limited. For instance certification and training requirements do not cover climate-friendly alternatives and there are monitoring gaps of e.g. recycling/reclamation activities, recipients of exempted gases, the distribution of HFCs after import/production and the export of HFC equipment. Also, there are F-gases that are not currently covered by either Annex I or Annex II (only monitoring) of the Regulation that are relevant on the EU market or starting to become commercialised. Finally, Article II substances are not subject to emission controls while there are some potential concerns about other environmental impacts due to emissions of some of these substances.

The Regulation **has been flexible to respond to some external challenges, but not to others**. The Regulation does not entail sufficient flexibility to allow for alignment with the Montreal Protocol, nor to any unforeseen issue related to the quota system, such as the lack of gas supply due to unexpected high growth in equipment that cannot (yet) replace HFCs. If such a situation should occur, it could create serious problems for certain sectors unless it is possible to swiftly adjust the phase-down without having to amend the Regulation in co-decision. Furthermore, the current rules have proven to be inadequate to allow the Member States and the Commission to address illegal activities and the undesirable multiplication of traders, in an effective way.

A5.6.4 Coherence

A certain amount of international and EU legislation affects the F-gas Regulation (and vice versa), e.g.

- International agreements, in particular the
  - Montreal Protocol on Substances that Deplete the Ozone Layer
  - Paris Climate Agreement
- EU environmental policies
  - Chemicals: Directive 2006/40/EC ("MAC Directive"), Regulation (EC) No 1005/2009 ("Ozone Regulation"), Directive 2010/75/EU ("Industrial Emissions Directive", IED), Regulation (EC) No 166/2006 on the establishment of a European Pollutant Release and Transfer (EPRTR), REACH (Regulation (EC) No 1907/2006)
  - Energy: Directive 2009/125/EC ("Eco-design 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")
  - Waste: Directive 2008/98/EC on waste ("Waste Framework Directive"), Directive 2012/19/EU ("Waste Electrical and Electronic Equipment Directive", WEEE)
- 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")
- Safety standards and building codes

A5.6.4.1 Coherence with international policies

A5.6.4.1.1 Montreal Protocol

The Regulation predates the Kigali Amendment to the Montreal Protocol and is therefore not fully aligned with these international rules so that **long-term compliance with the Montreal Protocol is not fully guaranteed for HFCs:**

- The EU phase-down concerns placing on the market (POM: includes import and EU production) whereas the Montreal Protocol regulates consumption (slightly different parameters than POM) and production separately. Hence, consumption and POM may not always develop in the same way, and **production may not be limited to the extent needed** to comply with the Montreal production phase-down/ban in each Member State[206].

[206] For consumption the so-called REIO clause apply, which means that EU must comply as a region. The REIO clause does not currently apply to production. There are individual phase-down schedules based on how much production occurred in each Member State in the past. If no production occurred it means production is banned. Only France and Germany have HFC production today.

- The EU HFC phasedown after 2030 is currently not legislated, whereas the Montreal Protocol has a last step in 2036 and continues at that level thereafter. Even if it is assumed that the placing on the market in the EU after 2030 stays at the limit required in 2030, **long-term compliance with the Protocol's consumption phase-down is not ensured**.
- **Quota exemptions that do not exist under the Protocol make it complex to safeguard compliance** for both the production and the consumption phase-downs under the Protocol. In particular the exemption for MDIs (asthma sprays) is problematic for compliance because it represents high quantities[207].
- **Minimum thresholds for placing gases on the market and for reporting** are not foreseen by the Montreal Protocol and therefore the EU's reporting data is currently slightly incomplete.
- **The Montreal Protocol's requirement to have HFC export and import licences** is fulfilled by requiring registration in the EU F-gas Portal and Licensing System before undertaking such activities. However, it is not stated clearly in the Regulation that this is a trade licence and for transparency it would be more appropriate to legally label it a licence.

Stakeholders overwhelmingly agree that further action is required to ensure compliance with the Montreal Protocol, in particular after 2030.

A5.6.4.1.2 UNFCCC and Paris Agreement on Climate Change

The Regulation aims to make **a proportionate contribution to the objective of the Paris Agreement** to stay well below a 2°C global temperature rise and pursue efforts to limit it to 1.5°C. This contribution is discussed in previous chapters above. There are also **reporting requirements on emissions of F-gases** in both the Regulation and under the United Nations Framework Convention on Climate Change (UNFCCC). [208] Article 20 of the Regulation calls on Member States to set up reporting systems to acquire to the extent possible emission data. However, given the relatively non-specific wording of this requirement, there are large discrepancies between Member States on how this is done. While some countries continue to rely on default emission factors or surveys to establish their national emissions, others including Belgium, Italy, Slovenia and Poland have established central databases of relevant equipment containing F-gases and installed volumes, losses, quantities added etc. are electronically logged by service personnel or operators which allows for acquiring very good data on emissions.

A5.6.4.2 Coherence with EU environmental policies

A5.6.4.2.1 Ozone Regulation

The Regulation is closely related to the Ozone Regulation, as it **concerns similar sectors and strategies to reduce gases or avoid their emissions, besides minor differences in**

[207] The other two exemptions, for semiconductor manufacture and for military equipment, are less relevant in quantitative terms.

[208] Regulation (EU) No 525/2013 ("MMR Regulation") and Regulation (EU) 749/2014 define the mechanism and requirements for reporting EU GHG emissions to the UNFCCC

definitions or containment measures[209]. Stakeholders are asking for similar approaches on both Regulations, wherever possible and sensible, in particular with regard to the custom measures to control illegal activities. The Ozone Regulation uses a Per-Shipment-Licensing approach to authorise imports and exports. Here an alignment is achieved with the Fgas Regulation through the development of the EU Single Window Environment for Customs, which enables automatic per shipment controls for both ODS and F-gases. The Ozone Regulation is being reviewed in parallel with this Regulation. While HFCs replaced ODS in the past, this is not anymore the case today since ODS have been eliminated in the EU in sectors where this took place (in particular refrigeration, AC, foams, aerosols). Therefore, changes to the ODS Regulation regulating the few remaining uses of ODS will not affect the Fgas Regulation.

A5.6.4.2.2 MAC Directive

Directive 2006/40/EC ("MAC Directive") relates to emissions from air-conditioning systems in new passenger cars and **complements the Regulation by having a prohibition on using strong greenhouse gases (i.e. HFCs) in this sector**. The same sector is covered by additional obligations contained in the (F-gas) Regulation such as the containment measures, including the training need for technicians. This is analogous to other F-gas sectors that are also affected by prohibitions as well as the phase-down and containment measures. Generally, there has been consensus amongst stakeholders in the OPC that coherence between the Regulation and the MAC Directive is high.

A5.6.4.2.3 Energy efficiency and eco-design legislation

There are important synergies between energy efficiency measures and the Regulation. The HFC phase-down and the prohibitions aim to drive the transition from high to low GWP refrigerants in existing and new RAC applications which can have an indirect impact on energy consumption depending on the efficiency of the new equipment. Based on experience from previous conversions in this sector, energy efficiency tends to go up on balance. Moreover, the Regulation was designed to only promote technologies that would provide at least equal energy efficiency. The Regulation also improves energy efficiency through better control, monitoring and maintenance of existing cooling equipment (to avoid the loss of refrigerant and thus prevent efficiency losses), including leakage checks repairs, leakage detection systems, and training and certification of technicians.

To be fully coherent with eco-design policies, Article 11(2) of the Regulation allows an exemption from the placing on the market bans if the equipment with HFCs would achieve lower overall GHG emissions during its life cycle than the same equipment without HFCs. To date there has been no need to use that exemption and despite this possible alignment some industry stakeholders have a perception that there are trade-offs between reducing F-gas emissions and energy efficiency, i.e. that there may be a lack of

[209] Most HFCs were phased in as replacements for substances that damage the ozone layer. The climate-warming impact was considered less important at the time. The ODS Regulation is therefore somewhat of a precursor to the Fgas Regulation with similar types of measures.

energy efficiency in equipment using lower GWP alternatives. However, only very limited examples could be provided by the same stakeholders. Overall, a trade-off between replacing refrigerants and efficiency was not the case in the observation period 2015-2019, and small efficiency gains were achieved overall. Eco-design requirements continue to be refined as technologies develop. In this way, Eco-design requirements have an impact on the charge amount needed, with higher efficiencies typically needing more refrigerant. Since hydrocarbon refrigerants[210] are more limited in potential refrigerant charge size by existing standards, their scope regarding energy efficiency improvements continues to be more limited than fluorinated alternatives, unless existing barriers in standards are addressed.

A revision of the Renewable Energy Directive (RED II) 2009/28/EC was proposed in 2021 which is expected to lead to an acceleration in the installation of new switchgear units. If this new installation base continues to use SF_6, 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 emissions of GHG to the atmosphere.

A5.6.4.2.4 Waste policies

Some stakeholders find that a lack of clarity if and when F-gases should be considered as waste affects the recovery, recycling and reclamation of F-gases. In the targeted interviews, Member State competent authorities noted that it is difficult to determine the classification of a substance as waste or not, especially when different Regulations apply, leading to disagreements within the market. Furthermore, this confusion may lead to artificial barriers being put in place for some of the activities being encouraged under the Regulation: 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'. Similarly, stakeholders also identified the rules on waste shipment (Regulation (EC) No 1013/2006) as a barrier to effective end-of-life F-gas treatment, as in some cases recovered refrigerants 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 when EU Member States without reclamation and destruction facilities intend to export used F-gases for reclamation and/or destruction purposes to other Member States. 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 also warned that, should transboundary shipments become too simple, this may open the market for actors with lower standards or levels of expertise in handling hazardous waste.

Stakeholders further pointed out that relevant terms such as "recovery" or reclamation" are defined differently by the Regulation and the Waste Framework Directive (Directive 2008/98/EC). Such differences are however the result of seeking close alignment of the Regulation with Montreal Protocol definitions. Other stakeholders, in particular NGOs,

[210] Hydrocarbons are the most straightforward solution to avoiding HFCs in small AC equipment

believed that setting minimum requirements and specifying the activities to be included in extended Producer Responsibility schemes by Member States in Art. 9 would achieve even better alignment.

The Waste Electrical and Electronic Equipment Directive 2012/19/EU ("WEEE Directive") complements the Regulation. The former is relevant for a number of equipment types affected by the Regulation, e.g. large household appliances (large cooling appliances, refrigerators, freezers, air conditioners), medical devices (freezers) etc. The WEEE sets out requirements for MS to (i) minimise disposal of WEEE in unsorted municipal waste to ensure correct treatment (and noting as a priority fluorinated GHGs), (ii) prohibit disposal of separately collected WEEE that has not undergone 'Proper Treatment' and (iii) ensure that collection and transport of WEEE is done in a way that optimises conditions for preparing for re-use, recycling and confinement of hazardous waste. In addition, the cost of such actions are covered by producer responsibility schemes. 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 used as insulation in domestic and small commercial refrigeration appliances (although foams do not require recovery under Art. 8 of the Regulation, Art. 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 ODS Regulation, but no mention is made of the 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, some stakeholders have noted that WEEE schemes in Member States need to be improved to better facilitate the recovery, recycling and reclamation of refrigerants.

A5.6.4.2.5 REACH Regulation

Under REACH, 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), which includes F-gases. Representatives of large chemical companies feel that REACH registration for importers is not fully complied with by competitors which creates a disadvantage for EU-based businesses. F-gas reporting and registration data could be exploited to achieve better enforcement. Under REACH there are currently ongoing efforts by some Member States to better identify the risks of PFAS, which includes HFCs and H(C)FOs due to their breakdown products (i.e. TFA).

A5.6.4.2.6 Industrial Emissions Directive (IED) and E-PRTR Regulation

The E-PRTR Regulation monitors emissions of HFCs, but only as an aggregate value in metric tonnes for all HFCs and therefore gives little indication of 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.

Under the IED, 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.

A5.6.4.2.7 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. A number of recently selected F-gas related projects aim to replace F-gases with climate-friendly refrigerants in various applications, train service technicians in the use of low GWP alternatives, support the updating of standards and raise awareness of climate-friendly technologies in various sectors.[211]

A5.6.4.3 Coherence with custom and surveillance policies

A5.6.4.3.1 Customs legislation

Effective customs controls are complicated by current rules. Customs controls and surveillance activities are relevant to the success of the Regulation and better alignment. Uncertainty about the role of customs in enforcing the Regulation has shown that instructions for customs and market surveillance authorities were not sufficiently clear. Border controls using the licensing system described above are limited by the fact that controls require manual checking of the company's registration in DG CLIMA's F-gas Portal and HFC Licensing System and the fact that many customs offices have not registered in the system themselves and therefore do not have access. The CERTEX/EU Single Window Environment for Customs system will remedy this issue and achieve automatic controls, but there are some data needs. Some stakeholders have also pointed out that special customs procedures such as transit and online trade may be vulnerable to misuse.

A5.6.4.3.2 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 have not been 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

[211] https://ec.europa.eu/environment/life/project/Projects/index.cfm?fuseaction=home.search&cfid=14659734&cftoken=4f1fb6e93a74514e-B83F4D45-9F09-8461-24ED460AF947F533

(interviews with Member States). In addition, stakeholders (interviews with MS) perceive that definitions of import and export also vary.

A5.6.4.3.3 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 Commission proposed an amendment to the Environmental Crime Directive in 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 should be maintained.

A5.6.4.3.4 Whistleblower Directive

Directive (EU) 2019/1937 of 23 October 2019 aims to strengthen the protection of whistleblowers under Union law as reports by whistleblowers feed national and Union enforcement systems with information, leading to effective detection, investigation and prosecution of breaches of Union law rules. The material scope of the Directive covers a wide range of key EU policy areas, including the protection of the environment. The criteria for determining which policy areas and acts should be included in the material scope of the Directive are the following: "there is a need to strengthen enforcement, underreporting by whistleblowers is a key factor affecting enforcement, and breaches of Union law can cause serious harm to the public interest" (recital 5). In addition, Article 2(1) defines the material scope of this Directive by means of a reference to a list of Union acts set out in the Annex. While several pieces of EU climate legislation are included in the Annex, including the Ozone Regulation, the F-Gas Regulation is not. To ensure coherence, the material scope of that Directive should be amended in order to include the F-Gas Regulation.

A5.6.4.3.5 Coherence with safety standards and building codes

A recent Commission report has pointed out that **standards and codes represent important barriers to the uptake of climate-friendly alternatives to HFCs** and they should be addressed with urgency.[212] In particular it was noted that existing restrictions on flammable refrigerants no longer appear justified on the grounds of safety due to technological development. Failure to do so would jeopardise the technological progress and therefore make reaching the Regulation's objectives more difficult.

The most relevant European safety standards for refrigeration, air conditioning and heat pumps are EN 378, a horizontal standard which covers the use in commercial and

[212] REPORT FROM THE COMMISSION on barriers posed by codes, standards and legislation to using climate-friendly technologies in the refrigeration, air conditioning, heat pumps and foam sectors (see https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52016DC0749&from=EN)

industrial applications, as well as specific product standards including: EN 60335-2-24 for household refrigerators and freezers, EN 60335-2-40 for heat pumps and air conditioners, and EN 60335-2-89 for commercial refrigeration appliances. These standards are referenced as harmonised standards in EU legislation (e.g. Machinery Directive 2006/42/EC) which gives their use a legal basis.[213]

The Commission gave a mandate (M/555) to CEN/CENELEC[214] to address these issues in European-level standards by drafting, on the basis of a thorough assessment, technical specifications for the safe installation and operation of cooling equipment containing flammable refrigerants. In March 2021, the final documents were issued by the Technical Committee WG 12 that was formed in response to the mandate.[215] In parallel, the EU-funded project LIFE FRONT provided relevant data such as a leak size/concentration database to support evidence-based risk assessment for the use of flammable refrigerants and released recommendations on how to safely raise the charge limits of flammable refrigerants.[216]

The overarching refrigeration and air conditioning standard EN 378 was updated in 2017 to include the refrigerant R744 (CO_2) and is currently, once again subject to review. A primary focus of this revision is the broader use of flammable refrigerants, particularly for equipment not explicitly covered through product standards. However, the process is not expected to be completed before 2024. The latter work will seek to include the technical specifications developed under Mandate M/555.

Concerning plug-in commercial refrigeration applications, the international standard IEC 60335-2-89 increased the refrigerant amounts (“charge limits”) from 150 g to 500 g for flammable refrigerants (e.g. hydrocarbons like propane) and for “mildly” flammable refrigerants (e.g. HF(C)Os), from 150 g to 1.2 kg. The corresponding European EN standard still needs to be adjusted in light of this international development and an updated standard is expected for early 2022. The latter standard is referred to by the Machinery Directive. EN 60335-2-24 for domestic refrigeration equipment was updated in 2020.

As regards air conditioning and heat pumps, a new proposal for the international product standard IEC 60335-2-40 is currently being discussed, including the issue of flammable refrigerants, and could be adopted by June 2022. Following this, an adjustment of the corresponding European standard EN 60335-2-40 would be necessary.

Certain restrictions for the application of flammable refrigerants also exist at Member State level, some of which are considered as important constraints. Some progress was made in those countries where restrictive rules had been identified, specifically in France,

[213] Without such reference in legislation, standards would represent technical documents whose use is voluntary.

[214] CEN and CENELEC are the European standardization organisations. https://www.cencenelec.eu/

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

[216] http://lifefront.eu/

Italy and Spain, which have recently amended their national building codes and fire prevention rules to allow installation of flammable refrigerants in certain types of public or high-rise buildings. However, some barriers still remain, as these updates often only allow the use of H(C)FOs and not hydrocarbons and there are still remaining restrictions for certain types of buildings. In other Member States, the national authorities believe that there were no such restricting rules at national level. However, this does not preclude that there continue to be restrictive rules at the local or regional level, such as specific fire protection codes.

In summary, while **some progress is made and some improvements have been achieved, in particular in commercial refrigeration, standard setting is a slow process and divergent industry interests[217] continue to hinder a timely, purely risk-based setting of standards that ensures high safety levels while allowing a maximal use of climate-friendly refrigerants.**

A5.6.4.4 Internal Coherence

As for internal coherence, the Regulation has generally been found to be consistent and coherent internally and across its implementing acts. This is also reflected in the fact that no requests for derogations for certain sectors have been received by the Commission to date. Nevertheless, some provisions were identified as not being fully aligned or sufficiently clear (mostly by authorities, rather than by industrial stakeholders). These provisions include:

- Consistency of thresholds for the import of pre-charged equipment. 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. This includes the 100 tCO2e *de minimis* exemption for pre-charged equipment which is not clearly stated but must be inferred from the reference in Article 14 to the quota system in Article 15 (which includes such an exemption).
- In Article 15 it is not sufficiently 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.
- The quota exemption for HFCs supplied directly for export (Article 15(2)(c)) only applies to bulk gases but some stakeholders initially thought that it also applied to HFCs supplied for exported equipment and products containing HFCs.

Reporting and verification have been key measures in the success of the Regulation in meeting its objectives and data reported under the Regulation and were mostly found to provide a reliable basis for monitoring how the EU industries react to the intervention.

[217] The technical background work on standards is done in technical working groups composed of industry stakeholders. Small companies with innovative technologies find it difficult to be represented in these groups as involvement is resource-intensive and therefore dominated by the established players.

The requirements have also supported the aim of the phase-down, helping to ensure compliance with the quota system, and supporting consistency across industry. However, the following issues were identified:

- There is an inconsistency between the need to have a quota authorisation for the import of equipment from 100 tCO_2e, but a reporting threshold of 500 tCO_2e, which complicates accounting of the authorisations used.
- There are different dates, thresholds and other requirements for reporting and verification on bulk and equipment which lack a sound logical basis and are inefficient.
- Article 17(4) provides that competent authorities, including customs authorities, shall have access to the HFC registry for information purposes. However, the provision does not specify whether and in which situation the authorities should actually use the HFC registry.

Also, a number of smaller clarifications would be needed (Annex A6.5).

A5.6.5 EU added value

There is a continued need for action at EU level due to the transboundary nature of the global warming effect of fluorinated greenhouse gases. It must be ascertained that F-gas emissions are being reduced at EU level in line with the climate ambitions of the European Green Deal.

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 supported by many different stakeholders and the competent authorities. Without the Regulation, each Member State would need to introduce their own mechanisms to regulate e.g. their national F-gas consumption. It would be much more costly to conduct 27 implementation measures rather than EU-wide measures.[218]

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 and can better and more easily ensure compliance with the Protocol. The climate targets to be achieved under the Green Deal are an order of magnitude that requires that strong, effective and coordinated policies are in place. 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 for the most efficient abatement solution to be found across a broader (EU) market, which is likely to lead to lower implementation costs. Furthermore, the ongoing,

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[218] For the recent evaluation of the ODS Regulation, which guarantees complying with the rules of the Protocol concerning ozone-depleting substances and implements similar measures as the Fgas Regulation for this purpose (e.g. prohibitions, reporting, licensing systems), it was calculated that introducing individual measures at MS level would cost 17 times the costs of EU-wide measures (in an EU of 28).

successful reduction of F-gas emissions is due to the combination of an EU-wide phase-down and prohibitions working together. Individual measures introduced by Member States 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.

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, minimising compliance burden for market players and providing for a level-playing field, e.g.:

- 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 agree that the Regulation has created a level playing field across the EU.
- Through the F-gas Portal, the Regulation has introduced a common electronic tool which companies 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 companies' 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. [219]
- Each Member State would have to set up a licensing system for goods being imported and exported to and from the EU from their territory. As outlined above, many companies do not operate solely in one Member State, but across borders. Thus, that would greatly increase the administrative burden for Member States and companies.

[219] This can be illustrated by the administrative efforts needed in the UK after BREXIT. They have replicated the EU system with important needs of staff and resources on the administrative side and industry trading in both the UK and the EU27 now have to deal with two phase-downs and two reporting systems and there is no environmental gain involved.

- A joint approach across Member States makes it easier to enforce F-gas rules. One Member State noted specifically that common elements such as definitions, labelling, etc. would be complicated to agree at national level.
- Common legislation has also enhanced the market for new alternatives (Stakeholder interviews).

Finally, given **the rules of the common market, ensuring compliance with the Kigali Amendment (e.g. consumption reduction rules, import and export licensing) at Member State level in an EU without borders would be very difficult if not impossible to do.**

A5.7 Conclusions

The Regulation has been mostly effective in meeting its original objectives and the individual measures were found to work well together to meet the objectives. The Regulation has driven a significant reduction in the supply and emissions of F-gases, in particular the HFCs, predominantly through a switch to gases with lower GWP, but also through the uptake of natural alternatives. The effectiveness of the Regulation as a whole would have been impacted if one or more of the measures had not been included. In particular the phase-down and accompanying prohibitions have had good synergistic effects and have been strong drivers for innovation. Leakage rates from equipment have declined and reclamation rates have gone up. That said, forward modelling indicates that the emission reductions in 2030 will be lower than expected in the 2012 impact assessment which was aligning measures with the outdated 2030 climate target. There are also continuing emissions from sectors or substances not yet covered by the phase-down measures or prohibitions or not yet included in the scope, and in some sectors high global warming potential (GWP) F-gases continue to be used where this could be avoided due to technological progress.

The Regulation enabled a joint EU negotiation position and the tabling of a proposal for a global phase-down. It also established the EU as a frontrunner in taking measures on F-gases and ensured EU global credibility on this issue. Since the adoption of the Kigali Amendment to the Montreal Protocol, the Regulation is the main instrument to ensure compliance with the international obligations to date. In addition, the Regulation has safeguarded high environmental ambition by maintaining the same obligations across the EU, while also ensuring a level-playing field for concerned industries and undertakings.

There are some challenges, however, which include safety standards that are not fully updated according to technological progress and hinder the use of climate-friendly alternatives, as well as the lack of personnel that have skills to install and maintain equipment with climate-friendly alternatives. In addition, illegal trade and the multiplication of bulk importers pose a challenge to the future implementation of the phase-down. Finally, some stakeholders express concerns about the increased use of H(C)FOs and potential effects related to degradation products such as TFA in the atmosphere.

The Regulation has resulted in significant emission savings at very low abatement costs linked to technological change (i.e. 6 € per tonne CO2e), even with minor gains in energy efficiency. Higher HFC prices imply higher gas cost to end-users that are still using HFCs. These costs are distributed over a large number of end-users and were offset by equivalent benefits to companies in the HFC supply chain. Most of these costs accrued in the refrigeration and air conditioning sector, where they represented 1% of the investment and operation costs of related equipment. Effects on the overall economy were very small and likely to have been slightly positive in some affected sectors (e.g. service sector and equipment manufacturing). While there are different patterns in use of different types of equipment in the northern and southern Member States, overall the costs were quite balanced between the two regions when taking into account the size of the population. Administrative costs were considered proportionate by stakeholders and are of a lower magnitude than the costs of technological change. A few areas linked to the reporting and verification obligations were identified where unnecessary burden may be reduced. The pandemic has been challenging to the sector, even though in some areas business profited (e.g. food retail, energy transmission). However, it has apparently been rebounding well in recent months.

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 as well as some adaptions to be fully compliant with the Montreal Protocol in the future. There are also some relevant gaps in the substances and activities covered by monitoring and reporting measures. Finally, there is currently no flexibility to react in case of undesirable effects of the quota system such as lack of supply.

The Regulation interacts with a number of regulatory instruments, such as other EU policy areas but also international agreements. In general, the Regulation was found to be externally consistent and coherent with other interventions that have similar objectives, although there are areas that have led to some incoherencies that should be addressed. An important area is customs law, where synergies with the EU Single Window Environment for Customs should be exploited and efficient border controls facilitated to stop illegal activities. Another important synergy is with the REACH Regulation where Member States-led efforts are underway to look into the relevance of persistent degradation products from H(C)FOs. Internal consistence of the Regulation is good, but some clarifications and alignments are needed.

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. 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 and helping to minimise costs during the technology conversion.

A5.8 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

A6 Individual Measures

Table 26 below lists the detailed measures included in the three options, arranged by policy objectives (A, B, C, D and E) and policy responses (A1, A2, ..). The singular measures are described in detail further below.

Table 27. Individual measures considered under the three options

Objective A – Achieving additional emission reductions
A1: Increasing the ambition of the HFC quota system (mutually exclusive)
• * Option 1: Steps included after 2030 simply to ensure long-term compliance with the HFC consumption schedule of the Protocol under all circumstances
• * Option 2 Steeper phase-down assuming replacement at proportionate costs
• * Option 3 Steepest phase-down based on maximum replacement of high GWP HFCs as soon as it is technically possible
A2: New prohibitions for F-gas products and equipment
• Prohibit placing on the market and installation of **fire protection equipment** with F-gases (i.e. Annex I) from 1 January 2024, except if required to meet safety rules. For enforcement it necessitates labeling of F-gas equipment to be used in accordance with safety rules.
• Prohibit placing on the market and installation of **small hermetic RAC[70] systems** (e.g. cream and ice cream makers, (slushed) ice makers, cooled trolleys, water coolers, juice makers, milk coolers (attached to coffee machines), beer and wine coolers, heat pump tumble driers etc.) with F-gases (i.e. Annex I) from 1 January 2025.
• Prohibit placing on the market and installation of RAC equipment with F-gases (i.e. Annex I) from 2024 for the existing prohibitions in Annex III [**extending HFC prohibition (preemptively) to PFCs]**
• Prohibit placing on the market and installation of the following **stationary AC** from 1 January 2025 ◦ of a rated capacity of up to 12 kW with F-gases with a GWP of 150 or more except if required to comply with safety rules ◦ of a rated capacity of more than 12 kW with F-gases with a GWP of 750 or more except if required to comply with safety rules For enforcement it necessitates labelling of F-gas equipment to be used in accordance with safety rules.
• Prohibit servicing **refrigeration equipment with charge sizes under 40 tCO2e** with F-gases (i.e. Annex I) with a GWP above 2500. [Remove the exemption from an existing prohibition (Article 13(3)]
• Prohibit **personal care products** (creams, mousses, foams) with F-gases from 1 January 2024:
• Prohibit placing on the market and installation of **skin cooling equipment** with F-gases 1 January 2024 except if required for strictly medical reasons. This necessitates labeling of HFC equipment for enforcement.
• Prohibit placing on the market and installation of the following **electrical switchgear**, unless evidence is provided that no other suitable alternative is available on technical grounds: ◦ medium voltage switchgear for primary distribution, differentiated by voltage level – up to 24 kV (2026) and 24-52 kV (2030), with insulating or breaking medium with GWP > 2000 ◦ medium voltage switchgear for secondary distribution differentiated by voltage level – up to 24 kV (2026) and 24-52 kV (2030), with insulating or breaking medium with GWP > 2000 ◦ high voltage switchgear, differentiated by voltage level – 52-145 kV and up to 50 kA short circuit current (2028) and more than 145 kV or more than 50 kA short circuit current (2031), with insulating or breaking medium with GWP > 2000

70 As throughout this document, RAC and AC includes heat pumps.

• Prohibit the *use* of desflurane as **inhalation anesthetic from 2026** unless there are no suitable alternatives for the intended use
A3: Extend requirements for prevention of F-gas emissions
• Extend **prevention requirement** to some substances listed, or proposed to be added (H(C)FOs, NF_3, SO_2F_2 and fluorinated ethers used as anesthetics)
• Extend prevention requirement to all relevant actors during **production, manufacturing, storage, transfer and transport** [currently only required for EU producers and equipment operators]
A4: Recovery obligation of insulation foams blown with HFCs
• Require destruction or reuse of HFCs in **metal-faced panels** from 1 January 2024
• Require destruction or reuse of HFCs in **laminated boards in built-up structures and cavities** from 1 January 2024, unless infeasibility is proven by the building owner/demolition company

Objective B – Seeking alignment with the Montreal Protocol
B1: To achieve full alignment, remove some exemptions not foreseen by the Montreal Protocol
• Remove exemption from the HFC quota system for Metered dose inhalers (MDIs) (Art. 15(2))

• Remove exemptions from the HFC quota system (Art. 15(2))
  • Etching of semiconductor material or cleaning of chemicals vapor deposition chambers within the semiconductor manufacturing sector
  • Military use

B2: To achieve full alignment, remove some thresholds not foreseen by the Montreal Protocol
• Remove quota system thresholds for placing HFCs on the market (Art. 15(2))
• Remove reporting thresholds for HFC production, import, export, and destruction (Art. 19)
B3: To achieve full alignment, make separate phasing down of HFC production
• Include a separate HFC production phase-down at entity level that is mirroring the Protocol's reduction schedule (see Annex A8)
B4: Disallow trade with countries that have not ratified the Kigali Amendment
• Prohibit import and exports of bulk HFCs from/to any country not party to the Kigali Amendment (2033 for Option 1; 2028 for Options 2 and 3)

Objective C – Improving implementation and enforcement
C1: Extend certification and training for RAC[71] technicians, adding energy efficiency and low-GWP alternatives
• Extend certification and training programmes to cover energy efficiency aspects
• Extend training and certification programmes to cover equipment with H(C)FOs and other relevant alternatives (e.g. CO_2, ammonia, hydrocarbons)
• Extend the coverage of the certification requirements for personnel and undertakings that carry out installation/servicing/maintenance/repair/decommissioning of RAC equipment containing H(C)FOs
C2: Including detailed rules to empower customs and surveillance authorities in the EU Member States and facilitate the use of the EU "Single Window environment for Customs"
• Empower the EC to require specification of the 8/10-digit TARIC code for special custom procedures when this becomes feasible under customs rules
• Limit the release of free circulation, even when following transit (T1) or similar procedures, to certain well-equipped destination offices with expertise in F-gas requirements
• Prohibit physical entry for goods that are prohibited from being placed on the market, including non-

[71] RAC: refrigeration and air conditioning (including heat pumps)

refillable cylinders with HFCs and HF(C)Os. This includes online sales.

C3: Strengthening obligations of economic operators to prevent illegal trade

- Require that producers and importers hold sufficient quota at the time of release for free circulation/placing on the market
- Require that importers have quota-exempted quantities labelled at the moment of POM/physical entry as “exempted from quota”
- Require Member States to impose minimum penalties for non-compliance with the quota system
- Require labelling of H(C)FO, NF_3, SO_2F_2 and fluorinated ethers used as anesthetics, as well as MDIs
- Strengthen the obligation on destruction of HFC-23 by-production to require evidence to be presented at import that HFC23 has been destroyed during the production process
- Require documentation for downstream sales of bulk HFC/F-gases (e.g. “declaration of conformity”) and record keeping
- Require mandatory certification for importers of bulk HFCs
- Requires mandatory certification for natural persons and undertakings selling bulk F-gases online

C4: Ensuring that only genuine F-gas traders participate in the quota system

- Remove right of authorising quota for new entrant companies (Art. 18(2))
- Align the establishment of the annual declaration-based quota allocation with the frequency of the quota allocation based on reference values (i.e. for three years)
- Introduce a moderate quota price of initially €3/CO2e and use the revenue to cover administrative costs related to running the quota system and return the residual amount to the EU budget

  Include flexibility to adjust in case of major HFC market disruptions and withhold some quantities when allocating quota with a view to distributing the amounts later

  Participation condition for companies (e.g. experience in trading with chemicals)

Objective D – Improving Monitoring and Reporting

D1: Reporting scope – substances

- Include new substances in Annex I
  - New PFCs
- Include new substances in Annex II
  - sulfurylfluoride (SO_2F_2)
  - 4 new H(C)FOs
  - 2 Inhalation anesthetics
  - A number of fluorinated ethers and alcohols
  - 2 fluorinated ketones and fluoronitriles
  - 3 other Fgases : Perfluorotripropylamine ($C_9F_{21}N$), Perfluoro-N-methylmorpholine ($C_5F_{11}NO$), Perfluorotributylamine (PFTBA, FC43, $C_{12}F_{27}N$)

D2: Reporting scope - F-gas related activities

- Include recipients of quota-exempted HFCs
- Include undertakings performing reclamation of F-gases
- Include exporters of products and equipment with F-gases (plus registration obligation)
- Include undertakings performing recycling (in addition to reclamation) of F-gases

D3: Emission reporting

- *Option 2: Encourage EU Member States to use electronic reporting systems for collection of F-gas service intervention, technicians, sale of non-hermetic equipment and emissions data (mutually exclusive)
- * Option 3: Require EU Member States to use electronic reporting systems for collection of F-gas service intervention, technicians, sale of non-hermetic equipment and emissions data (mutually

exclusive)
• Reporting obligations for operators of switchgear and electrical equipment with regard to SF_6 emissions
D4: Reporting process and data verification (see also Annex A10)
• Add obligation to provide NIL reports for quota holders • Add obligation to submit verification reports for bulk HFCs • Lower the threshold for verification of bulk HFCs placed on the market • Relax the threshold for verification of placing on the market products and equipment and align with verification of bulk • Align reporting and authorization thresholds for placing pre-charged products and equipment on the market • Align reporting and verification dates between bulk and pre-charged products and equipment
• Introduce an electronic verification process (separately for bulk and pre-charged products and equipment)

Objective E – More Coherence and Clarifications

All 3 options include the envisaged improvements (see Annex A6.5) to make the Regulation more coherent and clear.

A6.1 (A) Measures to increase ambition

A1. Phase-down ambition

The Regulation's main policy driver to reduce HFCs is the quota system ("phase-down"). Option 1 is having the least ambitious phase-down (simply compliant with the Protocol), Option 2 has a more ambitions phase-down (entailing abatement costs up to 390€ per tCO2e up to 2050 excluding a few sub-sectors with very high marginal abatement costs) and Option 3 has the steepest phase-down measures (maximum technical feasibility considering also safety and energy efficiency aspects, but not costs). Whereas the current Regulation is defining the steps in percentages of a baseline, for the three options the maximum annual quantities of HFCs that may be placed in total on the EU market each year in the future are given for better transparency, see Annex A7 "Operationalising the HFC placing on the market (POM) quota system (phase-down) going forward" for details.

The quota system directly affects producers and importers of bulk and importers of HFC cooling equipment. Potentially higher HFC gas prices for equipment that does not use climate-friendly alternatives and higher prices on equipment using alternatives due to technological conversion are mostly borne by equipment end-users such as in the food retail sector (cooling), AC users (building owners) etc. The quota system is implemented by the European Commission. Member States have to enforce compliance including through custom controls and market surveillance. Authorities and other non-industrial stakeholder mostly agree to increase the level of ambition, whereas F-gas producers and some stakeholders of the refrigeration and AC industry consider that the current level of ambitions is sufficient. Those that disagree are the manufacturers and users of innovative, alternative equipment, especially those employing natural alternatives with very low GWP (CO2, hydrocarbons, ammonia etc.).

A2. Additional prohibitions for equipment and products

The new prohibitions on equipment and products concern mostly placing on the market or installation as such equipment. There are also two use bans considered[72]. They typically are specified to cover all F-gases[73], but in practice they target a specific group of F-gases only. The prohibitions related to the RAC sectors, fire protection, personal care products and skin cooling equipment are directed towards HFCs and they thus complement the phase-down. While HFCs can be safely replaced, stakeholders have pointed out as regards air conditioning equipment that there remain technical barriers in building codes and in standards that prohibit substances with certain characteristics (e.g. flammability) that apply to alternatives with a GWP below 150. Therefore, for two prohibitions there is an exemption allowing HFCs with a higher GWP relating to safety rules. Since, the actor placing the equipment on the market cannot always know where it will be used, it is necessary to combine these exemptions with a labelling requirement as well as a prohibition to install the high GWP equipment. Some stakeholders agree that further HFC prohibitions are an essential complement to the phase-down, whereas others consider there is no need to increase ambition and/or that the phase-down should be the only measure targeting HFCs to allow maximum flexibility for industry.

The prohibition relating to electrical switchgear is targeting SF_6 and restricting the use of one inhalation aesthetic is targeting a substance with a high GWP for which there are good alternatives. These measures will achieve additional emission savings on top of those achieved by the phase-down measure.

Based on cost considerations, the number of additional prohibitions varies between the three options (see Table 1). Prohibitions need to be enforced by Member States, including through border controls and market surveillance. In case there are exemptions to the prohibitions, the products will have to be labelled to facilitate enforcement. As regards SF_6, manufactures of switchgears have been calling for prohibitions to give a clear signal whereas some users of switchgears such as network operators have called for longer transition times.

A3. Add additional requirements for preventing F-gas emissions

In Options 2 and 3, emission prevention measures (i.e. Article 3) that already apply to gases in Annex I will also become mandatory for gases in Annex II section I (i.e. H(C)FOs) and NF_3, as well as for the substances sulfurylfluoride and fluorinate ethers (to be newly added by measure D1) and others used as inhalation anaesthetics (isoflurane, norflurane (both newly added), in addition to desflurane and isoflurane (already in Annex

[72] Use in personal care products and the use of one anaesthetic

[73] To avoid that in the future another type on F-gases would be used, e.g. replacing HFCs with PFCs in cooling equipment

II and where already not prohibited by measure A2)). Intentional releases that are not technically necessary will be prohibited and operators must take precautions to prevent unintentional releases.

Sulfurylfluoride is used most as post-harvest fumigation agent for pest control in e.g. hardwood and softwood in containers destined for export[74]. Despite its high GWP of 4732 and increasing use, the emissions of sulphurylfluoride are not yet monitored or regulated.

Fluorinated ethers are regularly used as inhalation anaesthetics during operations in human medicine. In Europe, this use is limited to three substances, desflurane (HFE-236ea2; GWP 989, Regulation; GWP 2 590, AR6), sevoflurane (HFE-347mmz1; GWP 216, AR5; GWP 195, AR6) and isoflurane (HCFE-235da2; GWP 350, AR4; GWP 539, AR6; ODP 0.03, WMO 2018). According to medical experts, for human medicine desflurane and isoflurane are not needed in ca. 99 % of cases, as practically all operations with the indication for use of inhalation anaesthetics can be conducted with sevoflurane. Isoflurane is still used, mainly because it is the cheapest fluorinated ether. All gases do, however, differ in certain clinical aspects, such as duration of onset and offset, and how well tolerated they are by the patient. Isoflurane is routinely used in veterinary medicine and usually fully vented to the atmosphere, according to information from practitioners and clinics. Apart from that, it is also the main gas used in the newly obligatory anaesthesia of mail piglets during castration.

Furthermore, the requirement to take precautionary measures will be extended to all relevant companies in the EU carrying out production, manufacturing, storage, transfer or transport of gases and F-gas equipment (already currently in place for EU gas producers and equipment operators). Emissions from refrigerant container management and handling are estimated at 2-5 % of the entire refrigerant market by industry experts. This places some obligations on EU importers, distributors, and EU manufacturers to handle these substances with care, but such care should already be the case today under best practice refrigerant management procedures. In general authorities and also the relevant industry actors appear to support these type of measures.

A4. Recovery obligations for insulation foams

It becomes mandatory to recover/capture and destroy HFCs by incineration (or reuse the foam) for certain types of foams[75] found in construction and demolition wastes (See Annex A15 for detail). In this way, HFC quantities contained in foam banks will not be emitted at the end of life of these construction products but will need to undergo an organized recovery and recycling process to prevent emissions. This is fully aligned with a key policy measure suggested for a review of the ODS Regulation and will lead to

[74] There is also, to a much lesser degree, structural fumigation of dried fruits, tree nuts, grain flours and timbers.

[75] An insulation foam consist of a matrix material and a gas phase. During production a liquid was “blown” with HFCs that created the foam matrix after hardening. HFCs remain in the gas “bubbles” of the foam. Foams have long lifetimes of 50 years and more.

comprehensive treatment of end-of life foam products. Under Option 1 the obligation concerns only sandwich panels. Under Option 2 and 3 the obligation applies to both sandwich panels and laminated boards, however as regards the laminated boards[76] the obligation does not apply if the building owner and/or the contractor performing the works can provide proof that such recovery is infeasible and is keeping that proof for five years. Member States would need to enforce this obligation. This effort may often be linked to other requirements in existing national legislation on renovation/demolition works, waste policy and the need for separation of materials, in particular in light of objectives for a circular economy. There are also important synergies with the ODS Regulation, where this measure leads to important emission savings. A joint collection of ODS and HFC foams would facilitate the recovery and keep costs for auditing and separation down. In general, the relevant industry stakeholders appear to support these type of measures (as confirmed by the recent consultations for the review of the ODS Regulation).

A6.2 (B) Measures to align with the Protocol

B1. Removal of exemptions

In all options the exemption for MDIs from the quota system is removed, as it is not provided for in the rules of the Montreal Protocol and the quantities are significant[77]. MDIs currently use HFC-134a as a propellant, but HFC-227ea is also used in some cases. According to the relevant stakeholders (i.e. gas producers and some MDI manufacturers), MDIs with the more climate-friendly HFC-152a (GWP 124) should be available on the market starting in 2025 after an extensive period of testing, homologation and necessary approval by the European Medicines Agency that is currently ongoing. Research is also currently conducted on the safety of the unsaturated HFC-1234ze (GWP 7) as another alternative for use in MDIs.[78] Both these options would not require a change of usage by the patients that are used to the current HFC MDI inhalers. These new options complement other existing options such as dry powder inhalers and soft mist inhalers which are also suitable alternatives, but may be more difficult to use or get used to by patients depending on the personal situation.

In the absence of a policy driver, the market uptake of these alternatives is expected to be rather slow. Assumptions for the modelling were based on industry information and for the baseline scenario a decrease in the share of HFC-134a in new inhalers from 92% in 2020 to 48% in 2050 was assumed. For HFC-227ea, the share was assumed to decrease from 8 to 2 %. Consequently, a share in new inhalers with HFC-152a from 1 % in 2026 to 50 % in 2050 was assumed in the baseline scenario.

[76] Feasible to recover are foams installed in cavity or built-up structures, as well as block foams used in district heating or cooling pipes.

[77] In addition, HFCs amounts for MDI use have grown by about 45 % from 2015 to 2019 and have reached levels of over10 Mt CO_2e per year

[78] There are also other existing inhaler options to patients such as dry powder inhalers (DPI) or soft mist inhalers that do not use F-gases.

The MDI exemption concerns only a few HFC producers and MDI manufacturers. If the exemption is removed the latter may experience higher gas prices unless they switch to alternatives. The price of the gas is however only a very small part of the price of the overall product (less than 1%) which is mostly determined by the medicinal agent. On the other hand, when exemptions are removed, importers and producers will no longer be required to include special labelling for such quantities. Some producers of alternatives and MDIs would like to see a policy driver to support their actions of introducing alternatives more quickly. Others would like to have more time. Authorities and other stakeholder generally are supportive.

In order to account for the HFC quantities needed, the calculation rules for the determination of reference values for the HFC suppliers to the MDI sectors need to be amended. As a principle, the reference values for companies supplying HFCs to the MDI sector should be based on recent available data for the average POM in the EU-27 (i.e. 2020-2021). In the case of HFC suppliers for (previously exempted) MDIs, this data is available from company reporting under Art. 19 of the Regulation. The quota allocated to HFC suppliers of the MDI sector for the first reduction step 2024-2026 under a revised Regulation will equal 100% of the average e.g. 2021-2022 POM. For subsequent reduction steps, the relative reductions for the MDI sector will be proportionate to the reductions applicable to all other HFC use sectors (see also Annex A7). It means therefore that the sector will experience a gradual introduction of the alternatives, as the first phase-down step will not come before in 2027. This step will increase prices which will be a soft driver for change (given that the gas price is only a very small increment to the price of the product). Under these circumstances an insufficient of supply of HFCs to this sector is improbable. Nonetheless, in the unlikely event of a major HFC market disruption, measure C4 would provide the Commission with the flexibility to react and take countermeasures.

Option 3 also removes the exemptions for the much smaller semiconductor and military sectors. At present, no viable measures to reduce HFC demand in semiconductor industry for etching or cleaning of chemicals vapour deposition chambers are available. The EU semiconductor manufacturing industry is supplied with HFCs by specialised gas traders providing special-grade gas qualities. Those specialised trades have no or low reference values. If included in the quota system, these gas traders would need to rely on quota transfers from other quota holders in order to maintain HFC supply in case of constant HFC demand. A lift of the quota exemption for semiconductor manufacturing could thus possibly contribute to a supply risk for the semiconductor industry, beyond rising HFC prices. The calculation approach for determining reference values would therefore need to follow a similar approach as that for MDIs above to include the specialised HFC suppliers. This is also the case for military use which, based on reporting data, are very small amounts.

B2. Removal of thresholds

In all options the phase-down exemption for annual imports below 100 tCO2e (Art. 15(2)) and the minimum thresholds for reporting on production, imports, exports, and destruction (Art 19) for HFCs are removed, as they are not compatible with the Protocol. This places a burden on companies dealing with small quantities of HFC. However, in an estimation based on import data in Poland these appear to be only very few companies[79]. It may also limit illegal imports as these thresholds have allegedly been exploited to cover up illegal activities in the past. In the consultations stakeholders supported these type of measures.

B3. Production phase-down

In all options a separate HFC production phase-down mirroring the Protocol's requirements is included. This will give production rights and annual quota to seven[80] producing entities in four Member States that were active in the years 2011-2013 that were used for the Protocol's production baseline. Similar to the ODS Regulation, flexibility for industrial rationalization will be possible. Further details are described in Annex A8 "Separate production phase-down". The Member States and producers concerned appear to support this measure. See Annex A8 for further detail.

B4. Disallow trade with Parties that have not ratified the Kigali Amendment

In all options HFC bulk imports from and exports to countries that have not ratified the Kigali Amendment will be prohibited from 2033 (Option 1), and 2028 (Option 2 and 3). This measure would affect, in the same way, EU importers of gases sourced from non-Parties, as it affects EU exporters to such countries. For Options 2 and 3, this is slightly anticipating the Kigali Amendment deadline of 2033 for such trades, incentivising remaining Parties to implement it as soon as possible, which would save up to 0.4 degree Celsius of climate warming. It therefore represents an important contribution to reach the goals of the Paris Agreement to stay well below 2 degrees Celsius of climate warming and make efforts to reach 1.5 degrees Celsius. The latest scientific findings on climate change clearly indicate the need to limit the warming to as little as possible and emphasise that reaching the 1.5 degrees Celsius goal is crucial to avoid dangerous consequences. While there are differences in the rules for developed and developing countries in the Kigali Amendment, all countries have a first compliance step on HFC consumption already before 2033 as well as a baseline before 2025, so that early ratification is needed to ensure full implementation of the Kigali Amendment. So far 129 out of 197 parties to the Montreal Protocol have ratified the Kigali Amendment. Given that the Amendment was adopted in 2016, 12 years should be enough time to ensure timely completion of the national procedures to enable ratification by 2028 for the remaining Parties. In general, industry, authorities and other consulted stakeholders appeared to support these measures.

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[79] The Polish database (which does not apply a threshold) on imports to Poland (both from outside EU and from EU countries) did not have any entries below the threshold of Article 19 (database consulted in 2019)

[80] Only five of which currently have on-going HFC production (in DE and FR)

A6.3 (C) Measures to improve implementation and enforcement

C1. Extension of the RAC certification programmes

Member States will be required to include new aspects in the certification programme and training for technicians covering refrigeration, AC and heat pump equipment[81]. Under all options, know-how on energy efficiency must be included (Art. 10(3)). Options 2 and 3 also require that the programme include certification and training on HFC alternatives such as H(C)FOs and naturals (e.g. hydrocarbons, CO2 and ammonia), including practical training (Art. 10(1)). In addition, it becomes obligatory that the technicians hold the relevant certificate when performing certain activities on AC equipment containing H(C)FOs (Art. 11(4)). Currently only half of the current training centres are able to offer training programmes on the safe use of F-gas alternatives (including flammable, high-pressure and/or toxic refrigerants). The training programmes are spread unevenly across Member States. Thus, under this option Member States would have to update their certification programmes and ensure that training is available, if that is not the case already. Technicians will be certified with additional skills and may have to acquire a certificate even if they install equipment with H(C)FOs only. Industry stakeholders, in particular the association of service technicians AREA, strongly support these measures.

C2. Capacitate Customs to fight illegal imports

All options require that traders specify the 8-digit CN or 10-digit TARIC[82] code for relevant customs procedures[83] (already the case for "release for free circulation"). This is needed to allow an identification of the F-gas and will thus enable significantly better controls as customs can identify shipments as F-gas policy relevant and carry out risk-based controls. Furthermore, goods with F-gases that may not be placed on the market in the EU will also be prohibited from physical entry into the customs territory of the Union to make illegal circumvention of custom clearance more difficult, including online and from outside the Union. Surveillance authorities are required to monitor goods offered online. In addition, release for free circulation, even if following the use of special custom procedures, will only be permitted for goods sent to particular destination custom offices specially equipped for and knowledgeable on F-gases, to limit the feasibility of illegal activities. This may affect the logistics of legitimate traders but should not affect the volumes of trade. Member States would need to identify the customs offices that are equipped to handle HFC trade to ensure good control. Customs should control, using risk-based approaches, if the conditions are provided for such shipments. All stakeholders strongly support these measures as they are essential to fight illegal imports.

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81 in accordance with Commission Implementing Regulation (EU) 2015/2067

82 CN = Combined Nomenclature: https://ec.europa.eu/taxation_customs/business/calculation-customs-duties/customs-tariff/combined-nomenclature_en
TARIC = Integrated tariff of the EU https://ec.europa.eu/taxation_customs/business/calculation-customs-duties/what-is-common-customs-tariff/taric_en

83 already the case for "release for free circulation"

C3. Obligations of economic operators to fight illegal imports

All three options require producers and importers to have sufficient quota at the time of placing on the market instead of using an end-of-year balance that includes a deduction of exported quantities. This enables customs to stop imports before entry, instead of only relying on ex-post controls. Quota exceedance will be checked automatically via a link between the *CERTEX/Single Window Environment for customs* and the *F-gas Portal*. This approach may affect the logistics of some companies doing imports and exports, as later exports in the same year can no longer compensate for high imports in the beginning of the year. To close any loopholes, gases exempted from the phase-down should be labelled as such already at the time of entry.

Member States must already have proportionate effective and dissuasive penalties for all infringements of the Regulation. Option 2 and 3 specify that non-compliance with the rules of the quota system must be fined with an amount that is several times higher than the market value of HFCs illegally imported in bulk or contained in the imported equipment. The Directive 2008/99/EC on the protection of the environment through criminal law is being reviewed at the same time as the Regulation and is likely to also impose criminal sanctions on such offenses. These rules aim to have a deterrent effect on such activities.

Options 2 and 3 are also requiring that undertakings must provide evidence at the moment of placing on the market that HFC-23 was destroyed or captured during production in line with the Art. 7(2). As this is an existing obligation, the measure would only clarify when the evidence should be produced as well as specifying what such evidence could be (e.g. a declaration of conformity backed up by supplementary information where the gas was produced and how emissions of HFC-23 by-production were prevented during the production process). This is done to make the obligation more implementable for authorities, while not placing any substantial burden on companies that are compliant with current rules, except for a small admin burden of drawing up the declaration of conformity. This obligation affects both EU-based producers of gases as well as EU importers. Furthermore, a number of substances from Annex II would require labelling, namely HF(C)Os, NF_3, as well as SO_2F_2 and inhalation anaesthetics (to be added to the Regulation, see D1 below). MDIs should be labelled with information to inform the users that they contain strong greenhouse gases, in analogy to other products and equipment.

Option 3 also adds a mandatory certification similar to those currently issued to RAC technicians for importers of gases and for online sellers. This means that the latter two would have to get their personnel trained and certified. The option provides better overview over importers/online sellers and their personnel for competent and surveillance authorities and ascertains that handling of gases is appropriate. Finally, Option 3 would also require that downstream sales (i.e. sales within the EU, after import) of bulk HFCs would need to be documented and a certificate of conformity provided on their origins and compliance with the quota system. This places a burden of record keeping on distributors, service personnel and end-users. Member States would need to ensure compliance.

Stakeholders generally support the measures in Option 1 and 2. The Option 3 measures are supported by the large F-gas producers/importers who are concerned about fighting illegal trade and NGOs, and some Member States. Affected companies are less supportive.

C4. Limitation to genuine F-gas traders

All options include the measure to limit the right of authorising equipment importers to use one`s quota (i.e. essentially selling one's marketing rights in that year), to incumbent[84] companies, as this right has been misused by new entrant companies[85]. Furthermore, instead of providing the possibility to apply for quota from the reserve every year, such applications will instead cover a 3 year period. A yearly application has led to a multiplication of mailbox companies without previous experience or connection to the gas trade, limiting the availability of quota for those new entrants who required it for their on-going businesses. The measure should also reduce the administrative burden of companies as the yearly application cycle is replaced with a 3-year cycle.

Options 2 and 3 add a price per ton of CO2 allocated which must be paid by the companies that receive quota (i.e. gas importers in the same way as EU-based gas producers), in order to ascertain that participants have a legitimate interest in the HFC trade and to remove current gains of some stakeholders from the hitherto free distribution of a good that has a distinct value. Equipment importers and EU equipment manufacturers as well as end-users have pointed out that with the existing system (free allocation of quotas) they are asked to pay the bill, while gas importers, EU gas producers and others make an additional benefit out of increased HFC prices on the EU market. The price will be set at a moderate level to prevent that it is being passed on to the end-users. As for the proceeds, it seems preferable to simply assign the revenue to the EU budget after all related administrative expenditure is covered.[86] The European Commission will seek external assistance such as through an agency such as ECHA to handle the revenue collection. See Annex A7.3 for further detail. The Commission should have some flexibility to adapt quota allocations e.g. if the quota allocation price is having unintended effects, if there is a proven serious issue on the market linked to the quota system (e.g. a shortage of gas availability of critical infrastructure such as

[84] These have a minimum of two years of participation in the quota system.

[85] Currently these companies needed to prove physical supply of the gas, a requirement that has been difficult to ascertain, and has been circumvented in different ways, i.e. inconclusive evidence, forged evidence etc.

[86] Auctioning of quota has been discarded. HFC quotas are rights to sell HFCs (not to emit as is the case in the EU Emission Trading System) and an auctioning price would reflect the willingness to pay for higher market shares and would most likely lead to higher market concentration. Also, all quotas could be acquired by non-EU business, possibly state-funded, and lack of predictability would induce great uncertainty for EU businesses.

hospitals), when compliance cases are unsettled at the moment of annual quota allocation or to require certain skills/characteristics for quota-holding companies.

A6.4 (D) Monitoring and Enforcement

D1. Reporting scope – substances

Taking into account the latest information on types of substances and their quantitative relevance, a number of frequently used PFCs need to be added to complete Annex I:

- Perfluorodecalin (PFC-9-1-18)
- Perfluoro-2-methylpentane (C_6F_{14})

The following substances will be added to Annex II due to relevant GWPs or significant and/or rising usage:

- Sulfurylfluoride (SO_2F_2) used in particular for treating timber prior to export with significant emissions;
- the anaesthetics sevoflurane (GWP of 195[87]) and enflurane (GWP of 654);
- H(C)FOs:
    - HCFO-1224yd(Z), for use as refrigerant in RAC applications, but also as blowing agent, aerosol solvent, and cleaning solvent;
    - Cis/Trans-1,2-difluoroethylene (HFO-1132), new refrigerant for mobile AC
    - 1,1-difluoroethylene (HFO-1132a), part of new refrigerant blends and feedstock for fluoropolymers
    - 1,1,1,2,3,4,5,5,5(or1,1,1,3,4,4,5,5,5)-nonafluoro-4-(trifluoromethyl)pent-2-ene (C_6F_{12}) (and isomers), used as a co-blowing agent for improving thermal performance of insulating foams

- Fluorinated alternatives to SF_6 in switchgear:
    - Heptafluoroisobutyronitrile (2,3,3,3-tetrafluoro-2-(trifluoromethyl)-propanenitrile) with GWP of 2750
    - Iso-C3F7CN (NOVEC 4710) with GWP of 2100
    - NOVEC 5110 with GWP of 0.29
- Fluorinated ethers and alcohols: HFE-7300 (GWP 200); HFE-7100 ($C_4F_9OCH_3$; GWP 320), HFE-7200 ($C_4F_9OC_2H_5$; GWP: 55) used as heat transfer fluids, cleaning and rinsing agents for industry applications, carrier for lubricants and other specialized industry applications.

- Others:
    - Perfluorotributylamine (PFTBA, FC43, C12F27N) used as heat transfer fluid in the semiconductor industry. GWP: 8690.

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[87] All GWPs given in this section are latest available based on the IPCC Assessment Reports (i.e. 6th Assessment Report, or if not available 5th etc.)

- Perfluoro-N-methylmorpholine (C5F11NO) used as heat transfer fluid. GWP: 9500.
- Perfluorotripropylamine (C9F21N) used in electronics industry, for medical and analytical purposes.

The reporting system run by the EEA would need to be updated to take into account the additional reporting requirement. The reporters are expected to be mostly entities that are already reporting some fluorinated gases today.

D2. Reporting scope – reporters

Options 2 and 3 would put reporting obligations on recipients of quota-exempted HFCs (for better control of these transactions[88]), and all entities carrying out reclamation (currently only those that are also producers, importers or exporters have to do so). Such additional companies would be few as sophisticated equipment usually only employed by chemical industry (already affected by the current measure) is needed. Option 3 would also require recyclers to report such activities which increases the number of affected companies significantly. Furthermore, option 3 requires equipment exporters to report export of HFC equipment (to better estimate the EU's impact on other regions). The reporting system run by the EEA would need to be updated to take into account the additional reporting requirement. The number of equipment exporters affected is not known but may be similar to the number of equipment importers (over 2000 registered in DG CLIMA's Fgas Portal).

D3. Emission reporting

Option 2 would encourage Member States to establish electronic databases on emission-related activities such as servicing, sales of gas, losses etc. similar to those existing in some countries already (e.g. PL, IT, BE, SI). The data is already collected by companies following the obligations of Art. 6 (record keeping) today. Such national databases would serve to obtain better emission data and give authorities much better control over the use of F-gases as well as providing incentives to minimise losses. By way of example, primary data from a set of retailers in 2014/2015 showed that leak rates of their cooling equipment did not go below 6% and routinely went up to 10%. Companies who carry out leak checks conscientiously are also more likely to take better care of their systems. Under the option, equipment operators and/or service technicians would have to submit the relevant data electronically, rather than store them at their premises.

Option 3 makes these databases mandatory. Option 3 would also require emission reporting of SF_6 from decommissioning of switchgear in electrical transmission lines. This would require network operator and/or their servicing companies to report such data.

[88] Given that these options also remove some exemptions (option B1), the number of affected companies decreases.

D4. Reporting process and data verification

All options would make it an obligation to submit a verification report for bulk HFCs[89] (currently only on request by the Commission or competent authority), and an obligation to provide NIL reports for quota holders to better ensure that all relevant companies report their data. The reporting and verification thresholds for bulk gas and equipment, as well as reporting and verification dates, will be aligned. This will improve coverage of the relevant entities and contribute to more effective and efficient compliance checking (see separate Annex A10 on reporting and monitoring). The variance in thresholds was highlighted by competent authorities through the evaluation to have led to confusion in industry and a less than complete compliance checking. Rules are relaxed for equipment importers but made tighter for bulk gas importers (ca. 90% of HFC trade). The reporting system run by the EEA would need to be updated to take into account the changes to the reporting requirements.

Option 2 and 3 would add a requirement of submitting the verification reports for bulk HFCs and equipment electronically, that would clearly indicate the data to be verified. This would have to be enabled by the Commission via the electronic Fgas Portal and will be linked to the EEA's reporting platform BDR. Independent verifiers would be given direct access to the F-gas Portal, and would introduce their opinion directly in the system, similar as is the procedure for ETS compliance checking in e.g. Germany. Verification results as well as corrected data would immediately be available to the authorities. The reporting system run by the EEA would need to be updated to take into account these changes.

A6.5 (E) List of clarifications needed in Regulation

These clarifications were collected from stakeholders, in particular from Member States authorities, during the consultation. Others are based on DG CLIMA's experience in implementing this Regulation.

CLARIFY THAT

- *concerning prohibitions*

- transport, storage, sale and use of illegal goods, in particular the one-way cylinders (for all uses with Annex I, empty), is prohibited (not just the initial placing on the market). This includes online sales. It also includes a prohibition to make HFCs available to third parties, to transfer HFCs to third parties or to use HFCs which have been placed on the market in violation of the requirements of Article 15(1), including by internet sales, with the exception of provision, transfer or use for return or disposal.

- entry into EU territory of non-refillable F-gas containers is prohibited.

[89] It is already an obligation for data on equipment.

- *concerning the quota system*

- that the placing on the market of HFCs in excess of the quota limits is strictly prohibited.

- imported HFCs are always considered virgin and therefore require quota

- quotas are also required for gases emitted during production

- the exemption in Article 15(2)(c) does not cover exports of HFCs contained in pre-charged products or equipment.

- the principle of beneficial ownership for quota holders in the Regulation (currently in Implementing Regulation only).

- that the verification obligation for equipment imports applies to both their Art 19 report as well as their Declaration of Conformity pursuant to Art 14.

- imports of equipment with HFC quantities that are below 100 tCO2e on an annual basis are exempted from Article 14.

- authorisations can only be given/must be introduced into the registry (F-gas Portal)

- *concerning custom control and market surveillance*

- obligations of the importer fall on the consignee.

- imported gases are always considered virgin, and therefore cannot be used for servicing where this is allowed for reclaimed/recycled.

- all importers/exporters of bulk gases need to register before undertaking the relevant import/export activities. A relevant and valid registration is considered their import or export license. This is required by the Montreal Protocol, but the obligation is currently in an Implementing Regulation only.

- that a tCO2e metric (not only the weight) and operator's ID are added to the information required in the customs declaration for gases and equipment to allow for better automated controls, in the case of import and export.

- importers of pre-charged products and equipment need to register prior to import/export (while keeping the threshold of 100 tCO_2e).

- importers of pre-charged products and equipment need to have an Only Representative (OR) and specify their EORI number, similar to bulk gas importers.

- customs and surveillance authorities should seize illegal goods (products, equipment or gases) and dispose of them as appropriate. Goods should not be re-exported.

- customs should, based on risk profiling, make use of the information in the Fgas Portal & Licensing system when treating relevant custom declarations.

- customs should have clear instructions on role and procedures

- customs should exchange with competent authorities and surveillance authorities as well as the Commission relevant data for checking compliance and enforcement.

- customs and surveillance authorities should seize illegal goods (products, equipment or gases) and dispose of them as appropriate. Goods should not be re-exported.

- Member States shall use the registry to carry out enforcement activities including custom controls, market surveillance and company compliance checking.

- Member States should keep commercial and personal information related to companies in the Fgas Portal & Licensing System and the BDR system confidential.

- *concerning containment measures*

- the need for certification/attestations on selling HFCs to/purchasing HFCs by garages in Article 11(4).

- Article 6(1)(c) refers not only to installed gases but also to added gases as regard information to be included in the records by operators of equipment on the quantities of recycled or reclaimed F-gases.

- Article 6(1)(f) that information to be included in the records should also cover details about leakage repairs.

- Article 8(1) that the recovered refrigerant cannot be used for filling or refilling equipment unless it has been recycled or reclaimed.

- *concerning reporting*

- include, for transparency, also the 20-year time horizon GWP values relative to CO_2 for all substances listed in Annex I and II.

- the current GWP values on a 100-year basis for all substances but HFCs[90] by using the most recent available data from IPCC's Assessment Reports.

- minor corrections in Annex I and II to formulas, names, etc.

- *others*

- clarify some definitions where there is ambiguity such as "medical" or banned "hermetical" equipment
- add a list of allowed destruction technologies as stipulated by the Protocol

A6.6 List of discarded measures

A number of measures were suggested by stakeholder that were not considered for the impact assessment for reasons specified below:

- **Objective A**
- *A general prohibition of F-gases in the RAC sector*. This was not deemed feasible at this time as F-gases continue to be needed in many niche applications, albeit in falling numbers. Instead, the approach is to rely on the phase-down to further

[90] HFCs are linked to compliance with the Protocol which uses the IPCC's Assessment Report 4 as does the Regulation. A delegated act already would allow adjustment of the values should those change in the Protocol.

provide an economic incentive to use climate-friendly alternatives while specifying additional prohibitions in sub-sectors where there is no more need for medium and high GWP F-gases.

- *Remove the exemption for reclaimed and/or recycled high GWP F-gases for servicing existing stationary refrigeration equipment.* This measure was considered counterproductive since this existing exemption provides a strong incentive for recycling and reclaiming F-gases, rather than (illegally) venting them.

- *A prohibition on the use of HFCs in MDIs.* A prohibition date would not be possible in the near future as the alternatives would have to be available on the market in sufficient quantities to allow satisfying the demand. This sector requires a policy driver with a more gradual incentive to replace HFCs, in the interest of patients.

- *Extend coverage of emission prevention requirements to include all substances listed in Annex II.* This scope was considered too large as there is a number of substances in Annex II with very low use quantities. The scope was reduced to the relevant substances H(C)FOs (breakdown products!) and NF_3 (high quantity use) as well as some newly added substances (see retained measures A3).

- **Objective B**

- *Remove threshold for reporting on feedstock.* Contrary to the other thresholds for the quota system that are removed in order to align with the Protocol, this is not required by international rules, and therefore it was considered to leave the threshold in place in the interests of reducing the administrative costs for smaller entities.

- *Make an import quota system rather than a "placing on the market" quota system.* This would have allowed for easier compliance checking at customs but could have created issues for correctly offsetting quantities for export and other transactions in view of maintaining compliance with the Protocol and safeguarding environmental ambition of the quota system.

- **Objective C**

- *Separate certification programmes for low GWP alternatives, including for naturals.* The use of H(C)FOs in RAC is linked to HFC so an integration into existing certification programmes seems the most cost-effective way to certify the needed skills. A separate certification programme for naturals was deemed out of scope of the F-gas Regulation.

- *Requirement of certification for activities such as installation, maintenance, recovery etc. for natural alternatives to F-gases in RAC.* This was deemed out of scope of the F-gas Regulation.

- *Change of the frequency of quota allocation from once a year to twice a year.* This would have added more complexity and administrative burden for both authorities and companies. Also, planning certainty for quota holders would have been reduced.

- *Remove the option to make declarations for quota.* This measure would have excluded new entrants from joining altogether, which was deemed not acceptable even for a declining and strongly regulated market.

• **Objective D**

- *Reporting on use of inhalation anaesthetics by large volume users.* This would have required that hospitals would have to report on these emissions which would have placed a high burden on these critical infrastructures.
- *Include the possibility to adopt delegated acts to allow for amendments in Annex I and II if new scientific evidence become available.* This was considered too far reaching since it is not clear what would constitute sufficient "scientific evidence". The current legal text of the Regulation to rely on the Protocol's Scientific Assessment Panel and the IPCC's Assessment Reports is preferable.

Also, stakeholders suggested many different definitions to be adjusted (see background study). In most cases it seemed more straightforward to reply on agreed implementation practices rather than introduce new uncertainty with adjusted definitions.

A7 Operationalising the HFC placing on the market (POM) quota system (phase-down) going forward

A7.1 Methodological approach

The HFC POM phase-down as set out in the Regulation is characterised by the reduction schedule given in Annex V of the Regulation, expressed in percentages, which is used for two purposes:

a) Calculation of the EU-wide annual maximum quantities (MaxQ) of HFCs to be placed on the market 2015 onwards, featuring a complex calculation scheme including a baseline derived from 2009-2012 reporting data and quota exemptions;

b) Calculation of company-specific HFC quota based on reference values (RV-quota), i.e. grandfathering: Company-specific reference values, which are recalculated triennially to determine average POM of HFCs since 2015, are multiplied by the percentage given in Annex V for the respective year and by a factor of 0.89 to determine RV-quota. The gap between the total MaxQ and the sum of RV quota allocated to companies ("new entrants' reserve") is subsequently distributed on a pro-rata basis to all companies having submitted an annual declaration on additional need (D-quota).

In order to increase the transparency of the EU-wide schedule for the MaxQ of HFCs, it is proposed for the revision of the F-gas Regulation to abandon the complex MaxQ calculation rule of the Regulation and disentangle the previous Annex V schedule into

a) An explicit schedule for the maximum quantity of HFCs to be placed on the EU27 market, beginning in 2024 and expressed in tCO2e/year

b) A reduction schedule in percentage units beginning 2024, for the purpose of calculating RV-quota. The equation to calculate RV-quota from reference values involving the 89% reduction factor to feed the new entrants reserve would remain unchanged.

The percentages in the reduction schedule for RV-quota should be calculated by dividing the maximum quantities (expressed explicitly in tCO_2e) by a new 2015 base value to be defined in a revised Regulation. The 2015 base value needed for a revised Regulation should be calculated based on the methodology defined in F-gas Regulation 2014/517 to derive the 2015 MaxQ for the EU-28, and account for the change in geographical scope of the EU (EU-27 after Brexit) and for a change in scope of quota exemptions still applying from 2024 onwards (after the revision), based on available data.

Lifting the MDI quota exemption from 2024 requires that special calculation rules for the triennial RV-recalculation needs to be introduced in order to avoid that the supply of HFCs to this previously exempted sector would be cut by the quota system initially. As a principle, **2024 allocations levels of RV quota to MDI suppliers should be at 100% of**

the levels established before lifting the exemption (e.g. available data for 2020-22), and that subsequent reduction steps will be proportionate to the relative reduction steps as defined for the overall HFC POM. In the case of HFC suppliers for (previously exempted) MDIs, this data is available from company reporting under Art. 19. It should be noted that exports of MDIs containing HFCs are not considered bulk HFC exports and thus not subject to the quota exemption for exports according F-gas Regulation Art 15(2)(c).

To calculate RVs for HFC suppliers to the (previously exempted) MDI sector, the average POM from recent years (e.g. 2020-21) needs to be increased in order to arrive at a quota that would represent 100% as a starting point. This increase is to be calculated

a) by dividing by the percentage calculated for 2024 in the new reduction schedule to be applied for the RV-quota calculation, and

b) by dividing by the 'new entrants reduction factor' of 0.89.

This RV can be used for the calculation of RV-quota like for all other companies, by multiplying with the 0.89 reduction factor and by multiplying with the RV-quota reduction percentage for the respective year[91]. **As the result of this calculation approach, the RV-quota allocated to HFC suppliers of the MDI sector for the first reduction step 2024-2026 under a revised Regulation will be 100% of the POM in the most recent years available.** For subsequent reduction steps, the relative reductions for the MDI sector will be proportionate to the reductions applicable to all other HFC use sectors. The first such subsequent reduction step for the overall market that will affect MDIs will come in 2017.

A7.2 Total annual quantities for the different reduction schedules

The maximum quantity of HFCs for the EU27 in the years 2021-2023 is approximately 62.3 Mt CO_2e under the current Regulation. **Table 27** shows the calculated limits for the different Options and including a removal of the exemption for MDIs from 2024.

[91] Essentially the POM values are increased by phase-down factor and new entrants factor first, so that when these are applied using the Annex V and VI methodology, they cancel out and MDI gases are

Table 28. Options for the F-gas Regulation phase-down schedule for the maximum quantity of HFCs placed on the EU27 market [Mt CO_2e]

	Baseline	Option 1	Option 2	Option 3
	t CO2e	t CO2e	t CO2e	t CO2e
2021 - 2023 (existing Regulation)	62 273 330	62 273 330	62 273 330	62 273 330
2024 - 2026	37 535 263	49 035 263	41 701 077	41 039 167
2027 - 2029	25 166 229	36 666 229	17 688 360	15 963 275
2030 - 2032	19 865 215	31 365 215	9 132 097	6 916 849
2033 - 2035	19 865 215	28 717 529	8 445 713	5 794 785
2036 - 2038	19 865 215	20 538 147	6 782 265	5 467 823
2039 - 2041	19 865 215	20 538 147	6 136 732	5 006 355
2042 - 2044	19 865 215	20 538 147	5 491 199	4 544 888
2045 - 2047	19 865 215	20 538 147	4 845 666	4 083 420
2048 onwards	19 865 215	20 538 147	4 200 133	3 621 953

Figure 25 gives the time series for the maximum quantity, i.e. the total quota available to the EU market in those years. For improved comparability of the discussed options in terms of considered quota exemptions, a time series was added for an adjusted baseline which incorporates a lifting of the MDI quota exemption as of 2024, assuming high MDI demand of approximately 11.5 Mt CO_2e per year, consistent with the scenario definition for Option 1. It is apparent that the ambition of the schedule of the maximum quantity in Option 1 basically follows the "adjusted" baseline and features two (significant) reduction steps in 2033 and 2036 in order to safely stay below MP consumption limits. Options 2 and 3 have earlier reductions starting in 2024, 2027 and 2030.

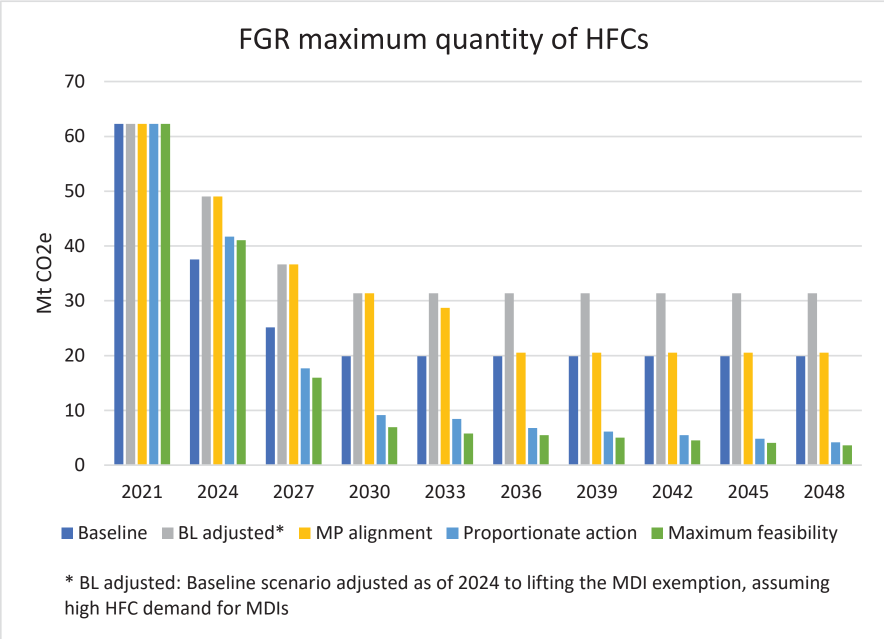

Figure 25: Options for the development of maximum quantity of HFCs

A7.3 Introduction of a Quota Allocation Price

Under the existing Regulation the allocation of quota under the HFC phase-down has been for free. It is based mostly 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. While the existing approach would be maintained in Option 1, the introduction of a fixed quota allocation price is considered in the Options 2 and 3. That allocation price is proposed to be set at initially 3 €/ t CO_2e for 2024 to be well below recent market levels on HFC price increases (average 6 €/t CO_2e since 2015 as OEM purchasing prices[92]) to avoid significant pass-through to end-users.

The procedure for implementing the allocation price could work as follows:

Step1 subject to quota price: Calculation of 'reserved quota' based on reference values, penalties and declarations to get quota from the Reserve:

1) Calculation of Reference Value-based quota for each incumbent[93], taking into account potential quota penalties for incumbents.
2) Determination of the total HFC quota available in the Reserve taking into account the total amount allocated on the basis of reference values minus penalties (Step 2 in the Regulation).

[92] Source: Öko-Recherche HFC price monitoring on behalf of the European Commission, prices at all levels of the supply chain are monitored quarterly since 2015

[93] The reference values will have to be re-calculated to take into account quantities that are linked to uses that are currently exempted from the phase-down.

3) Calculation of Declaration-based quota from the Reserve for each declaring company while taking into account applicable quota penalties (penalty amounts are being re-distributed to other declarants).

4) Flexibility for the European Commission to temporarily withhold some quota allocations in case of pending decisions on e.g. quota penalties.

Step 2: Requesting payment for reserved quota

5) Quota holders are informed of the total amounts reserved for allocation to them based on reference values and/or declaration, and requested to pay the allocation price for the reserved amount by an appropriate deadline.

Step 3: Redistribution of unpaid reserved quota

6) Quota amounts where the allocation price has not been paid by the deadline will be distributed free of charge, on a pro-rata basis to all declarants which have fully paid their allocation price and whose declaration had not yet been fully satisfied.

Step 4: Quota allocation

7) The reserved quota for which the price has been paid in addition to a possible top up resulting from the redistribution of unpaid reserved quota is allocated to the company.

Step 5: Ad hoc allocation of temporarily withhold quota

8) Where cases relating to withheld quota have been resolved, the quota will be allocated against payment if it is allocated to one quota holder. If it is to be redistributed among all quota holders who have declared a quota need, it will be allocated for free.

Table 28 shows the total amount of quota allocation revenue that could be collected annually if all quota is fully paid during Step 2 (i.e. no quota allocated under Step 3) and based on total quota amounts foreseen for 2024 under the different options (assuming that all companies pay the quota price). IF unadjusted, the total revenue would decline proportional to the maximum quantity as shown in Table 27 above.

Table 29: Expected volume of quota allocation revenues

		Option 1	Option 2	Option 3
2024 Maximum quantity of HFCs	Mt CO2e	49.0	41.7	41.0
Revenue for sale at 3 €/t CO2e	Mio €/a	*	125.1	123.1

Note: * In option 1, no quota allocation price is included.

The allocation price collected from quota holders will reduce the benefit that would normally occur in the HFC supply chain due to the HFC price increases resulting from the phase-down.

A8 Separate production phase-down

Next to the HFC consumption phase-down, the Protocol's Kigali Amendment features a parallel phase-down scheme for the production of HFCs in the EU and its Member States. The EU & their Member States can under the Protocol's REIO[94] clause (Article 2(8)(a)) decide jointly whether

a) each Member State would need to comply individually with their respective HFC production phase-down, or
b) the EU would comply jointly as a REIO.

While the HFC consumption phase-down is complied with jointly as a REIO, the status quo for HFC production currently is compliance at Member State level. A REIO compliance would need to be notified to the Ozone Secretariat of the Protocol. With an EU-wide scheme addressing the HFC production phase-down in a revised Regulation, Member States would have the option to in the future to agree to switch to the REIO approach without in any way endangering compliance.

In order to facilitate compliance with the Protocol's HFC production phase-down, both jointly as EU or at Member States basis, the introduction of an EU-wide phase-down scheme for HFC production, similar to the one that was successfully implemented under the Ozone Regulation that ended in 2020, is proposed for all three policy options in the same way, as described below.

A8.1 Metrics to be considered for the HFC production phase-down

"Production" as defined under the Protocol is produced amounts minus feedstock use minus destruction. As clarified by means of the reporting rules,

- feedstock use eligible for subtraction is limited to produced amounts for feedstock use in the own country (for EU MS, this would apply on MS level), and
- non-captured amounts of generated HFCs (by-production) are not considered.

The baseline for the HFC production phase-down under the Protocol is calculated by adding

- the average 2011-2013 HFC production (defined as above) and
- 15% of the HCFC production baseline (as defined below).

The HCFC production baseline is the average of

- 1989 HCFC production + 2.8% of 1989 CFC production
- 1989 HCFC consumption + 2.8% of 1989 CFC consumption[95]

[94] Regional Economic Interest Organisation

[95] For the Member States of the EU-12 of 1989 (Belgium, Denmark, France, Germany, Greece, Ireland, Italy, Luxembourg, Netherlands, Portugal, Spain and the United Kingdom) consumption data for individual MS is not available. For those parties to the MP, the Ozone Secretariat at UNEP thus uses HCFC & CFC production data only for the calculation of the HFC production baselines.

Consumption under the Protocol is production (as defined above) plus imports minus exports.

The envisaged Regulation's HFC production phase-down would apply to remaining EU HFC producers. For those companies, uncaptured by-production, production for feedstock use and production destroyed before placing on the market should be considered (= subtracted from gross production reported in section 1A of the reporting questionnaire under F-gas Regulation Art 19). "Downstream" destruction of recovered used HFCs, imported into or collected within the EU, should not be considered for the F-gas Regulation production phase-down. Any such amounts (~ 0.5 – 2 Mt CO_2e/a in 2015-2019, EU28) can be considered a safety margin for compliance with the Protocol's production phase-down, both at Member State or possibly at EU/REIO level.

The activity subject to limitations under the EU production phase-down should thus be:

"Production for Sale" (PfS) = Gross production (BDR: 1A) – uncaptured (by-) production amounts – Production for destruction – Production for feedstock use

A8.1.1 Definition of production for destruction

In this context, production for destruction covers the following as annually reported under Art 19:

a) Captured production amounts destroyed by the producer
b) Captured production amounts handed over by the producer to another company for destruction

A8.1.2 Definition of production for feedstock use

The subtraction for feedstock use may possibly refer to

a) own feedstock use by the producer
b) production for feedstock use with in the own MS
c) production for feedstock use by any company within the EU
d) production for feedstock use anywhere.

Note that cases a) & b) have been reported so far. Only cases a) & b would be subtractable under MP monitoring rules for compliance on EU MS level. However, to avoid any conflict with EU internal market principles, **the definition should be extended to cases a, b & c**[96]**.**

A8.1.3 Coverage of HFC-161

HFC-161 is an HFC according to Annex I of the Regulation, but it is not covered under the MP. So far, no production of HFC-161 has been reported in the EU. **An explicit**

[96] In case HFC amounts would be reported for feedstock use in other EU MS, those could possibly be counterbalanced by downstream destruction of used HFCs, subject to subtraction under MP accounting rules for HFC production. Nevertheless, such an approach could *theoretically* lead to MP non-compliance at MS level. If EU MS will opt for the REIO approach, non-compliance at EU is even more unlikely.

exemption of HFC-161 from the EU PfS production phase-down is thus not necessary.

A8.2 The Protocol's HFC production baseline for the EU and its Member States

The Protocol's HFC baseline of EU Member States sum up to 84.3 MtCO_2e for the EU27. 72% thereof are derived from 2011-2013 HFC production (corrected for feedstock use and destruction according to Protocol definitions), 28% are derived from the 1989 HCFC production baseline. 98% of the aggregated HFC production baselines for the EU27 are allocated to a set of five Member States: France, Germany, Spain, the Netherlands and Italy.

A8.2.1 HFC production in the EU

Since 2015, HFC Production (defined as Production for Sale, PfS) in the EU27 has been limited to France and Germany. HFC production ended 2014 in Spain, and 2012 in Italy. For all other EU MS, the Protocol's HFC production baseline is fully derived from the HCFC production baseline, i.e. from production capacities in place over 30 years ago which for that reason do not correspond anymore to today's activity. The distribution of the PfS baseline between MS thus significantly differs from the Protocol's HFC production baseline. 2011-2013 PfS of HFCs was reported by 7 companies in the EU27: 2x DE, 1x ES, 3x FR & 1x IT.

A8.2.2 Allocation of Protocol's HFC production baseline to EU HFC producers

Given the world-wide HFC consumption phase-down schemes agreed under the Protocol, the Protocol's HFC production phase-down scheme needs to ascertain that overall production is phased down, but at the same time attempts to address a level-playing field between HFC producers located in different parties to the Protocol, while leaving more time for developing countries. The objective of the proposed Regulation's HFC production phase-down scheme at EU level is thus to facilitate compliance with the Protocol's production phase-down at Member State and EU levels. The allocation method of the EU HFC production baseline to companies involved should ideally feature a complete distribution of total available EU production rights.[97]

The general approach for the allocation of the Protocol baseline to companies is to assign to companies their 2011-2013 PfS baseline and additionally allocate a top-up based on the gap between the EU27 Protocol HFC production baseline and the aggregated EU27 2011-2013 PfS baseline (since the Protocol allows for more rights than distribution based solely on PfS). That gap amounts to 22.6 Mt CO_2e, which is about 27% of the EU27 baseline under the MP or 37% of the EU-wide 2011-2013 PfS baseline. That gap of 22.6 Mt CO_2e would, following the considerations above, be distributed among the 7 EU27 PfS incumbents.

[97] Given that „production“ is also part of the “placing on the market” HFC quota system which is going down quickly, a re-introduction of production into the EU is not feasible

However, a relevant condition for a distribution of the gap is also that the EU production phase-down scheme shall be designed to safeguard compliance with the Protocol's production phase-down not only at aggregated EU27 level, but also at Member State levels (in case the REIO clause is never used). An allocation approach for the gap which would avoid a stricter restriction of HFC production than in the case of measures taken individually by affected Member States (i.e. France and Germany) to comply with the Protocol's HFC production phase-down does necessarily require that the gaps at Member State level (i.e. Protocol baseline vs. PFS at DE, FR, …level) are also allocated to the HFC producers of the respective Member State. Given such an approach, the Protocol baselines for France, Germany, Italy and Spain could be fully distributed, while the Protocol baselines for the other EU27-MS, amounting to about 5.2 Mt CO_2e, or 23%, of the EU wide 'gap' would not be directly allocated to EU HFC producers.

For the allocation of the French and German gaps to French and German HFC producers, a distribution method needs to be defined, for Italy and Spain this does not matter as only one company per Member State is involved. The gap could be distributed either

a) Pro rata (same amount in t CO_2e per company in the respective Member State), or
b) Proportional to the size of the 2011-2013 PfS baseline of each company, or
c) In any combination of both approaches above (e.g. 50% of gap distributed pro rata, 50% proportional etc)

The choice of the distribution method for the gap will imply at what speed and schedule the involved companies per MS will need to reduce domestic production. The pro-rata approach appears to be easiest to justify. However, the choice of approach does not have further implications on the general workings of the EU production phase-down, or the assessment of impacts.

A8.3 Approach for legal implementation in the F-gas Regulation

For the legal implementation in a revised Regulation, it is suggested to follow the approach taken in the ODS-Regulation for the ODS production phase-down which allows both companies and Member States to engage in transfers of production rights.

A9 Prohibitions considered in the impact assessment

A9.1 Prohibition of F-gases (Annex I) in new fire protection equipment

The prohibition is based on the significant decrease of HFCs used as fire extinguishing agents since 2015 as well as the large-scale use and availability of non-F-gas alternatives which was confirmed by industry stakeholders and consulted experts. Alternative technologies are common in this sector and allow for an immediate replacement of HFCs, except for when national safety standards are to be met in special applications including mining, military, aviation, and nuclear power plants which require substances with special extinguishing capacities that cannot be met by the alternatives currently available on the market. From 2024, all HFC quantities needed can come from reclaimed quantities. PFCs and SF_6 are not used.

A9.2 Prohibition of F-gases (Annex I) in new small hermetic refrigeration and heat pump appliances

The prohibition addresses small hermetic refrigeration and heat pump appliances for household and commercial use which still use high-GWP HFCs (PFCs and SF_6 are not used), but where suitable alternatives are fully available. Examples include cream and ice cream makers, (slushed) ice makers, water coolers, juice makers, milk coolers attached to coffee machines, beer and wine coolers, heat pump tumble driers etc.

Due to the small charge size and the hermetic nature of these appliances, end-of life recovery of the HFC charge is typically not carried out as many appliances are not separated in the waste scheme so that the full charge is often emitted at end-of-life. Alternatives to HFCs for small hermetic refrigeration units (such as R290) are already widely available and allow for immediate and full replacement of HFCs.

The prohibition concerns manufacturers, importers and distributors of small hermetic appliances.

A9.3 Prohibition the use of PFCs in RACHP equipment

PFCs are contained in a few refrigerant blends, especially blends that were introduced as retrofit options (drop-in) for equipment formerly containing HCFCs (R22; R503) or CFCs (R13) to allow the use of existing equipment and systems until end-of-life. Examples include R413A (“Isceon 49”; R134a 88%; C_3F_8 9%; isobutane 3%), R508A (“Klea 5R3”; R23 39%; C_2F_6 61%) and R508B (“Freon 95” or “Suva 95”; R23 46%; C_2F_6 54%; for ultra-low temperature applications).

The analysis of reported data shows that PFCs play a niche role as refrigerants today. Even though the use of such blends is not necessary anymore as there are suitable alternatives, new equipment running on PFC refrigerant blends is still entering the market.

The prohibition refers to refrigerant manufacturers and equipment producers, importers and distributors as well as RAC service technicians.

A9.4 Prohibition of F-gases (Annex I) in stationary AC and heat pumps

The prohibition relates to stationary air conditioning equipment and heat pumps (heating and cooling mode)

- of a rated capacity of up to 12 kW that contain, or whose functioning relies upon fluorinated greenhouse gases with a GWP of 150 or more from 1 January 2025 and
- of a rated capacity of more than 12 kW that contain, or whose functioning relies upon fluorinated greenhouse gases with a GWP of 750 or more from 1 January 2025.

Current technology trends towards low-GWP alternatives can be seen in all AC and heat pump applications and already resulted in the introduction of A2L and A3 refrigerants (such as R32, R454C, R290) in a wide range of air conditioning and heat pump products and ahead of the prohibition spelled out in Annex III(15) of the current regulation[98,99]. At the same time, research on charge-size minimisation for flammable refrigerants is progressing fast. In addition, both small and larger single-split air conditioning systems and heat pumps offer great potential for further GWP reductions. However, due to larger charge sizes, safety concerns are more limiting for the larger equipment types (i.e. larger than 12kW) at this moment in time, so that the introduction of low-GWP alternatives will likely need more time. Given the expected growth rates of the heat pump sector, which is currently driven mainly by the promotion of more energy efficient heating, the choice of refrigerant is also fundamentally relevant to reduce emissions from the anticipated and desirable growth in this sector. Safety standards are being revised to allow for easier use of low-GWP alternatives including flammables at higher charges and are expected be updated in the near term (i.e. 2022) according to information from experts involved in the standardisation working groups. The metrics for this prohibition are based on capacity (kW) to align with other relevant regulations (e.g. eco-design regulation), and the prohibition would refer to placing on the market as well as installation of such equipment from 2025. This date would give sufficient time for further technological refinement and progress on updating the relevant standards in line with technology. For perspective, R32 was introduced in this sector in a timeframe of 4 years from near zero to close to 90 %, even without a prohibition deadline.

An exemption would be included to allow for continued use of HFCs where standards and codes do not currently allow for the use of A3 refrigerants, i.e. hydrocarbons. Equipment for this purpose would need to carry special labelling and evidence such as technical documentation needs to be kept and provided upon request to Member State authorities. This

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98 EU COM 2020: The availability of refrigerants for new split air conditioning systems that can replace fluorinated greenhouse gases or result in a lower climate impact. https://ec.europa.eu/clima/sites/clima/files/news/docs/c_2020_6637_en.pdf

99 Announcement by Midea to introduce R290 in split air conditioning units in the EU in 2021 at the Green Cooling Summit 2021, 26 May 2021.

exemption would allow for further technical development as stakeholders such as the industry associations EPEE or JBCE pointed out that there may be special circumstances such as long pipes or similar that require higher charges than permitted under safety standards.

The prohibition would concern manufacturers, importers and distributors of stationary air conditioning and heat pump equipment as well as end-users and service companies.

A9.5 Removal of exemption for smaller refrigeration equipment from the prohibition of using high GWP F-gases

The current provision to use F-gases with GWP >2500 for servicing and maintenance from 2020 onwards exempts stationary and mobile refrigeration equipment with a charge size below 40 t CO_2 equivalents. Feedback from industry showed that this exemption is not relevant in practice, i.e. a distinction is often not made between charge sizes above and below 40 tCO_2e during service and maintenance. Alternatives to high-GWP refrigerants (R404A, R507) are available for all stationary and mobile refrigeration applications including the exempted capacity range.

The stakeholders concerned by removing this exemption are manufacturers, equipment owners/operators, service companies performing maintenance work at existing systems and, indirectly, refrigerant importers and distributors.

A9.6 Prohibition of F-gases (Annex I) in personal care products

This prohibition relates to the use of HFCs and PFCs in personal care products (SF_6 is not used) such as creams and liquids for skin and nail care (mainly perfluorodecalin) as well as sprays and mousses for hair and skin care. The use of F-gases in these product types is limited as various alternatives are commonly used by most manufacturers. F-gases contained in this type of products are fully emitted and cannot be recovered or contained (emissive uses).

Stakeholders concerned include manufacturers, importers and distributers of personal care products currently containing F-gases. They would need to adapt their product formulations where they do not already use the alternatives.

A9.7 Prohibition of the use of F-gases (Annex I) for skin cooling

Skin cooling equipment relying on HFCs are not only used for purely medical, but also for cosmetic purposes in beauty treatments, e.g. hair removal, and direct emissions occur from such uses. Alternatives are available and should allow for replacement of HFCs.

A9.8 Prohibition of SF_6 in new switchgear

In recent years, several alternatives to SF_6 in both medium-voltage (MV) and high-voltage (HV) electrical switchgear were developed. While the market introduction in the MV segment is more advanced and alternatives are widely available, this is not yet the case for some HV applications so that a little more time is needed for this market segment. The prohibitions distinguish between voltage and distribution levels and relates to

- **new MV electrical switchgear** for primary and secondary distribution, differentiated by voltage level – up to 24 kV from 2026 and 24-52 kV from 2030,
- **new HV electrical switchgear**, in the range of 52-145 kV and up to 50 kA short circuit current from 2028, more than 145 kV or more than 50kA short circuit current from 2031, using F-gases with GWP > 2000 as insulating or breaking medium.

Industry input and literature research suggest that several alternative mixtures and substances are available with GWP<2000 within the indicated time frames. The transition from SF_6 towards lower-GWP alternatives will lead to a reduction in the demand of SF_6.

A9.9 Use prohibition of desflurane as inhalation anaesthetic

The prohibition relates to the use of the fluorinated inhalation anaesthetic desflurane (GWP 989) that is currently not restricted but is commonly used throughout the EU and fully emitted during use. Recently, a technology to capture inhalation anaesthetics has been developed but it is not yet widely available. Suitable alternatives include sevoflurane (GWP 216; AR5) and isoflurane (GWP 350; AR4) which are both widely available and commonly applied as well and can replace desflurane in almost all cases. An exemptions to the prohibition is specified for the few instances where this may not be the case.

The prohibition would affect producers, importers and distributors of medical products as well as end-users such as hospitals and clinics.

A10 Detailed analysis on reporting and verification thresholds

A10.1 Verification thresholds for HFC bulk producers/ importers and for importers of cooling equipment containing HFCs

A10.1.1 Bulk POM verification thresholds

Based on the quota amounts[100] received by companies in the years 2018, 2020 and 2021[101], an analysis was conducted to determine the share of companies which received quota amounts above different thresholds as well as the share of total allocated quota covered by different verification thresholds.

Under the assumption that the total number of companies remains at 2021 levels (i.e. 1772) between 2021 and 2030 and that companies' share of total allocated quota is constant during this period, a projection of shares of companies and quota below different thresholds was developed, for the phase-down schedule of the current Regulation.

Table 30: Share of companies which received quota amounts above different thresholds

% of companies with quota …	2018	2020	2021	2025	2030
>500t CO_2e	100%	99%	99%	98%	97%
>1,000t CO_2e	100%	99%	98%	95%	86%
>2,000t CO_2e	99%	99%	89%	86%	83%
>2,500t CO_2e	99%	98%	88%	85%	59%
>3,000t CO_2e	99%	98%	87%	84%	30%
>5,000t CO_2e	98%	98%	84%	32%	15%
>10,000t CO_2e	97%	19%	23%	14%	3%
>20,000t CO_2e	33%	17%	12%	3%	2%

Source: *DG Clima HFC registry, own calculations*

Table 31: Share of total allocated quota covered by different verification thresholds

% of Quota covered with threshold	2018	2020	2021	2025	2030
>500t CO_2e	100.0%	100.0%	100.0%	100.0%	99.9%
>1,000t CO_2e	100.0%	100.0%	100.0%	99.8%	99.3%
>2,000t CO_2e	100.0%	100.0%	99.5%	99.3%	99.0%
>2,500t CO_2e	100.0%	100.0%	99.5%	99.2%	94.4%
>3,000t CO_2e	100.0%	100.0%	99.4%	99.1%	87.5%
>5,000t CO_2e	100.0%	99.9%	99.1%	88.0%	82.7%
>10,000t CO_2e	99.9%	91.6%	85.7%	82.3%	75.3%
>20,000t CO_2e	91.8%	90.8%	81.0%	75.2%	74.1%

[100] Both quota allocated based on reference values as well as quota based on declarations were considered.

[101] 2019 was not considered as that year had a very high number of new entrants, before introduction of Commission Regulation (EU) 2019/661 requiring more registration data from applicants

Source: *DG Clima HFC registry, ÖkoRecherche et al (2021)*

The analysis indicates that while the current threshold for verification of bulk (i.e. 10,000 tCO_2e) affects 19 % of companies and covers about 92 % of reportable quota use in 2020, the same threshold would only cover about 75 % of reportable quota use in 2030. In order to achieve a quota coverage closer to 100% in the 2030 time horizon, the threshold for the verification obligation would need to be lowered to at least 2,000 t CO_2e. Then, a quota coverage of 99%, affecting 83% of quota holders (approx. 1500 out of ~1800 assumed quota holders) would be reached. **A threshold of 1,000 t CO_2e would de facto have very similar effects like a threshold of 2,000 t CO_2e. Only few additional companies are likely to be affected.**

A10.1.2 RAC Equipment verification thresholds

Authorisation use as reported by equipment importing companies for the year 2020 (approximately 1,000 companies reporting on imports of approx. 10 Mt CO2e) was compared to different thresholds for verification. It shows that while the current de facto threshold of 100 tCO_2e requires about 83 % of equipment importing companies to verify their report, a threshold of 500 t CO_2e would reduce this share to 61% and a threshold of 1000 t CO_2e would require less than half of equipment importing companies to verify their report. **Due to the large amount of small equipment importing companies, a verification threshold of 1000t t CO2e would however still cover 98% of the HFCs in imported equipment**.

Table 32: Authorisation use by companies compared to verification thresholds

	% of companies with authorisation use in need of verification	% of authorisation use in need of verification covered by threshold
>100t CO_2e	83%	100%
>500t CO_2e	61%	99%
>1000t CO_2e	48%	98%
>2,000t CO_2e	36%	96%
>2,500t CO_2e	33%	96%
>3000t CO_2e	29%	95%
>5000t CO_2e	22%	92%
>10,000t CO_2e	15%	86%
>20,000t CO_2e	8%	76%

Source: *Data reported by companies to EEA BDR, own calculations*

A10.1.3 Conclusion on verification thresholds for bulk and equipment

For a joint threshold for bulk & equipment verification, i.e. aligning the two thresholds for better coherence and transparency, **a threshold of 1,000 t CO_2e is suggested** which would likely cover about 99% of bulk quota & 98% of equipment imports while lifting the verification obligation for approx. 50% of equipment importers and thus reducing the burden for small companies.

A10.1.4 Overview of changes envisaged to the reporting and verification thresholds

A number of changes to reporting and monitoring rules are foreseen due to (i) the need to adjust to the Protocol, (ii) control illegal trade more efficiently, (iii) improve clarity of the rules for companies and (iv) reduce administrative burden where possible. Table 32 gives an overview of all changes considered under the three options and the rationale for doing so.

Table 33. Overview of considered changes to the reporting and verification rules

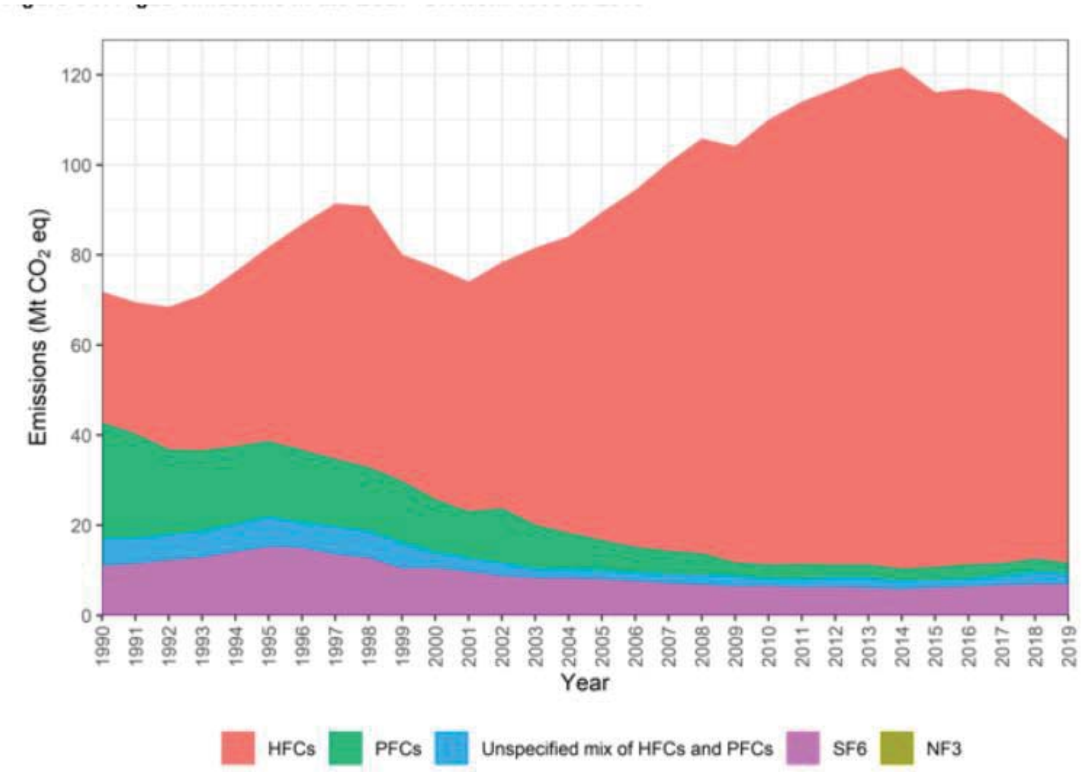
Measure target	Status quo	Comment	Option 1	Option 2	Option 3
Reporting obligation & thresholds (Art 19)					
Production	Threshold: 1t / 100 t CO_2e of Annex I & II	For HFCs, a reporting threshold is inconsistent with the EU reporting obligation under the MP	Remove threshold for HFCs, keep threshold for other Annex I & Annex II gases	= option 1	= option 1
Bulk import	Threshold: 1t / 100 t CO_2e of Annex I & II	For HFCs, a reporting threshold is inconsistent with the EU reporting obligation under the MP	Remove threshold for HFCs, keep threshold for other Annex I & Annex II gases	= option 1	= option 1
Bulk export	Threshold: 1t / 100 t CO_2e of Annex I & II	For HFCs, a reporting threshold is inconsistent with the EU reporting obligation under the MP	Remove threshold for HFCs, keep threshold for other Annex I & Annex II gases	= option 1	= option 1
Destruction	Threshold: 1t / 1000 t CO_2e of Annex I & II	For HFCs, a reporting threshold is inconsistent with the EU reporting obligation under the MP	Remove threshold for HFCs, keep threshold for other Annex I & Annex II gases	= option 1	= option 1
Reclamation	None	Obligation currently only for producers, bulk importers and exporters	none	Add obligation for Annex I & Annex II gases, threshold: 1t / 100 t CO2e	= option 2
Recycling	None	Obligation currently only for producers, bulk importers and exporters in 2014 F-gas Regulation	none	none	Add obligation for Annex I & Annex II gases, threshold: 1t / 100 t CO2e
Recipients of quota-exempted gases for military, semiconductor & MDIs (unless exemption removed)	none		none	Add obligation to report on received exempted HFCs & identify supplier, no threshold	= option 2
Product/Equipment imports	Threshold: 500 tCO_2e of Annex I & II	This currently conflicts with 100 tCO_2e HFC threshold for authorisation obligation and verification obligation	Threshold: 100 tCO_2e of HFCs and 500 tCO_2e of Annex I & II	= option 1	= option 1
Product/Equipment exports	None	SF_6 likely relevant in absolute terms	none	none	Threshold: 1t / 100 t CO_2e of HFCs &

Measure target	Status quo	Comment	Option 1	Option 2	Option 3
					SF_6
Operation and decommissioning of electrical equipment / SF_6	None	**Reporting on lifetime losses by grid operators:** Scope of reportable data should include: Country of operation, type and quantity of refilled equipment, SF_6 amounts refilled **Reporting obligation directed to undertakings active in the decommissioning of electrical equipment (EoL treatment).** Scope of reportable data should include: Country of decommissioning, type of equipment, Standard charge, Recovered charge, Supplementary Obligation for equipment operators to provide standard charge to decommissioner to be added	None	None	Threshold: 5 kg SF_6 [~ 100 t CO_2e)
Mandatory NIL report for companies with activities below thresholds	None	Would help compliance checks for quota & authorisation holders	Obligatory for quota holders	= option 1	= option 1
Verification obligation & thresholds (Art 19 & 14)					
POM of HFCs (bulk)	Threshold: 10 000 t CO2e	Many new entrants are falling under the threshold	Threshold: 1000 t CO_2e	Threshold: 1,000 t CO_2e	= option 1
POM of HFCs in RAC equipment	In F-gas Regulation 2014, de-facto 100t CO_2e threshold based on Art 14 pointing to Art 15		Threshold: 1,000 t CO_2e	= option 1	=option 1
Submission obligation for verification reports (Art 19 & 14)					
POM of HFCs (bulk)	On request by authorities	BDR submission facility is available	Obligatory in all cases above threshold	= option 1	= option 1
POM of HFCs in RAC equipment	Obligatory in all cases above threshold	BDR submission facility is available	Keep	Keep	Keep
Timing of reporting obligation (Art 19)					
All reporters	31 March		Keep	Keep	Keep
Timing of verification (& submission) obligation (Art 19, Art 14)					
POM of HFCs (bulk)	30 June	Joint date for bulk & equipment preferable, 30 June is challenge for compliance process	30 April	= option 1	= option 1
POM of HFCs in RAC equipment	31 March	Aligning reporting deadline bulk & equipment. Timespan between report & verification makes sense many Verifiers are busy with ETS for 31 March deadline	30 April	= option 1	= option 1

Measure target	Status quo	Comment	Option 1	Option 2	Option 3
Integration of electronic verification into the BDR reporting process					
POM of HFCs (bulk)	none	Process modelled after established ETS processes would render verification processes more efficient and easier accessible for compliance checks. Processes would cover verification thresholds & submission obligations & is in line with approach to timing deadlines; Admin burden for EEA to set up	none	Set legal basis	= option 2
POM of HFCs in RAC equipment	none		none	Set legal basis	= option 2

A11 Detailed information on emissions

A11.1 Historic development of emissions



Source: (UCFCCC, 2021)

Figure 26: F-gas emissions in EU27 + UK from 1990 to 2019

HFCs rose quickly in the 1990s due to the replacement of ODS, in particular in refrigeration and AC, but also in foams, aerosols etc. The reductions from 1997-2001 were achieved due to the elimination of HFC-23 emissions in chemical industrial production. However, the growing trend of HFC emissions continued until 2014, after which the EU F-gas policy started to take effect and led to year-on-year decreases until today. Emissions of PFCs, and from 1996 onwards also SF_6, could be reduced until ca. 2010, most likely due to higher awareness and better production and management processes. However, from 2010 onwards, the emissions of both substance (groups) has stagnated

A11.2 Baseline development of emissions

The existing Regulation reduced the emission of F-gases in the EU (see Evaluation report, Annex A5). For the future, the projections show that without further EU action (baseline scenario), the emissions will decrease until 2040 and thereafter stagnate until 2050 at 27 Mt CO_2e. F-gas emission reductions will only reach 44MtCO2e in 2030, while the original objective for a cost-efficient contribution would be a 60% reduction from 2005 levels, e.g. 33 MtCO2e (see Figure 26).

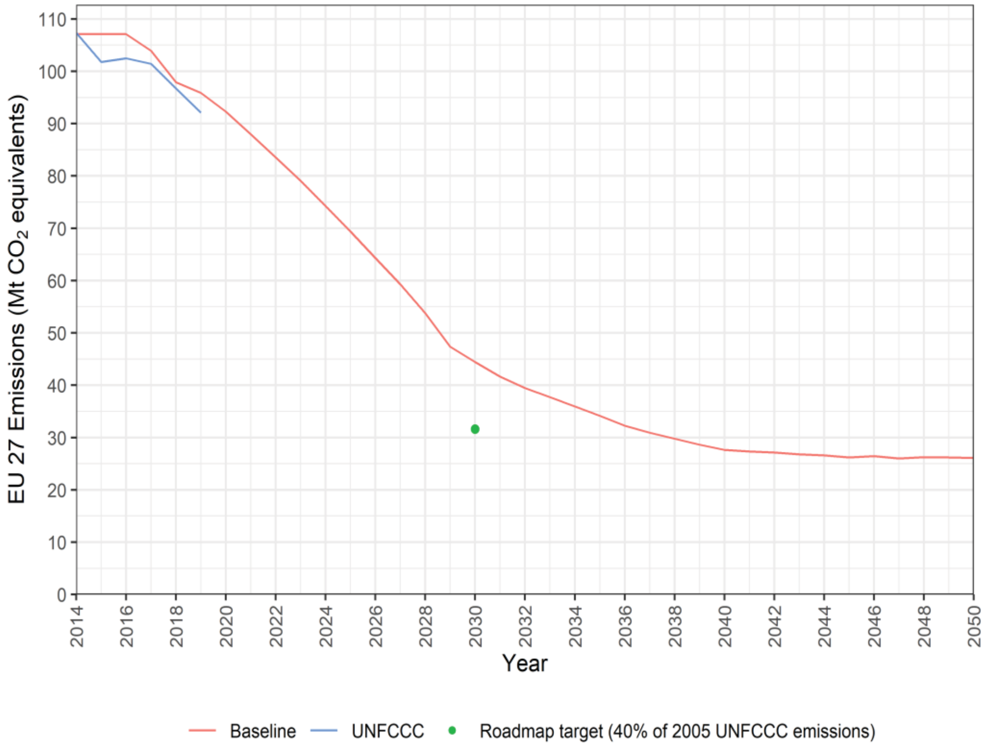


Figure 27: EU27 modelled baseline F-gas emissions and data reported under the UNFCCC [in tCO2e]

Source: *AnaFgas modelling, UNFCCC (https://unfccc.int/documents/275968). Reported values under United Nation Framework Convention on Climate Change (UNFCCC) are included for comparison to the modelled*

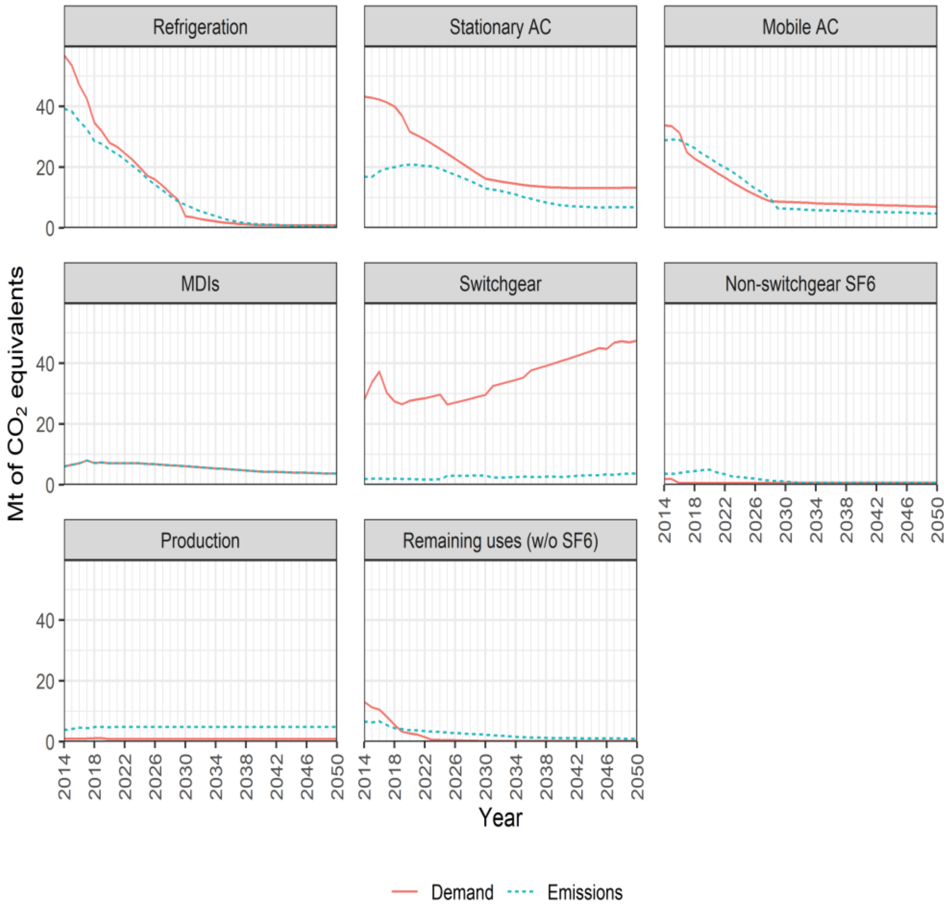


Figure 27. Baseline development of F-gas demand and emissions at sectoral level

A11.3 Emissions of the Options

Under Option 1, emissions will exceed baseline values until 2046 and will drop slightly below the baseline from 2047. In contrast, under Option 2, emissions slightly fall below the baseline already in 2025, further strongly decrease until 2040 and then level out until 2050 at around 14 Mt CO_2 eq. Option 3 shows a similar development in emissions, but the decrease is more pronounced and emissions level out at around 13 Mt CO_2 until 2050.

Across all scenarios, HFCs are by far the most important contributor to the overall emissions, especially in the years until 2040. Under Option 2 and 3, SF_6 shows slightly more reduction in emission compared to the baseline and the Option 1, while other F-gases (PFCs, unsaturated H(C)FCs and NF_3) show no discernible difference between the options.

As for cumulative emissions from 2024 until 2050, Option 1 does slightly worse than the baseline (increase of 3%), but Option 2 and 3 lead to significant savings (253 and 280 MtCO2e, respectively or reductions of 25 and 28% from the baseline). See Table 34.

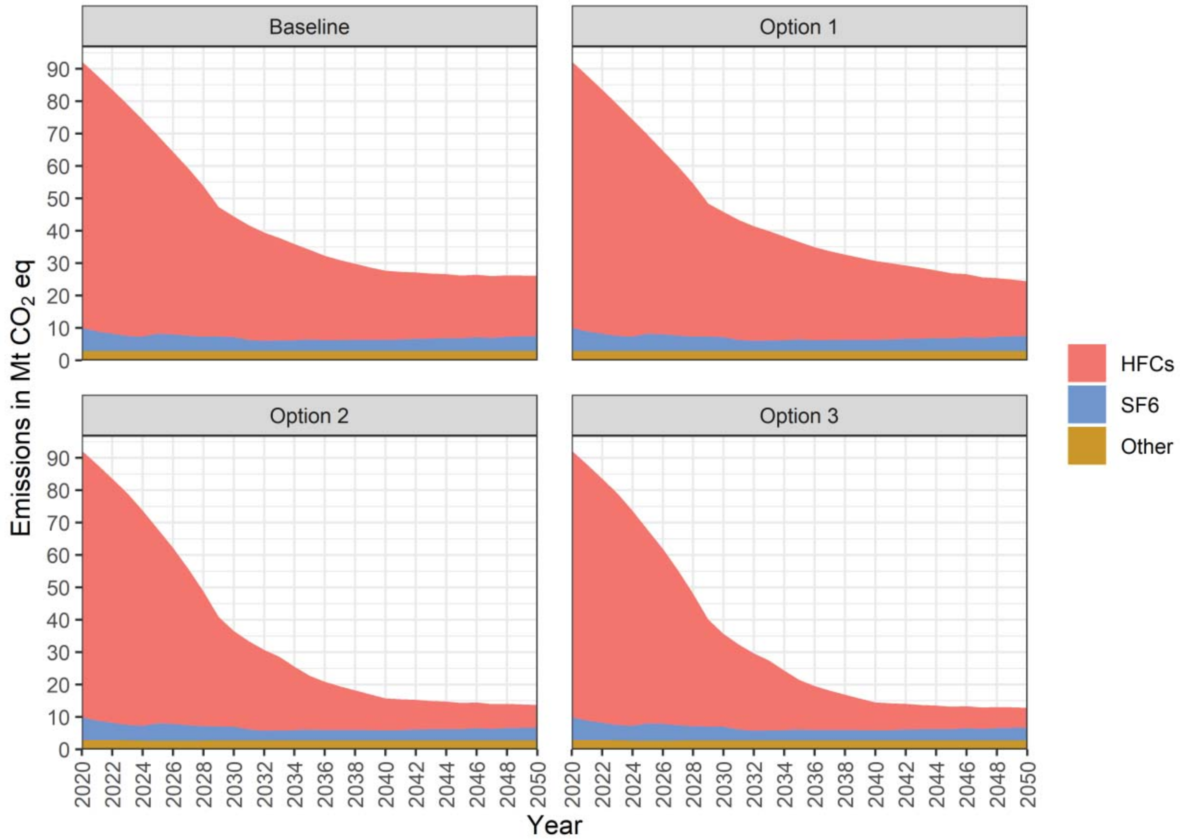


Figure 28. Modelled emissions of F-gases under the different scenarios in the EU-27
Source: *AnaFgas modelling*

Table 34. Modelled emissions of F-gases in Mt CO_2 eq under the different options in the EU-27

Year	Gas group	BL	O1	O2	O3	O1-BL	O2-BL	O3-BL
2020	**Total**	**92**	**92**	**92**	**92**	**0 (0%)**	**0 (0%)**	**0 (0%)**
	HFCs	82	82	82	82	0 (0%)	0 (0%)	0 (0%)
	SF6	7	7	7	7	0 (0%)	0 (0%)	0 (0%)
	Other	3	3	3	3	0 (0%)	0 (0%)	0 (0%)
2025	**Total**	**69**	**69**	**68**	**68**	**0 (0%)**	**-1 (-1%)**	**-1 (-1%)**
	HFCs	61	61	60	60	0 (0%)	-1 (-2%)	-1 (-2%)
	SF6	5	5	5	5	0 (0%)	0 (0%)	0 (0%)
	Other	3	3	3	3	0 (0%)	0 (0%)	0 (0%)
2030	**Total**	**44**	**46**	**37**	**36**	**2 (5%)**	**-7 (-16%)**	**-8 (-18%)**
	HFCs	37	39	30	29	2 (5%)	-7 (-19%)	-8 (-22%)
	SF6	4	4	4	4	0 (0%)	0 (0%)	0 (0%)
	Other	3	3	3	3	0 (0%)	0 (0%)	0 (0%)
2035	**Total**	**35**	**37**	**23**	**21**	**2 (6%)**	**-12 (-34%)**	**-14 (-40%)**
	HFCs	28	30	17	15	2 (7%)	-11 (-39%)	-13 (-46%)
	SF6	4	4	3	3	0 (0%)	-1 (-25%)	-1 (-25%)
	Other	3	3	3	3	0 (0%)	0 (0%)	0 (0%)
2040	**Total**	**27**	**30**	**16**	**15**	**3 (11%)**	**-11 (-41%)**	**-12 (-44%)**

	HFCs	21	24	10	9	3 (14%)	-11 (-52%)	-12 (-57%)
	SF6	3	3	3	3	0 (0%)	0 (0%)	0 (0%)
	Other	3	3	3	3	0 (0%)	0 (0%)	0 (0%)
2045	**Total**	**26**	**27**	**14**	**13**	**1 (4%)**	**-12 (-46%)**	**-13 (-50%)**
	HFCs	19	20	8	7	1 (5%)	-11 (-58%)	-12 (-63%)
	SF6	4	4	3	3	0 (0%)	-1 (-25%)	-1 (-25%)
	Other	3	3	3	3	0 (0%)	0 (0%)	0 (0%)
2050	**Total**	**27**	**25**	**14**	**13**	**-2 (-7%)**	**-13 (-48%)**	**-14 (-52%)**
	HFCs	19	17	7	6	-2 (-11%)	-12 (-63%)	-13 (-68%)
	SF6	5	5	4	4	0 (0%)	-1 (-20%)	-1 (-20%)
	Other	3	3	3	3	0 (0%)	0 (0%)	0 (0%)

Note: BL is baseline; O1, O2, and O3 are the 3 options

Table 35. Sum of modelled cumulative emissions of F-gases in Mt CO_2 eq from 2024 to 2050 for the different options for important sectors in the EU-27

Sector	BL	O1	O2	O3	O1-BL	O2-BL	O3-BL
Refrigeration	128	134	112	107	6 (5%)	-16 (-13%)	-21 (-16%)
Stationary AC	284	311	169	169	27 (10%)	-116 (-41%)	-116 (-41%)
Mobile AC	187	187	150	127	0 (-)	-37 (-20%)	-60 (-32%)
Switchgear	78	78	71	71	0 (-)	-7 (-9%)	-7 (-9%)
MDIs	138	138	66	66	0 (-)	-72 (-52%)	-72 (-52%)
Other	200	200	196	196	0 (-)	-4 (-2%)	-4 (-2%)
Total	**1 016**	**1 050**	**763**	**736**	**33 (3%)**	**-253 (-25%)**	**-280 (-28%)**

Note: BL is baseline; **O1, O2, O3** are the three options

Looking at the major use sectors, emissions from stationary AC applications show the most pronounced deviations between Options (

Figure 29). Cumulative emissions from 2020 to 2050 are higher for Option 1 compared to the baseline in the sectors of stationary AC and refrigeration. Both Options 2 and 3 show lower cumulative emissions for all sectors, with Option 3 having the lowest emissions. Differences between Option 2 and 3 are mostly due to differences in mobile AC and, to a lesser extent, refrigeration applications. The sector "Others" in

Figure 29 contains multiple smaller sectors that are shown in detail in Figure 30. The largest contributors to the emissions in this diverse category are HFCs and PFCs from the production of halocarbons. There are only small differences between the options in the sector "Others". Overall, Options 2 and 3 would lead to a 19 % and 21 % cumulative reduction in F-gas emissions in CO_2 eq from 2020 to 2050, respectively.

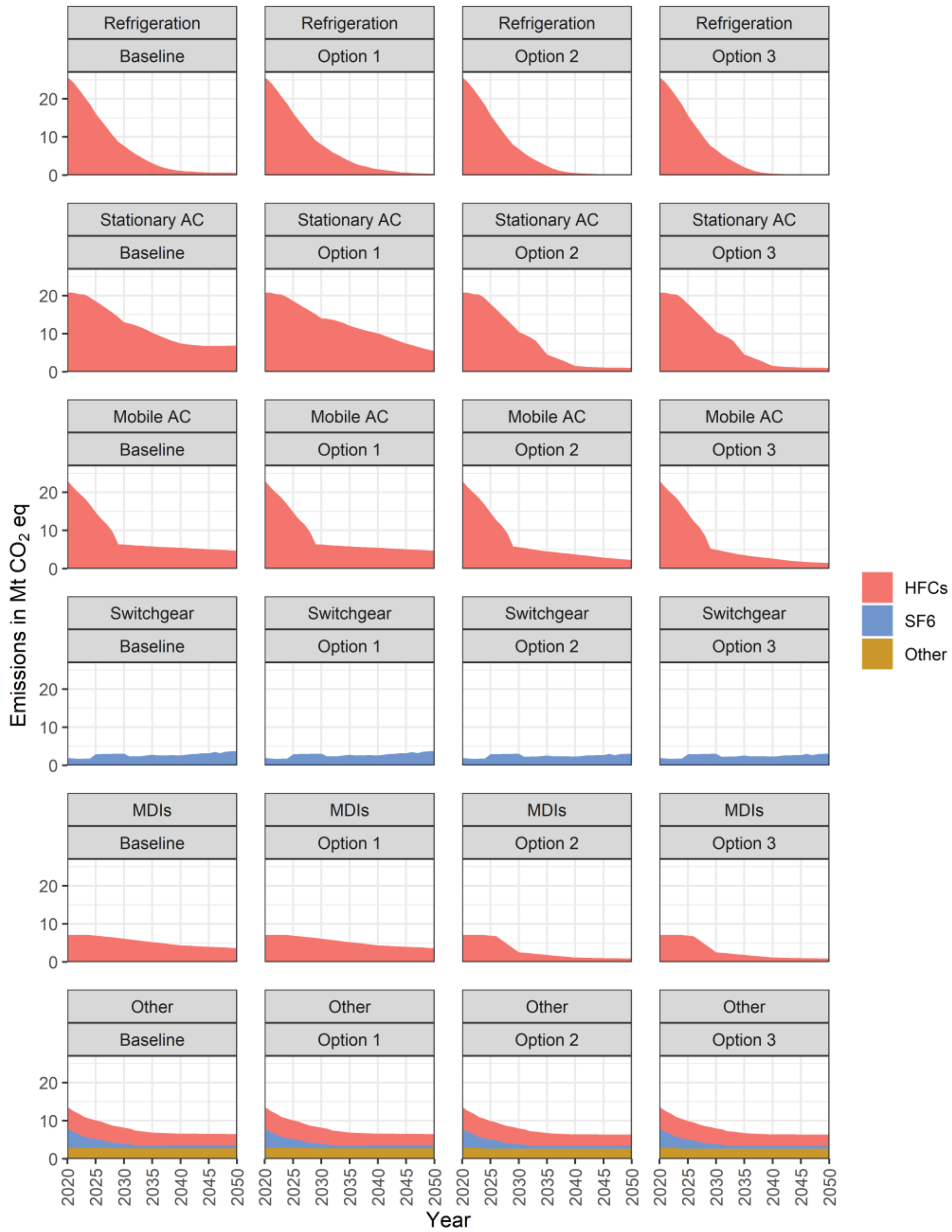


Figure 29. Modelled emissions of F-gases under the different options in the EU-27 by major sectors
Source: *AnaFgas modelling*

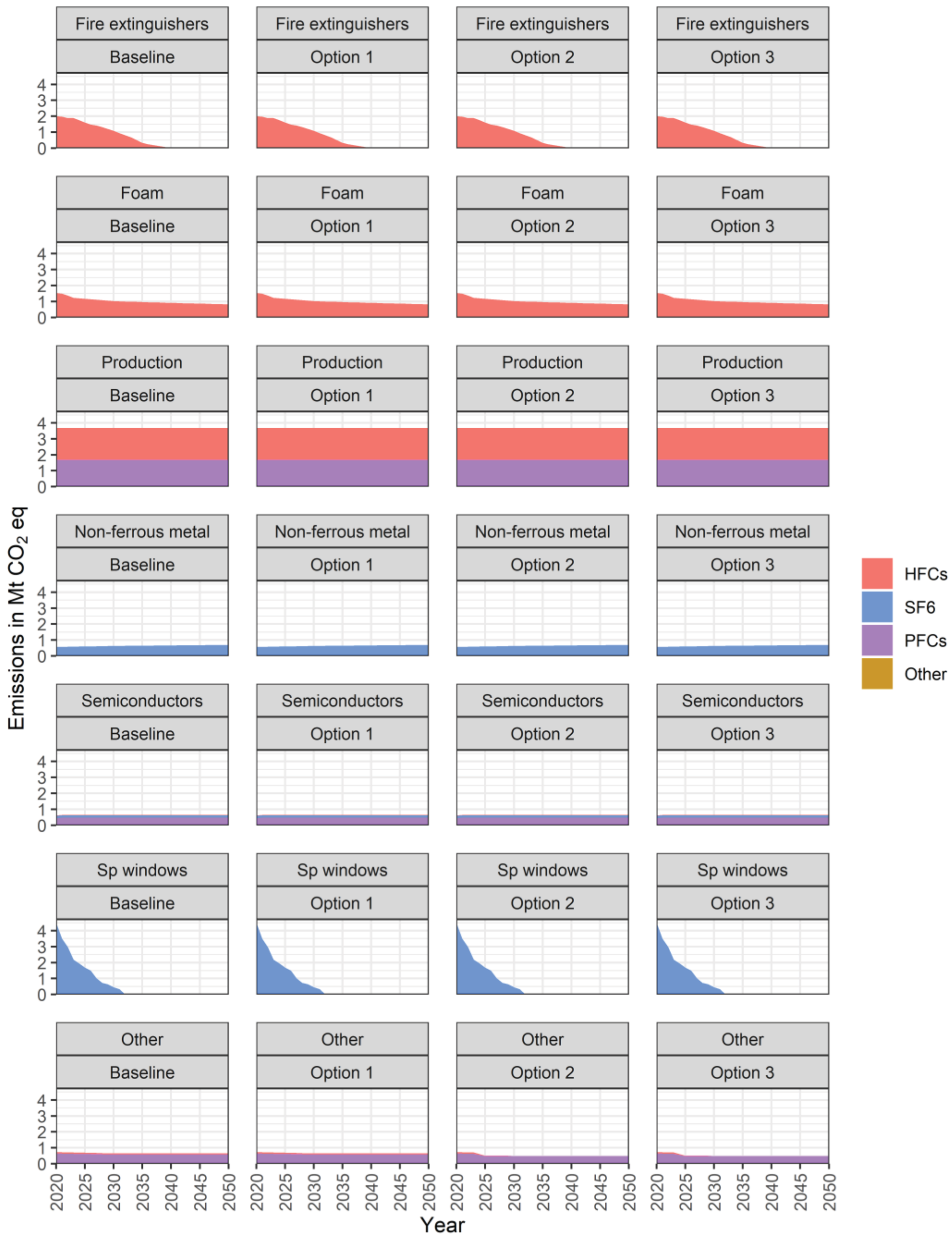


Figure 30. Modelled emissions of F-gases under the different scenarios in the EU-27 in the sector "Other"
Notes: 'Production' is F-gases emitted in the production process of HFCs, 'Sp window' is soundproof windows
Source: *AnaFgas modelling*

A11.4 Emissions of HFO-1234yf

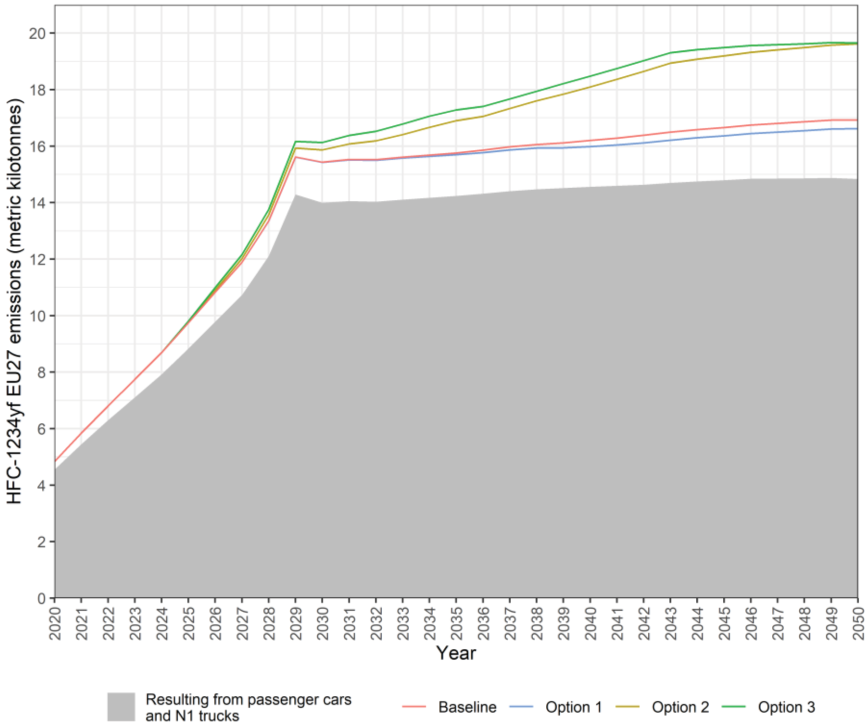


Figure 31: EU-27 emissions of HFC-1234yf in the 2015 – 2050 time period
Source: *AnaFgas modelling 2021*

A12 AnaFgas Cost Modelling Results

A12.1 Operative adjustment costs to industry under the existing Regulation (2015-2019)

Table 36. Operative adjustment costs to end-users/equipment operators under the existing Regulation

	Total equipment operators' adjustment cost	*thereof:* cost of HFC price increase (= cost for equipment operators, = revenue in HFC supply chain)	*thereof:* Cost of technological change (= net EU industry adjustment cost)	Total equipment operators' adjustment cost
	Mio € / year	Mio € / year	Mio € / year	% of equipment operators' totex in counterfactual scenario
Domestic Refrigeration	-3.7	-	-3.7	-0.0%
Commercial refrigeration – Hermetics	-6.1	2.3	-8.4	-0.2%
Commercial refrigeration - Condensing units	92.2	88.8	3.4	1.0%
Commercial refrigeration - Central systems	491.7	405.2	86.6	5.8%
Industrial refrigeration - small	103.6	76.4	27.2	4.4%
Industrial refrigeration - large	316.6	75.8	240.8	4.5%
Transport refrigeration - Vans	7.2	7.1	0.2	1.5%
Transport refrigeration - Trucks & Trailers	51.5	46.9	4.6	0.9%
Transport refrigeration - Ships	22.1	21.0	1.2	10.5%
Room AC - Moveables	2.1	3.1	-1.0	0.5%
Room AC - Single split	201.2	190.7	10.6	0.9%
Room AC - Rooftop	90.1	85.6	4.5	0.5%
Room AC - VRF	99.3	99.2	0.1	1.5%
Minichillers	1.1	1.2	-0.1	0.1%
Displacement chillers - small	15.9	10.2	5.7	1.3%
Displacement chillers - large	94.5	73.3	21.2	1.5%
Centrifugal chillers	9.3	7.6	1.7	1.0%
Heat pumps - small	42.3	30.2	12.1	0.2%
Heat pumps - medium	27.9	24.8	3.1	0.4%
Heat pumps - large	-3.1	4.5	-7.5	-0.1%
Mobile AC - Passenger cars	271.0	271.0	-	0.2%
Mobile AC - Buses	23.2	23.2	-0.0	0.4%
Mobile AC - Trucks N1	29.3	25.1	4.2	0.4%
Mobile AC - Trucks N2	4.9	4.9	-	0.6%
Mobile AC - Trucks N3	16.0	16.0	-	0.6%
Mobile AC - Passenger ships	16.7	16.7	-	10.7%
Mobile AC - Cargo ships	11.3	11.3	-	10.7%

	Total equipment operators’ adjustment cost	*thereof:* cost of HFC price increase (= cost for equipment operators, = revenue in HFC supply chain)	*thereof:* Cost of technological change (= net EU industry adjustment cost)	Total equipment operators’ adjustment cost
	Mio € / year	Mio € / year	Mio € / year	% of equipment operators’ totex in counterfactual scenario
Mobile AC - Tram	0.4	0.4	-	0.5%
Mobile AC - Metro	0.1	0.1	-	0.5%
Mobile AC - Train	1.2	1.2	0.0	0.5%
Aerosols - technical	22.4	12.5	9.9	7.2%
Aerosols - MDIs	-	-	-	-
Fire extinguishers	44.8	25.8	18.9	22.0%
Solvents	1.8	1.5	0.3	11.8%
Foam OCF	-	-	-	-
Foam XPS	29.1	12.4	16.7	26.1%
Foam PU spray	26.1	21.1	5.0	15.4%
Foam PU non-spray	14.1	10.4	3.7	15.0%
Total	**2 169**	**1 707**	**461**	

Source: *AnaFgas cost modelling*

A12.2 Average emission reduction costs under existing Regulation (2015-2019)

Table 37. Average emission reduction costs to end-users/equipment operators under the existing Regulation

	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_2e	Mio €	€ / t CO_2e
Domestic Refrigeration	0.013	-13.3	-1 052
Commercial refrigeration - Hermetics	0.035	-26.7	-758
Commercial refrigeration - Condensing units	0.143	-2.7	-19
Commercial refrigeration - Central systems	6.938	95.9	14
Industrial refrigeration - small	1.365	20.3	15
Industrial refrigeration - large	3.684	37.1	10
Transport refrigeration - Vans	0.027	0.7	27
Transport refrigeration - Trucks & Trailers	0.543	13.2	24
Transport refrigeration - Ships	0.228	0.8	3
Room AC - Moveables	0.176	-5.8	-33
Room AC - Single split	4.146	18.1	4
Room AC - Rooftop	0.245	-11.8	-48
Room AC - VRF	0.007	0.2	24
Minichillers	0.005	-1.2	-250
Displacement chillers - small	0.052	0.5	10
Displacement chillers - large	0.342	3.8	11
Centrifugal chillers	0.055	-1.9	-34
Heat pumps - small	0.247	-24.4	-99
Heat pumps - medium	0.106	-4.5	-43
Heat pumps - large	0.137	1.8	13
Mobile AC - Passenger cars	-	-	NA
Mobile AC - Buses	0.008	2.5	334
Mobile AC - Trucks N1	0.121	9.5	78
Mobile AC - Trucks N2	-	-	NA
Mobile AC - Trucks N3	-	-	NA
Mobile AC - Passenger ships	-	-	NA
Mobile AC - Cargo ships	-	-	NA
Mobile AC - Tram	-	-	NA
Mobile AC - Metro	-	-	NA
Mobile AC - Train	0.000	0.0	513

	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_2e	Mio €	€ / t CO_2e
Aerosols - technical	1.359	10.3	8
Aerosols - MDIs	-	-	NA
Fire extinguishers	1.164	13.9	12
Solvents	0.026	0.3	11
Foam OCF	-	-	NA
Foam XPS	0.008	0.1	10
Foam PU spray	0.006	0.0	5
Foam PU non-spray	0.002	0.0	7
Total	**21.2**	**137**	**6.4**

Source: *AnaFgas cost modelling*

A12.3 Equipment operators' additional adjustment cost for the policy options at sub-sector level

Table 38. Option 1: Equipment operators' additional adjustment costs, 2024 – 2036 average (costs difference to the baseline)

Sector	Option 1, 2024-2036			
	total adjustment cost vs baseline		*thereof:* additional cost of HFC price increase	*thereof:* cost of technological change (= net compliance cost)
	Mio EUR/year	% of baseline totex	Mio EUR/year	Mio EUR/year
Domestic Refrigeration	0.0	0.0%	0.0	0.0
Commercial refrigeration - Hermetics	0.0	0.0%	0.0	0.0
Commercial refrigeration - Condensing units	25.5	0.3%	24.5	0.9
Commercial refrigeration - Central systems	-33.2	-0.4%	-13.8	-19.3
Industrial refrigeration - small	-10.5	-0.4%	-4.7	-5.8
Industrial refrigeration - large	-8.7	-0.2%	-8.7	0.0
Transport refrigeration - Vans	-0.9	-0.2%	-0.9	0.0
Transport refrigeration - Trucks & Trailers	-4.1	-0.1%	-4.1	0.0
Transport refrigeration - Ships	-0.9	-0.5%	-0.9	0.0
Room AC - Moveables	0.0	0.0%	0.0	0.0
Room AC - Single split	12.5	0.1%	4.1	8.4
Room AC - Rooftop	1.7	0.0%	9.1	-7.3
Room AC - VRF	5.5	0.1%	18.1	-12.6
Minichillers	2.6	0.4%	0.3	2.4
Displacement chillers - small	2.0	0.1%	3.8	-1.8
Displacement chillers - large	12.3	0.2%	23.2	-10.9
Centrifugal chillers	-0.7	-0.1%	-0.7	0.0
Heat pumps - small	50.2	0.1%	15.4	34.8
Heat pumps - medium	34.0	0.3%	20.8	13.2
Heat pumps - large	-1.8	0.0%	-1.8	0.0
Mobile AC - Passenger cars	-11.9	-0.1%	-11.9	0.0
Mobile AC - Buses	-6.7	-0.1%	-6.7	0.0
Mobile AC - Trucks N1	-12.4	-0.2%	-12.4	0.0
Mobile AC - Trucks N2	-2.5	-0.3%	-2.5	0.0
Mobile AC - Trucks N3	-9.4	-0.3%	-9.4	0.0
Mobile AC - Passenger ships	-7.1	-3.4%	-7.1	0.0
Mobile AC - Cargo ships	-4.6	-3.5%	-4.6	0.0
Mobile AC - Tram	-0.2	-0.1%	-0.2	0.0
Mobile AC - Metro	0.0	-0.1%	0.0	0.0
Mobile AC - Train	-0.5	-0.1%	-0.5	0.0
Aerosols - technical	-0.1	0.0%	-0.1	0.0
Aerosols - MDIs	186.6	0.0%	186.6	0.0
Fire extinguishers	-4.9	-2.3%	-4.9	0.0
Solvents	-0.2	-2.5%	-0.2	0.0

Sector	Option 1, 2024-2036			
	total adjustment cost vs baseline		*thereof:* additional cost of HFC price increase	*thereof:* cost of technological change (= net compliance cost)
	Mio EUR/year	% of baseline totex	Mio EUR/year	Mio EUR/year
Foam OCF	0.0	0.0%	0.0	0.0
Foam XPS	-0.1	0.0%	-0.1	0.0
Foam PU spray	0.0	0.0%	0.0	0.0
Foam PU non-spray	0.0	0.0%	0.0	0.0
Switchgear MV	0.0	0.0%	0.0	0.0
Switchgear HV	0.0	0.0%	0.0	0.0
Total	**211.7**	**0.0%**	**209.8**	**1.9**

Table 39. Option 1: Equipment operators' additional adjustment costs, 2050 (costs difference to the baseline)

Sector	Option 1, 2050			
	total compliance cost vs baseline		*thereof:* additional cost of HFC price increase	*thereof:* cost of technological change (= net compliance cost)
	Mio EUR/year	% of baseline totex	Mio EUR/year	Mio EUR/year
Domestic Refrigeration	0.0	0.0%	0.0	0.0
Commercial refrigeration - Hermetics	0.0	0.0%	0.0	0.0
Commercial refrigeration - Condensing units	-20.0	-0.2%	4.9	-24.9
Commercial refrigeration - Central systems	-132.3	-1.6%	-53.9	-78.4
Industrial refrigeration - small	3.4	0.1%	4.2	-0.7
Industrial refrigeration - large	0.5	0.0%	0.5	0.0
Transport refrigeration - Vans	0.1	0.0%	0.1	0.0
Transport refrigeration - Trucks & Trailers	1.7	0.0%	1.7	0.0
Transport refrigeration - Ships	0.8	0.7%	0.8	0.0
Room AC - Moveables	0.0	0.0%	0.0	0.0
Room AC - Single split	-262.3	-1.0%	-171.3	-91.0
Room AC - Rooftop	-15.9	-0.1%	16.3	-32.2
Room AC - VRF	17.2	0.1%	30.1	-12.9
Minichillers	-2.8	-0.8%	0.2	-3.0
Displacement chillers - small	-1.2	-0.1%	1.2	-2.5
Displacement chillers - large	0.7	0.0%	10.5	-9.8
Centrifugal chillers	0.0	0.0%	0.0	0.0
Heat pumps - small	-85.9	-0.1%	-9.2	-76.7
Heat pumps - medium	-139.4	-0.7%	-15.4	-124.0
Heat pumps - large	0.0	0.0%	0.0	0.0
Mobile AC - Passenger cars	22.6	2.1%	22.6	0.0
Mobile AC - Buses	11.1	0.2%	11.1	0.0
Mobile AC - Trucks N1	24.8	0.3%	24.8	0.0
Mobile AC - Trucks N2	5.0	0.6%	5.0	0.0
Mobile AC - Trucks N3	19.7	0.7%	19.7	0.0
Mobile AC - Passenger ships	5.6	3.1%	5.6	0.0
Mobile AC - Cargo ships	3.3	3.0%	3.3	0.0
Mobile AC - Tram	0.1	0.1%	0.1	0.0
Mobile AC - Metro	0.1	0.3%	0.1	0.0
Mobile AC - Train	0.8	0.3%	0.8	0.0
Aerosols - technical	0.1	0.1%	0.1	0.0
Aerosols - MDIs	185.7	0.0%	185.7	0.0
Fire extinguishers	14.6	6.2%	14.6	0.0
Solvents	0.4	5.1%	0.4	0.0
Foam OCF	0.0	0.0%	0.0	0.0
Foam XPS	0.0	0.0%	0.0	0.0

Sector	Option 1, 2050			
	total compliance cost vs baseline		*thereof:* additional cost of HFC price increase	*thereof:* cost of technological change (= net compliance cost)
	Mio EUR/year	% of baseline totex	Mio EUR/year	Mio EUR/year
Foam PU spray	0.0	0.0%	0.0	0.0
Foam PU non-spray	0.0	0.0%	0.0	0.0
Switchgear MV	0.0	0.0%	0.0	0.0
Switchgear HV	0.0	0.0%	0.0	0.0
Total	**-341.4**	**0.0%**	**114.6**	**-456.1**

Table 40. Option 2: Equipment operators' additional adjustment costs, 2024 – 2036 average (costs difference to the baseline)

Sector	Option 2, 2024-2036			
	total compliance cost vs baseline		*thereof:* additional cost of HFC price increase	*thereof:* cost of technological change (= net compliance cost)
	Mio EUR/year	% of baseline totex	Mio EUR/year	Mio EUR/year
Domestic Refrigeration	0.0	0.0%	0.0	0.0
Commercial refrigeration - Hermetics	-2.8	-0.1%	-0.2	-2.6
Commercial refrigeration - Condensing units	3.6	0.0%	22.2	-18.7
Commercial refrigeration - Central systems	53.0	0.6%	75.4	-22.4
Industrial refrigeration - small	81.9	3.2%	80.8	1.1
Industrial refrigeration - large	54.0	1.2%	42.8	11.2
Transport refrigeration - Vans	-2.1	-0.4%	0.2	-2.3
Transport refrigeration - Trucks & Trailers	-27.1	-0.5%	6.7	-33.7
Transport refrigeration - Ships	2.1	1.2%	2.2	-0.1
Room AC - Moveables	0.0	0.0%	0.0	0.0
Room AC - Single split	-271.7	-1.1%	-200.7	-71.0
Room AC - Rooftop	7.2	0.0%	-26.0	33.2
Room AC - VRF	27.7	0.3%	-34.2	61.9
Minichillers	-4.1	-0.7%	0.0	-4.1
Displacement chillers - small	3.8	0.3%	-0.9	4.7
Displacement chillers - large	11.0	0.2%	-10.4	21.4
Centrifugal chillers	2.3	0.3%	4.3	-1.9
Heat pumps - small	-118.1	-0.3%	-15.7	-102.4
Heat pumps - medium	-24.0	-0.2%	-3.9	-20.1
Heat pumps - large	1.3	0.0%	5.6	-4.3
Mobile AC - Passenger cars	80.7	0.7%	80.7	0.0
Mobile AC - Buses	64.5	1.2%	23.2	41.3
Mobile AC - Trucks N1	69.4	1.0%	33.0	36.4
Mobile AC - Trucks N2	12.0	1.4%	3.9	8.1
Mobile AC - Trucks N3	58.9	2.1%	19.8	39.1
Mobile AC - Passenger ships	30.9	14.9%	34.6	-3.6
Mobile AC - Cargo ships	18.7	14.4%	20.7	-1.9
Mobile AC - Tram	3.5	2.4%	0.4	3.1
Mobile AC - Metro	0.9	2.9%	0.1	0.8
Mobile AC - Train	-11.7	-3.5%	2.3	-14.1
Aerosols - technical	0.4	0.2%	-0.2	0.6
Aerosols - MDIs	209.5	0.0%	207.5	2.0
Fire extinguishers	36.4	17.1%	36.4	0.0
Solvents	-0.9	-11.9%	-1.5	0.5
Foam OCF	0.0	0.0%	0.0	0.0
Foam XPS	0.3	0.2%	0.3	0.0

Sector	Option 2, 2024-2036			
	total compliance cost vs baseline		***thereof:*** additional cost of HFC price increase	***thereof:*** cost of technological change (= net compliance cost)
	Mio EUR/year	% of baseline totex	Mio EUR/year	Mio EUR/year
Foam PU spray	0.0	0.0%	0.0	0.0
Foam PU non-spray	0.0	0.0%	0.0	0.0
Switchgear MV	26.2	3.5%	0.0	26.2
Switchgear HV	23.1	3.7%	0.0	23.1
Total	**420.8**	**0.1%**	**409.4**	**11.5**

Table 41. Option 2: Equipment operators' additional adjustment cost, 2050 (costs difference to the baseline)

Sector	Option 2, 2050			
	total compliance cost vs baseline		*thereof:* additional cost of HFC price increase	*thereof:* cost of technological change (= net compliance cost)
	Mio EUR/a	% of baseline totex	Mio EUR/a	Mio EUR/a
Domestic Refrigeration	0.0	0.0%	0.0	0.0
Commercial refrigeration - Hermetics	0.0	0.0%	0.0	0.0
Commercial refrigeration - Condensing units	-137.7	-1.7%	-2.7	-135.0
Commercial refrigeration - Central systems	-134.0	-1.6%	-54.4	-79.6
Industrial refrigeration - small	10.5	0.4%	19.8	-9.3
Industrial refrigeration - large	-9.9	-0.4%	2.4	-12.4
Transport refrigeration - Vans	-2.1	-0.3%	0.4	-2.5
Transport refrigeration - Trucks & Trailers	-15.9	-0.2%	7.2	-23.1
Transport refrigeration - Ships	5.1	4.6%	5.4	-0.3
Room AC - Moveables	0.0	0.0%	0.0	0.0
Room AC - Single split	-512.6	-2.0%	-286.9	-225.7
Room AC - Rooftop	-209.9	-1.4%	-27.5	-182.4
Room AC - VRF	21.8	0.1%	27.2	-5.4
Minichillers	-41.4	-12.4%	-0.7	-40.8
Displacement chillers - small	-10.4	-0.7%	-5.0	-5.4
Displacement chillers - large	-64.2	-1.1%	-45.4	-18.9
Centrifugal chillers	-7.9	-1.0%	0.0	-7.9
Heat pumps - small	-456.6	-0.4%	-74.4	-382.2
Heat pumps - medium	-373.2	-1.8%	-107.8	-265.4
Heat pumps - large	0.0	0.0%	0.0	0.0
Mobile AC - Passenger cars	278.6	26.1%	278.6	0.0
Mobile AC - Buses	104.6	2.0%	90.5	14.1
Mobile AC - Trucks N1	147.6	2.0%	81.1	66.5
Mobile AC - Trucks N2	10.4	1.3%	-11.6	22.0
Mobile AC - Trucks N3	72.3	2.5%	-42.9	115.2
Mobile AC - Passenger ships	-14.0	-7.8%	7.5	-21.5
Mobile AC - Cargo ships	-7.8	-7.0%	4.4	-12.2
Mobile AC - Tram	-0.4	-0.3%	-0.3	-0.1
Mobile AC - Metro	0.7	3.1%	0.4	0.3
Mobile AC - Train	-11.2	-3.5%	7.6	-18.7
Aerosols - technical	0.6	0.2%	-0.6	1.1
Aerosols - MDIs	169.7	0.0%	138.5	31.2
Fire extinguishers	180.1	76.9%	180.1	0.0
Solvents	-1.2	-14.5%	-1.7	0.5
Foam OCF	0.0	0.0%	0.0	0.0
Foam XPS	0.0	0.0%	0.0	0.0

Sector	Option 2, 2050			
	total compliance cost vs baseline		*__thereof:__* additional cost of HFC price increase	*__thereof:__* cost of technological change (= net compliance cost)
	Mio EUR/a	% of baseline totex	Mio EUR/a	Mio EUR/a
Foam PU spray	0.0	0.0%	0.0	0.0
Foam PU non-spray	0.0	0.0%	0.0	0.0
Switchgear MV	92.1	8.9%	0.0	92.1
Switchgear HV	81.2	9.3%	0.0	81.2
Total	**-835.2**	**-0.1%**	**189.4**	**-1024.6**

Table 42. Option 3: Equipment operators' additional compliance cost, 2024 – 2036 average (costs difference to the baseline)

Sector	Option 3, 2024-2036			
	total compliance cost vs baseline		*thereof:* additional cost of HFC price increase	*thereof:* cost of technological change (= net compliance cost)
	Mio EUR/a	% of baseline totex	Mio EUR/a	Mio EUR/a
Domestic Refrigeration	0.0	0.0%	0.0	0.0
Commercial refrigeration - Hermetics	-2.8	-0.1%	-0.2	-2.6
Commercial refrigeration - Condensing units	5.8	0.1%	30.0	-24.1
Commercial refrigeration - Central systems	-0.8	0.0%	49.8	-50.5
Industrial refrigeration - small	102.8	4.1%	101.7	1.1
Industrial refrigeration - large	64.3	1.5%	53.1	11.2
Transport refrigeration - Vans	-4.5	-0.8%	-0.1	-4.4
Transport refrigeration - Trucks & Trailers	-50.9	-0.9%	4.4	-55.3
Transport refrigeration - Ships	1.1	0.6%	1.2	-0.1
Room AC - Moveables	0.0	0.0%	0.0	0.0
Room AC - Single split	-265.7	-1.1%	-194.8	-71.0
Room AC - Rooftop	18.6	0.1%	-14.6	33.2
Room AC - VRF	53.3	0.5%	-8.6	61.9
Minichillers	-4.0	-0.7%	0.1	-4.1
Displacement chillers - small	4.4	0.3%	-0.3	4.7
Displacement chillers - large	15.5	0.3%	-5.9	21.4
Centrifugal chillers	3.4	0.4%	5.3	-1.9
Heat pumps - small	-114.2	-0.3%	-11.7	-102.4
Heat pumps - medium	-18.4	-0.1%	1.6	-20.1
Heat pumps - large	3.6	0.0%	7.8	-4.3
Mobile AC - Passenger cars	99.8	0.8%	99.8	0.0
Mobile AC - Buses	108.0	2.1%	12.2	95.8
Mobile AC - Trucks N1	70.0	1.0%	12.5	57.5
Mobile AC - Trucks N2	9.4	1.1%	-4.6	14.0
Mobile AC - Trucks N3	58.6	2.1%	-34.2	92.8
Mobile AC - Passenger ships	30.9	14.8%	38.1	-7.2
Mobile AC - Cargo ships	22.1	17.0%	24.7	-2.5
Mobile AC - Tram	3.8	2.6%	0.4	3.4
Mobile AC - Metro	1.3	4.1%	0.1	1.2
Mobile AC - Train	18.6	5.6%	2.9	15.7
Aerosols - technical	0.4	0.2%	-0.2	0.6
Aerosols - MDIs	228.1	0.0%	226.1	2.0
Fire extinguishers	46.0	21.6%	46.0	0.0
Solvents	-0.9	-11.9%	-1.5	0.5
Foam OCF	0.0	0.0%	0.0	0.0

Sector	Option 3, 2024-2036			
	total compliance cost vs baseline		*__thereof:__* additional cost of HFC price increase	*__thereof:__* cost of technological change (= net compliance cost)
	Mio EUR/a	% of baseline totex	Mio EUR/a	Mio EUR/a
Foam XPS	0.3	0.3%	0.3	0.0
Foam PU spray	0.0	0.0%	0.0	0.0
Foam PU non-spray	0.0	0.0%	0.0	0.0
Switchgear MV	26.2	3.5%	0.0	26.2
Switchgear HV	23.1	3.7%	0.0	23.1
Total	**557.4**	**0.1%**	**441.7**	**115.7**

Table 43. Option 3: Equipment operators' additional adjustment cost, 2050 (costs difference to the baseline)

Sector	Option 3, 2050			
	total compliance cost vs baseline		*thereof:* additional cost of HFC price increase	*thereof:* cost of technological change (= net compliance cost)
	Mio EUR/year	% of baseline totex	Mio EUR/year	Mio EUR/year
Domestic Refrigeration	0.0	0.0%	0.0	0.0
Commercial refrigeration - Hermetics	0.0	0.0%	0.0	0.0
Commercial refrigeration - Condensing units	-175.1	-2.2%	-5.2	-169.8
Commercial refrigeration - Central systems	-135.4	-1.6%	-55.2	-80.2
Industrial refrigeration - small	14.6	0.6%	23.9	-9.3
Industrial refrigeration - large	-9.4	-0.4%	3.0	-12.4
Transport refrigeration - Vans	-5.4	-0.8%	-0.4	-5.0
Transport refrigeration - Trucks & Trailers	-53.3	-0.7%	-7.2	-46.1
Transport refrigeration - Ships	3.6	3.2%	4.0	-0.4
Room AC - Moveables	0.0	0.0%	0.0	0.0
Room AC - Single split	-512.6	-2.0%	-286.9	-225.7
Room AC - Rooftop	-203.3	-1.3%	-20.8	-182.4
Room AC - VRF	53.0	0.3%	58.4	-5.4
Minichillers	-41.4	-12.4%	-0.6	-40.8
Displacement chillers - small	-10.4	-0.7%	-5.0	-5.4
Displacement chillers - large	-64.2	-1.1%	-45.3	-18.9
Centrifugal chillers	-7.9	-1.0%	0.0	-7.9
Heat pumps - small	-456.6	-0.4%	-74.4	-382.2
Heat pumps - medium	-372.5	-1.8%	-107.2	-265.4
Heat pumps - large	0.0	0.0%	0.0	0.0
Mobile AC - Passenger cars	322.1	30.2%	322.1	0.0
Mobile AC - Buses	-8.1	-0.2%	-23.6	15.6
Mobile AC - Trucks N1	159.4	2.1%	89.7	69.7
Mobile AC - Trucks N2	4.9	0.6%	-19.3	24.2
Mobile AC - Trucks N3	51.3	1.7%	-76.1	127.3
Mobile AC - Passenger ships	-28.4	-15.8%	-2.1	-26.3
Mobile AC - Cargo ships	-12.7	-11.4%	1.2	-13.9
Mobile AC - Tram	-0.4	-0.3%	-0.3	-0.1
Mobile AC - Metro	1.1	4.6%	0.5	0.6
Mobile AC - Train	22.6	7.1%	8.7	13.9
Aerosols - technical	0.6	0.2%	-0.6	1.1
Aerosols - MDIs	185.9	0.0%	154.7	31.2
Fire extinguishers	208.2	88.9%	208.2	0.0
Solvents	-1.2	-14.5%	-1.7	0.5

Sector	Option 3, 2050			
	total compliance cost vs baseline		*thereof:* additional cost of HFC price increase	*thereof:* cost of technological change (= net compliance cost)
	Mio EUR/year	% of baseline totex	Mio EUR/year	Mio EUR/year
Foam OCF	0.0	0.0%	0.0	0.0
Foam XPS	0.0	0.0%	0.0	0.0
Foam PU spray	0.0	0.0%	0.0	0.0
Foam PU non-spray	0.0	0.0%	0.0	0.0
Switchgear MV	92.1	8.9%	0.0	92.1
Switchgear HV	81.2	9.3%	0.0	81.2
Total	**-897.8**	**-0.1%**	**142.2**	**-1040.1**

A12.4 Emission reduction cost at sub-sector level

Table 44. Option 1: Emission reduction cost, new equipment installed in 2024 – 2036 average

Sector	Option 1		
	new equipment installed, annual average 2024-2036		
	lifetime-integrated emission reductions compared to baseline	Cost of technological change of lifetime-integrated emission reductions	Calculated emission reduction cost for technological change
	Mt CO_2e	Mio €	€ / t CO_2e
Domestic Refrigeration	0.00	0.0	NA
Commercial refrigeration - Hermetics	0.00	0.0	NA
Commercial refrigeration - Condensing units	-0.24	13.0	NA
Commercial refrigeration - Central systems	-1.53	-14.0	NA
Industrial refrigeration - small	-0.17	-4.5	NA
Industrial refrigeration - large	0.00	0.0	NA
Transport refrigeration - Vans	0.00	0.0	NA
Transport refrigeration - Trucks & Trailers	0.00	0.0	NA
Transport refrigeration - Ships	0.00	0.0	NA
Room AC - Moveables	0.00	0.0	NA
Room AC - Single split	-0.82	3.6	NA
Room AC - Rooftop	-0.19	-8.2	NA
Room AC - VRF	-0.64	-19.0	NA
Minichillers	-0.01	4.6	NA
Displacement chillers - small	-0.03	-0.3	NA
Displacement chillers - large	-0.27	-3.3	NA
Centrifugal chillers	0.00	0.0	NA
Heat pumps - small	-0.54	169.1	NA
Heat pumps - medium	-0.49	50.4	NA
Heat pumps - large	0.00	0.0	NA
Mobile AC - Passenger cars	0.00	0.0	NA
Mobile AC - Buses	0.00	0.0	NA
Mobile AC - Trucks N1	0.00	0.0	NA
Mobile AC - Trucks N2	0.00	0.0	NA
Mobile AC - Trucks N3	0.00	0.0	NA
Mobile AC - Passenger ships	0.00	0.0	NA
Mobile AC - Cargo ships	0.00	0.0	NA
Mobile AC - Tram	0.00	0.0	NA
Mobile AC - Metro	0.00	0.0	NA
Mobile AC - Train	0.00	0.0	NA
Aerosols - technical	0.00	0.0	NA

Sector	Option 1		
	new equipment installed, annual average 2024-2036		
	lifetime-integrated emission reductions compared to baseline	Cost of technological change of lifetime-integrated emission reductions	Calculated emission reduction cost for technological change
	Mt CO_2e	Mio €	€ / t CO_2e
Aerosols - MDIs	0.00	0.0	NA
Fire extinguishers	0.00	0.0	NA
Solvents	0.00	0.0	NA
Foam OCF	0.00	0.0	NA
Foam XPS	0.00	0.0	NA
Foam PU spray	0.00	0.0	NA
Foam PU non-spray	0.00	0.0	NA
Switchgear MV	0.00	0.0	NA
Switchgear HV	0.00	0.0	NA
Total	**-4.9**	**191.4**	**NA**

Table 45. Option 1: Emission reduction cost, new equipment installed in 2050

Sector	Option 1		
	new equipment installed in 2050		
	lifetime-integrated emission reductions compared to baseline	Cost of technological change of lifetime-integrated emission reductions	Calculated emission reduction cost for technological change
	Mt CO_2e	Mio €	€ / t CO_2e
Domestic Refrigeration	0.00	0.0	NA
Commercial refrigeration - Hermetics	0.00	0.0	NA
Commercial refrigeration - Condensing units	0.29	-27.6	-96.3
Commercial refrigeration - Central systems	0.40	-44.1	-111.3
Industrial refrigeration - small	0.00	0.2	NA
Industrial refrigeration - large	0.00	0.0	NA
Transport refrigeration - Vans	0.00	0.0	NA
Transport refrigeration - Trucks & Trailers	0.00	0.0	NA
Transport refrigeration - Ships	0.00	0.0	NA
Room AC - Moveables	0.00	0.0	NA
Room AC - Single split	2.69	-127.7	-47.5
Room AC - Rooftop	0.01	-33.5	-4460.0
Room AC - VRF	0.10	-6.0	-61.2
Minichillers	0.00	0.0	NA
Displacement chillers - small	0.00	0.0	NA
Displacement chillers - large	0.00	0.0	NA
Centrifugal chillers	0.00	0.0	NA
Heat pumps - small	0.45	-204.3	-451.3
Heat pumps - medium	0.46	-338.3	-734.2
Heat pumps - large	0.00	0.0	NA
Mobile AC - Passenger cars	0.00	0.0	NA
Mobile AC - Buses	0.00	0.0	NA
Mobile AC - Trucks N1	0.00	0.0	NA
Mobile AC - Trucks N2	0.00	0.0	NA
Mobile AC - Trucks N3	0.00	0.0	NA
Mobile AC - Passenger ships	0.00	0.0	NA
Mobile AC - Cargo ships	0.00	0.0	NA
Mobile AC - Tram	0.00	0.0	NA
Mobile AC - Metro	0.00	0.0	NA
Mobile AC - Train	0.00	0.0	NA
Aerosols - technical	0.00	0.0	NA
Aerosols - MDIs	0.00	0.0	NA
Fire extinguishers	0.00	0.0	NA
Solvents	0.00	0.0	NA

Sector	Option 1		
	new equipment installed in 2050		
	lifetime-integrated emission reductions compared to baseline	Cost of technological change of lifetime-integrated emission reductions	Calculated emission reduction cost for technological change
	Mt CO_2e	Mio €	€ / t CO_2e
Foam OCF	0.00	0.0	NA
Foam XPS	0.00	0.0	NA
Foam PU spray	0.00	0.0	NA
Foam PU non-spray	0.00	0.0	NA
Switchgear MV	0.00	0.0	NA
Switchgear HV	0.00	0.0	NA
Total	**4.4**	**-781.1**	**-178.1**

Table 46. Option 2: Emission reduction cost, new equipment installed in 2024 – 2036 average

Sector	Option 2		
	new equipment installed, annual average 2024-2036		
	lifetime-integrated emission reductions compared to baseline	Cost of technological change of lifetime-integrated emission reductions	Calculated emission reduction cost for technological change
	Mt CO_2e	Mio €	€ / t CO_2e
Domestic Refrigeration	0.00	0.0	NA
Commercial refrigeration - Hermetics	0.00	-2.8	-2209.3
Commercial refrigeration - Condensing units	0.43	-54.1	-124.7
Commercial refrigeration - Central systems	0.83	-27.9	-33.6
Industrial refrigeration - small	0.15	0.7	4.6
Industrial refrigeration - large	0.05	1.9	40.1
Transport refrigeration - Vans	0.02	-2.4	-109.0
Transport refrigeration - Trucks & Trailers	0.13	-36.1	-285.5
Transport refrigeration - Ships	0.05	-0.2	-3.6
Room AC - Moveables	0.00	0.0	NA
Room AC - Single split	3.90	-168.3	-43.1
Room AC - Rooftop	0.48	26.4	54.5
Room AC - VRF	1.45	35.6	24.5
Minichillers	0.01	-19.9	-3955.8
Displacement chillers - small	0.02	0.5	21.6
Displacement chillers - large	0.25	4.2	16.6
Centrifugal chillers	0.00	-6.9	-2094.8
Heat pumps - small	0.76	-308.3	-408.0
Heat pumps - medium	0.42	-109.4	-260.5
Heat pumps - large	0.03	-13.2	-389.9
Mobile AC - Passenger cars	0.00	0.0	NA
Mobile AC - Buses	0.14	47.3	333.9
Mobile AC - Trucks N1	0.56	51.3	92.4
Mobile AC - Trucks N2	0.11	9.7	85.1
Mobile AC - Trucks N3	0.40	51.3	128.3
Mobile AC - Passenger ships	0.24	-21.7	-91.4
Mobile AC - Cargo ships	0.19	-16.3	-87.7
Mobile AC - Tram	0.01	2.6	219.1
Mobile AC - Metro	0.00	0.6	234.9
Mobile AC - Train	0.02	-28.5	-1809.3
Aerosols - technical	0.01	0.6	88.9
Aerosols - MDIs	2.42	2.1	0.9
Fire extinguishers	0.00	0.0	NA
Solvents	0.04	0.5	13.4

Sector	Option 2		
	new equipment installed, annual average 2024-2036		
	lifetime-integrated emission reductions compared to baseline	Cost of technological change of lifetime-integrated emission reductions	Calculated emission reduction cost for technological change
	Mt CO_2e	Mio €	€ / t CO_2e
Foam OCF	0.00	0.0	NA
Foam XPS	0.00	0.0	NA
Foam PU spray	0.00	0.0	NA
Foam PU non-spray	0.00	0.0	NA
Switchgear MV	0.16	53.0	335.8
Switchgear HV	0.53	26.6	50.2
Total	**13.8**	**-501.1**	**-36.3**

Table 47. Option 2: Emission reduction cost, new equipment installed in 2050

Sector	Option 2		
	new equipment installed in 2050		
	lifetime-integrated emission reductions compared to baseline	Cost of technological change of lifetime-integrated emission reductions	Calculated emission reduction cost for technological change
	Mt CO_2e	Mio €	€ / t CO_2e
Domestic Refrigeration	0.00	0.0	NA
Commercial refrigeration - Hermetics	0.00	0.0	NA
Commercial refrigeration - Condensing units	0.06	-49.8	-862.7
Commercial refrigeration - Central systems	0.40	-44.1	-111.3
Industrial refrigeration - small	0.05	-5.2	-102.5
Industrial refrigeration - large	0.00	0.1	141.5
Transport refrigeration - Vans	0.00	-2.4	-951.4
Transport refrigeration - Trucks & Trailers	0.04	-20.9	-483.5
Transport refrigeration - Ships	0.00	0.0	NA
Room AC - Moveables	0.00	0.0	NA
Room AC - Single split	3.58	-170.2	-47.5
Room AC - Rooftop	0.36	-231.3	-637.3
Room AC - VRF	1.19	-3.4	-2.8
Minichillers	0.01	-46.6	-7917.3
Displacement chillers - small	0.02	-0.4	-16.9
Displacement chillers - large	0.28	-6.2	-22.2
Centrifugal chillers	0.00	-8.6	-96505.5
Heat pumps - small	1.36	-612.8	-451.3
Heat pumps - medium	1.25	-394.5	-315.8
Heat pumps - large	0.00	0.0	NA
Mobile AC - Passenger cars	0.00	0.0	NA
Mobile AC - Buses	0.08	25.7	333.9
Mobile AC - Trucks N1	0.82	64.0	78.4
Mobile AC - Trucks N2	0.20	17.4	87.0
Mobile AC - Trucks N3	1.01	129.3	128.2
Mobile AC - Passenger ships	0.00	0.0	NA
Mobile AC - Cargo ships	0.00	0.0	NA
Mobile AC - Tram	0.01	0.5	94.0
Mobile AC - Metro	0.00	0.3	261.7
Mobile AC - Train	0.01	-31.0	-3035.9
Aerosols - technical	0.01	1.2	88.9
Aerosols - MDIs	2.84	32.5	11.4
Fire extinguishers	0.00	0.0	NA
Solvents	0.04	0.5	13.5

Sector	Option 2		
	new equipment installed in 2050		
	lifetime-integrated emission reductions compared to baseline	Cost of technological change of lifetime-integrated emission reductions	Calculated emission reduction cost for technological change
	Mt CO_2e	Mio €	€ / t CO_2e
Foam OCF	0.00	0.0	NA
Foam XPS	0.00	0.0	NA
Foam PU spray	0.00	0.0	NA
Foam PU non-spray	0.00	0.0	NA
Switchgear MV	0.55	186.1	335.8
Switchgear HV	1.86	164.4	88.4
Total	**16.0**	**-1005.2**	**-62.7**

Table 48. Option 3: Emission reduction cost, new equipment installed in 2024 – 2036 average

Sector	Option 3 new equipment installed, annual average 2024-2036		
	lifetime-integrated emission reductions compared to baseline	Cost of technological change of lifetime-integrated emission reductions	Calculated emission reduction cost for technological change
	Mt CO_2e	Mio €	€ / t CO_2e
Domestic Refrigeration	0.00	0.0	NA
Commercial refrigeration - Hermetics	0.00	-2.8	-2209.3
Commercial refrigeration - Condensing units	0.50	-68.8	-136.4
Commercial refrigeration - Central systems	1.08	-52.3	-48.4
Industrial refrigeration - small	0.15	0.7	4.6
Industrial refrigeration - large	0.05	1.9	40.1
Transport refrigeration - Vans	0.03	-4.8	-153.4
Transport refrigeration - Trucks & Trailers	0.16	-62.2	-376.9
Transport refrigeration - Ships	0.07	-0.3	-3.6
Room AC - Moveables	0.00	0.0	NA
Room AC - Single split	3.90	-168.3	-43.1
Room AC - Rooftop	0.48	26.4	54.5
Room AC - VRF	1.45	35.6	24.5
Minichillers	0.01	-19.9	-3955.8
Displacement chillers - small	0.02	0.5	21.6
Displacement chillers - large	0.25	4.2	16.6
Centrifugal chillers	0.00	-6.9	-2094.8
Heat pumps - small	0.76	-308.3	-408.0
Heat pumps - medium	0.42	-109.4	-260.5
Heat pumps - large	0.03	-13.2	-389.9
Mobile AC - Passenger cars	0.00	0.0	NA
Mobile AC - Buses	0.26	119.1	457.1
Mobile AC - Trucks N1	0.87	75.8	87.3
Mobile AC - Trucks N2	0.19	15.8	83.5
Mobile AC - Trucks N3	0.96	122.6	127.9
Mobile AC - Passenger ships	0.33	-32.2	-98.8
Mobile AC - Cargo ships	0.22	-19.5	-89.2
Mobile AC - Tram	0.01	2.9	204.6
Mobile AC - Metro	0.00	1.2	402.5
Mobile AC - Train	0.02	18.2	1030.2
Aerosols - technical	0.01	0.6	88.9
Aerosols - MDIs	2.42	2.1	0.9
Fire extinguishers	0.00	0.0	NA
Solvents	0.04	0.5	13.4

Sector	Option 3		
	new equipment installed, annual average 2024-2036		
	lifetime-integrated emission reductions compared to baseline	Cost of technological change of lifetime-integrated emission reductions	Calculated emission reduction cost for technological change
	Mt CO_2e	Mio €	€ / t CO_2e
Foam OCF	0.00	0.0	NA
Foam XPS	0.00	0.0	NA
Foam PU spray	0.00	0.0	NA
Foam PU non-spray	0.00	0.0	NA
Switchgear MV	0.16	53.0	335.8
Switchgear HV	0.53	26.6	50.2
Total	**15.4**	**-361.2**	**-23.4**

Table 49. Option 3: Emission reduction cost, new equipment installed in 2050

Sector	Option 3 new equipment installed in 2050		
	lifetime-integrated emission reductions compared to baseline	Cost of technological change of lifetime-integrated emission reductions	Calculated emission reduction cost for technological change
	Mt CO_2e	Mio €	€ / t CO_2e
Domestic Refrigeration	0.00	0.0	NA
Commercial refrigeration - Hermetics	0.00	0.0	NA
Commercial refrigeration - Condensing units	0.00	-46.4	-22822.8
Commercial refrigeration - Central systems	0.40	-44.1	-111.3
Industrial refrigeration - small	0.05	-5.2	-102.5
Industrial refrigeration - large	0.00	0.1	141.5
Transport refrigeration - Vans	0.00	-4.7	-951.4
Transport refrigeration - Trucks & Trailers	0.09	-41.7	-483.5
Transport refrigeration - Ships	0.00	0.0	NA
Room AC - Moveables	0.00	0.0	NA
Room AC - Single split	3.58	-170.2	-47.5
Room AC - Rooftop	0.36	-231.3	-637.3
Room AC - VRF	1.19	-3.4	-2.8
Minichillers	0.01	-46.6	-7917.3
Displacement chillers - small	0.02	-0.4	-16.9
Displacement chillers - large	0.28	-6.2	-22.2
Centrifugal chillers	0.00	-8.6	-96505.5
Heat pumps - small	1.36	-612.8	-451.3
Heat pumps - medium	1.25	-394.5	-315.8
Heat pumps - large	0.00	0.0	NA
Mobile AC - Passenger cars	0.00	0.0	NA
Mobile AC - Buses	0.28	148.6	529.8
Mobile AC - Trucks N1	0.82	64.0	78.4
Mobile AC - Trucks N2	0.20	17.4	87.0
Mobile AC - Trucks N3	1.07	136.9	128.1
Mobile AC - Passenger ships	0.00	0.0	NA
Mobile AC - Cargo ships	0.00	0.0	NA
Mobile AC - Tram	0.01	0.5	94.0
Mobile AC - Metro	0.00	0.9	822.4
Mobile AC - Train	0.01	21.7	2111.0
Aerosols - technical	0.01	1.2	88.9
Aerosols - MDIs	2.84	32.5	11.4
Fire extinguishers	0.00	0.0	NA
Solvents	0.04	0.5	13.5

Sector	Option 3		
	new equipment installed in 2050		
	lifetime-integrated emission reductions compared to baseline	Cost of technological change of lifetime-integrated emission reductions	Calculated emission reduction cost for technological change
	Mt CO_2e	Mio €	€ / t CO_2e
Foam OCF	0.00	0.0	NA
Foam XPS	0.00	0.0	NA
Foam PU spray	0.00	0.0	NA
Foam PU non-spray	0.00	0.0	NA
Switchgear MV	0.55	186.1	335.8
Switchgear HV	1.86	164.4	88.4
Total	**16.3**	**-841.2**	**-51.7**

A12.5 Emission reduction costs baseline scenario

Table 50. Equipment operators baseline compliance cost at sector level, 2024 – 2036 average (costs difference to the counterfactual scenario assuming no 2014 F-gas Regulation revision)

Sector	baseline scenario			
	total baseline compliance cost vs counterfactual scenario assuming no 2014 F-gas Regulation revision		**thereof: additional cost of HFC price increase**	**thereof: cost of technological change (= net compliance cost)**
	Mio EUR/a	**% of counterfactual totex**	**Mio EUR/a**	**Mio EUR/a**
Refrigeration	754.1	2.3%	634.6	119.5
Stationary A/C	845.0	0.7%	976.2	-131.2
Mobile A/C	611.2	2.1%	453.0	158.1
Propellants, solvents & fire protection	74.3	0.0%	36.0	38.3
Foam	56.8	16.0%	0.9	55.9
Other HFCs	0.0	NA	0.0	0.0
SF_6	0.0	0.0%	0.0	0.0
Total	**2341.3**	**0.3%**	**2100.8**	**240.5**

Table 51. Equipment operators' baseline compliance cost at sector level, 2050 (costs difference to the counterfactual scenario assuming no 2014 F-gas Regulation revision)

Sector	baseline scenario			
	total baseline compliance cost vs counterfactual scenario assuming no 2014 F-gas Regulation revision		thereof: additional cost of HFC price increase	thereof: cost of technological change (= net compliance cost)
	Mio EUR/a	% of counterfactual totex	Mio EUR/a	Mio EUR/a
Refrigeration	-388.1	-1.2%	88.3	-476.4
Stationary A/C	-1193.3	-0.5%	849.6	-2042.9
Mobile A/C	584.1	3.3%	381.1	203.0
Propellants, solvents & fire protection	95.5	0.0%	62.1	33.4
Foam	54.6	15.3%	0.0	54.6
Other HFCs	0.0	NA	0.0	0.0
SF_6	0.0	0.0%	0.0	0.0
Total	**-847.2**	**-0.1%**	**1381.1**	**-2228.3**

A12.6 Energy use

Table 52. EU-27 final annual energy use savings in the refrigeration & AC (RAC) sector between 2024-2036 (average) and in 2050 for the 3 policy options compared to the baseline (changes in GWh/a and percentage)

Sector	Unit	time horizon	Option 1	Option 2	Option 3
Refrigeration	GWh per year		-0.1	0.7	0.9
	% of baseline	2024- 2036 average	-0.1%	0.4%	0.6%
Stationary A/C	GWh per year		-0.8	1.6	1.4
	% of baseline	2024- 2036 average	-0.1%	0.2%	0.2%
Mobile A/C	GWh per year		0.0	0.3	0.5
	% of baseline	2024- 2036 average	0.0%	0.3%	0.6%
Total RAC sector	**GWh per year**	**2024- 2036 average**	**-0.9**	**2.5**	**3.0**
	% of baseline		**-0.1%**	**0.3%**	**0.3%**
Total RAC sector	***GWh per year***	***2050***	***2.3***	***8.2***	***9.1***
	% of baseline		***0.1%***	***0.5%***	***0.5%***

Source: *AnaFgas modelling*

A13 Detailed modelling results of GEM-E3

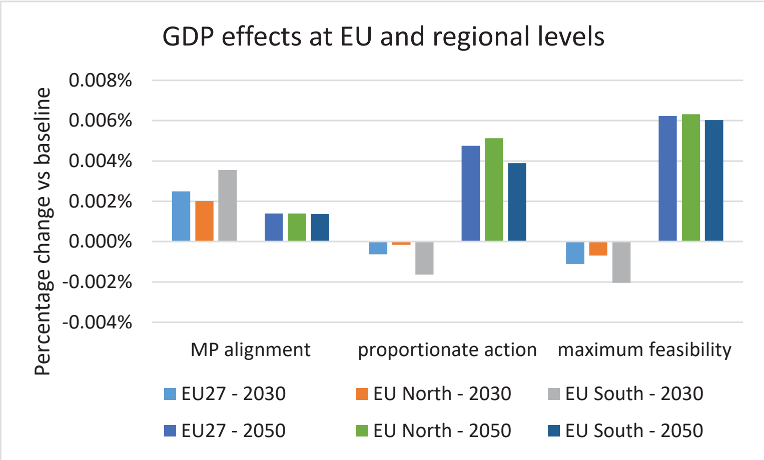


Figure 32. Effects of the Options on GDP

Note: EU South: Bulgaria, Croatia, Cyprus, France (25% of model results for France), Greece, Italy, Malta, Portugal, Romania, Spain; EU North: other EU27 MS, including 75% of model results for France.
“MP alignment” is Option 1, “proportionate action” is Option 2, “maximum feasibility” is Option 3

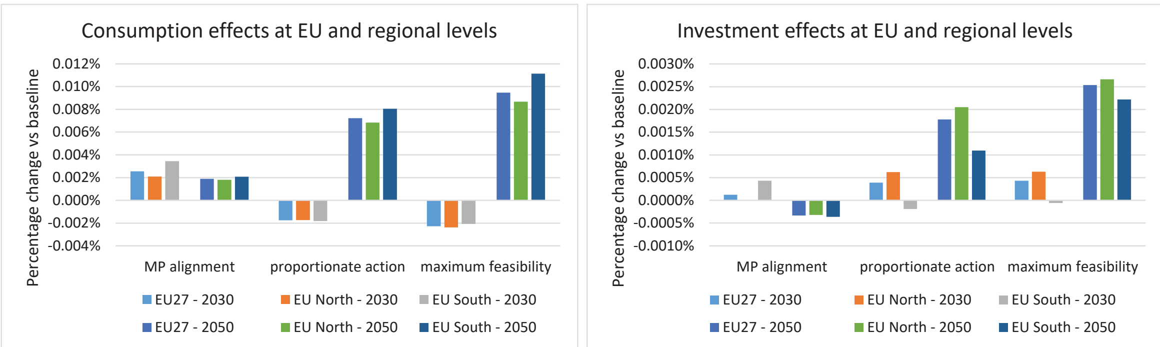


Figure 33: Consumption and investment effects

Note: EU South: Bulgaria, Croatia, Cyprus, France (25% of model results for France), Greece, Italy, Malta, Portugal, Romania, Spain; EU North: other EU27 MS, including 75% of model results for France.
“MP alignment” is Option 1, “proportionate action” is Option 2, “maximum feasibility” is Option 3

Table 53. Effects for the ‘other equipment goods’ sector, policy options in comparison to the baseline

indicator	time horizon	baseline		percentage change vs baseline		
				Option 1	Option 2	Option 3
output	2030	714.5	bn USD 2014	-0.14%	0.13%	0.15%
imports	2030	55.5	bn USD 2014	-0.19%	0.19%	0.22%
exports	2030	83.7	bn USD 2014	0.01%	-0.02%	-0.03%
investment	2030	33.9	bn USD 2014	-0.14%	0.13%	0.15%
employment	2030	5335	thousand persons	-0.14%	0.12%	0.15%
output	2050	924.1	bn USD 2014	0.09%	0.19%	0.20%

imports	2050	81.8	bn USD 2014	0.13%	0.44%	0.46%
exports	2050	134.7	bn USD 2014	0.00%	-0.13%	-0.14%
investment	2050	43.3	bn USD 2014	0.09%	0.20%	0.20%
employment	2050	4786	thousand persons	0.09%	0.19%	0.19%

A14 Detailed information on administrative costs

A14.1 Costs to industry – current Regulation

Table 53 below shows the estimated additional administrative costs per relevant measure required to ensure compliance with the Regulation. It also explains the feedback received, and the assumptions and expert guesses made in order to arrive at an estimate of total cost per measure.

Table 54. Administrative costs for industrial stakeholders under the current Regulation

Measure	Action	Overlap with Costs Included in Mitigation Model	Impact on costs relative to the 2006 Regulation as determined by stakeholder feedback	Estimated number of Companies Impacted	Average Working Days Reported per annum	Estimated Total Sector Working Days	Total Cost (EUR, M)
Record Keeping (Article 6)	Record keeping for each piece of leak-checked equipment New requirement for refrigerated trucks and trailers and ORCs included in the 2014 F-gas Regulation	No	Increase in Costs: 4 Responses No Change/significant impact: 1 Response It has been noted within stakeholder feedback that the costs attributed to this measure have not necessarily diverged from the costs incurred as a result of the 2006 Regulation. The costs provided through stakeholder feedback have been adjusted to take into account that the 2014 Regulation represented an increase in scope of record keeping only.	The extension of scope of the 2006 Regulation will require truck and trailer operators to oblige with the requirement on record keeping. The total number of companies impacted has been derived from the number of refrigerated trucks and trailers operated within the EU. The number has been derived based upon the total number of registrations of refrigerated trailers in Germany, France, Spain and Poland in 2016, as referred to in the ICCT[102]. Based upon the proportion of semi-trailers which are known to be refrigerated (based upon ICCT figures), a total number of refrigerated trailers has been estimated. Using population sizes, this figure has been extrapolated to provide an estimate for the total number of refrigerated trailers in the EU. Total: 25,752	Range reported by stakeholders (Excluding outliers): 5-20 days pa Average (Excluding outliers): 8 days per large company pa The above costs determined through stakeholder feedback for large stationary RAC companies have been reduced to be relevant for the sector of trucks and trailers only (estimated to be approximately 0.5 day per year). The costs have been applied equally across all sized firms.	12,900 p.a.	3

[102] https://theicct.org/sites/default/files/publications/EU_Trailer_Market_20180921.pdf

Training and Certification (Article 10)	Attending training programmes Completion of theoretical and practical tests (examination) Receiving personal certificates or company certificates	No	Increase in Costs: 1 Responses No Change/significant impact: 3 Responses	The total number of companies impacted has been based upon the number of companies which are required to ensure their employees (technicians for specialised refrigerated trucks and trailers) attend the appropriate training course.. Although the exact number is uncertain, based upon expert judgment this is expected to be approximately 5% of the number of service companies in the RACHP sector (derived from a survey by AREA).	Range reported by stakeholders (Excluding outliers): 5-10 days pa Average (Excluding outliers): 8 days per large company pa However, as the stakeholder costs include the costs of attending training, which is considered a compliance cost, the costs have been revised down based on expert judgement of the administrative burden. Values for small and medium companies (scaled down by reporting thresholds): Small: 0.5day pa Medium: 1 day pa Large: 2	9,400 p.a.	2.2

Labelling and product and equipment information (Article 12)	Labelling of F-gas containers Labelling of products or equipment containing or relying on F-gases	No	Increase in Costs: 6 Responses No Change/significant impact: 2 Responses	The extended labelling requirements (relative to the 2006 Regulation) concern few adjustments and more details. The extension is expected to impact producers labelling F-gas containers and equipment manufacturers. The number of companies has been derived from the number of bulk producers, importers and equipment importers as provided in the 2020 EEA report. Additionally, an estimate of the number of companies manufacturing equipment within the EU has been included. Given costs will vary with levels of activity, this has then been split by size according to the split of companies in the EEA reporting database. Total: 4,699 Large: 36 Medium: 191 Small: 4,455	The administrative cost has been determined through analysis of stakeholder feedback. Due to the high average cost reported through feedback, and the known costs already incurred as a result of the 2006 Regulation, expert judgement has been used to support the final cost estimation. It should also be noted that the costs are closely related to those incurred as a result of CLP or REACH Regulations. Average cost (large company): 1 days per annum Values for small and medium companies (scaled down by reporting thresholds): Small: 0.25 day pa Medium: 0.5 day pa	1,245 p.a.	0.3

Admin costs linked to documenting compliance for pre-charged equipment with HFCs . HFC equipment importers (EEA) - EU equipment manufacturers.	Documentation of compliance and drawing up a declaration of conformity Verification of documentation and declaration of conformity by an independent auditor Registering in the electronic HFC registry	No (if costs relate to registering & managing transactions in the registry. Cost for authorisations purchases etc are captured in technical cost modelling)	Increase in Costs: 3 Responses No Change/significant impact: 1 Response	The number of companies impacted has been based upon the number of equipment importers as registered through the HFC registry. In addition, the number of EU equipment manufacturers (estimated based upon expert judgement) will also be impacted. Total: 2,900 Given costs will vary with levels of activity, this has then been split by size according to the split of companies in the EEA reporting database. Large:22 Medium:118 Small: 2,749	Range reported by stakeholders (Excluding outliers): 1-40 days pa Average (Excluding outliers): 27 days per large company pa The costs for medium sized companies is expected to be approximately half of the costs of large companies. The costs incurred by smaller companies is expected to be a quarter of those incurred by large companies.	20,749 p.a.	4.77
Admin costs linked to Complying with the HFC phase-down and quota system (Article 15 + Article 16 + Annex V + Annex VI) and registration in the HFC Registry (Article 17) and its use for quota management and transfer.*	Applying for HFC quota/declaring quota need Transfer of HFC quota and/or quota authorisations (excl. purchase price) Registering in the electronic HFC registry	No (if costs relate to registering & managing transactions in the registry. Cost for quota purchases etc are captured in technical cost modelling)	Increase in Costs: 8 Responses	Quotas are required for the import and production of bulk HFC's. The number of bulk importers (1694) and F-gas producers as reported for the year 2019 in the EEA report on fluorinated greenhouse gases 2020. Total: 1701 Given costs will vary with levels of activity, this has then been split by size according to the split of companies in the EEA reporting database. Large: 13 Medium: 69 Small: 1,613	Range reported by stakeholders (Excluding outliers): 1-50 days pa Average (Excluding outliers): 15 days per large company pa The costs for medium sized companies is expected to be approximately half of the costs of large companies. The costs incurred by smaller companies is expected to be a quarter of those incurred by large companies.	6,709 p.a.	1.54

Reporting and verification*	Preparation of the annual F-gas report Verification of the F-gas report by an independent auditor Submission of the F-gas report and the verification report through the Business Data Repository (BDR)	No	Increase in Costs: 7 Responses No Change/significant impact: 1 Response	The number of companies impacted has been aggregated based upon four criteria: - Number of equipment importers operating above the threshold of > 100 t CO2e (1024) - Number of bulk importers required to report (1694) - Number of bulk importers operating above > 10000 t CO2e requiring verification (179) - Number of bulk exporters require to report (112) Total: 3,009 Given costs will vary with levels of activity, this has then been split by size according to the split of companies in the EEA reporting database. Large: 23 Medium: 122 Small: 2,853	Range reported by stakeholders (Excluding outliers): 5-30 days pa Average (Excluding outliers): 13 days per large company pa The costs for medium sized companies is expected to be approximately half of the costs of large companies. The costs incurred by smaller companies is expected to be a quarter of those incurred by large companies.	10,499 p.a.	2.4
Total						**61,540**	**14,1**

In addition to the administrative costs outlined in the table above, stakeholders were also asked to provide feedback on the costs associated with the measures related to Articles 3, 7 and 8, some of which are rather adjustment costs then administrative costs. The costs for these measures are not captured in the AnaFGas costs.

Table 55. Additional adjustment costs to Industry (not covered by the AnaFGas modelling)

Measure	Action	Impact on costs relative to the 2006 Regulation as determined by stakeholder feedback	Range of estimated Cost Per Company (Based on Stakeholder Feedback)	Number of companies impacted	Total Cost [million €]
Prevention of F-gas emission (Articles 3 & 7)	Preventing emissions from production	Increase in Costs: 7 Responses No Change/significant impact: 1 Response To note responses also considered costs incurred as a result of Article 3	Cost per company has been estimated at approximately 3.5 days per year based on stakeholder feedback of combined costs for Article 3 and Article 7 and understanding of the sector	The costs associated with Article 7 are expected to impact approximately 1700 companies. This has been based upon the known number of importers of bulk gases, as determined by the 2020 EEA report[103]	0.4
Recovery of F-gases (Article 8)	Carrying out recovery of F-gases from equipment by a certified person so that those gases are recycled, reclaimed or destroyed The requirement existed in the 2006 F-gas Regulation for most sectors. Additional provision was introduced in the 2014 Regulation for refrigerated trucks and trailers	Increase in Costs: 7 Responses No Change/significant impact: 1 Response	5 – 10 days/year (excluding outliers and based upon three stakeholders) Average cost (Large RAC company): 7 days/year However, for refrigerated trailer operators specifically the costs have been revised downward and are estimated to be approximately 1 days per year.	. The number of companies has been set to the equivalent as the number of companies impacted by Article 6 'Record keeping'. The costs have been adjusted down to take into consideration that the measure is only an extension. The cost will only impact the refrigerated trucks and trailers sector.	5.9

103 https://www.eea.europa.eu/publications/fluorinated-greenhouse-gases-2020

A14.2 Costs to industry – policy options

Table 56. Results and detail on the calculations and assumptions regarding administrative costs to industry

Policy Measure	Scenario	Number of companies	Days/Year per Company	Total Days (Annual)	Total Days (One-off)	Total Annual Cost (EUR,M)	Total One Off Cost (EUR, M)	Explanation
Apply requirements for prevention of emissions of fluorinated gases to some substances listed in Annex II and some new substances	Policy Options 2 and 3	Total: 13,075 Similar effort assumed for large and small companies	Large: 1 Medium: 1 Small: 1	N/A	13,075	-	3	The policy measure is associated with 'Article 3 (Prevention of emissions)' and the costs are therefore expected to be predominately compliance costs. The number of companies impacted will be based upon the number of users of SO_2F_2, anesthetics, NF_3 and HCFOs. The bulk of the users are related to the use of anesthetics. Based on data reported by the European Hospital and Healthcare Foundation, there are approximately 2.9 hospitals per 100,000 inhabitants. Based upon the current population of the EU this would equate to approximately 13,000 hospitals. The use of SFOF2 (predominately logistics companies for wood storage and fumigation), NF_3 (solar /PV energy and semi-conductor industry) and HCFOs (EV battery cooling) represent only a small number of additional EU users concerned, estimated to be approximately 50 – 100. A small one-off administrative cost is expected to determine any requirements necessary to prevent a leakage of emissions. This cost is expected to be approximately 1 day, and will be consistent across all users regardless of size. There are not expected to be any ongoing reporting requirements associated with the policy measure.
Apply requirements for prevention of emissions of F-gases to manufacturing, transport, transfer and storage of bulk gases also to non-producers	Policy options 2 and 3	Total: 19,016 Large: 1711 Medium: 380 Small: 16,925 Similar effort assumed for large and small	Large: 1 Medium: 1 Small: 1	19,016	-	4.4	-	As a result of the policy measure, the requirement will be extended to service companies, importers and distributors. Although the measure will be a legal requirement, it is already considered to be best practice within industry, and therefore it is estimated that approximately 85% of relevant companies will not be impacted. The number of service companies has been based on a survey by AREA and complementary information from MS authorities. The number of importers has been based upon EEA BDR reporting, and the number of distributors through expert judgement of the sector. The administrative burden has been estimated to be approximately 1 day linked to identifying

Policy Measure	Scenario	Number of companies	Days/Year per Company	Total Days (Annual)	Total Days (One-off)	Total Annual Cost (EUR,M)	Total One Off Cost (EUR, M)	Explanation
		companies						and regular checking of processes in place to avoid emissions. The breakdown of company size has been based upon a German industrial survey determining the number of employees at German service operators.
Remove the limit for reporting on production, import, export and destruction of Annex I and II gases (HFCs only)	All options	Total: 100 Large:1 Medium:4 Small:95 Similar effort assumed for large and small companies	1 day	100	-	0.02	-	The removal of the reporting limit is expected to impact approximately 100 companies. This is based upon checks conducted by of the Polish CBR database for imports/exports for which no threshold applies. This search yielded no entries which were below the current threshold definition. Production & destruction below the threshold are very unlikely (as those who operate such facilities have higher amounts per year). It has therefore been concluded that there will be a very low number of affected companies: Those companies affected would be those which buy a few bottles per year abroad. The policy change would require these additional companies to now submit an additional report, with an expected additional administrative burden of approximately one day expected, based upon current reporting costs and the fact that the report will consist of very little input data.
F-gas certification programmes also to include HCFOs and F-gas free alternatives and practical training on all alternatives and add energy efficiency issues to be part of training (stationary RACHP)	Policy Options 2 and 3	Total:125,649 Large: 1,425 Medium: 5,101 Small: 119,122	Large: 6 Medium: 2 Small: 0.6	90,225		20.8		The number of companies impacted is based upon the number of company certificates in the RACHP sector as determined by a survey by AREA and complementary information from MS authorities. Certification will become more expensive for those companies that wish to train their personnel in the future, as the training is more extensive (practical training) and the scope is wider. **The costs determined here are related to having personnel trained. These costs are considered adjustment costs.** Large companies are expected to train 3 employees per year, medium sized companies 1 and small companies between 0 – 1 employee. These extra costs may also be regarded as adjustment costs and following the training is not explicitly required, only certification is.
F-gas certification programmes also to include HCFOs and F-	Policy Options 2 and 3	Total:125,649 Large: 1,425	0.2 (a couple hours per	25,130		5.8		The number of companies impacted is based upon the number of company certificates in the RACHP sector as determined by a survey by AREA and complementary information from MS

Policy Measure	Scenario	Number of companies	Days/Year per Company	Total Days (Annual)	Total Days (One-off)	Total Annual Cost (EUR,M)	Total One Off Cost (EUR, M)	Explanation
gas free alternatives and practical training on all alternatives and add energy efficiency issues to be part of training (stationary RACHP)	(energy efficiency also included on Option 1)	Medium: 5,101 Small: 119,122	company only)					authorities. The current administrative costs linked to certification are based upon data collected through stakeholder engagement for the evaluation of the Regulation. Certification will become more expensive for those companies that wish to train their personnel in the future, as the training is more extensive (practical training) and the scope is wider. **The costs determined here are only the true admin costs related to obtaining and presenting certificates**. The requirement to install etc. stationary RAC only by certified personnel only has an additional bearing if such equipment holds pure HCFOs, rather than HFC blends with HCFOs which are already covered by today's obligations. This is the case in very few applications. The administrative cost linked to energy efficiency issues are expected to be very minor as this will entail only an additional aspect of the training curriculum.
General prohibition of entry into EU territory of non-refillable F-gas containers and other illegal goods under the Regulation and extend the scope to unsaturated HFCs	All policy options	Total: 204 Large: 2 Medium: 8 Small: 193 Similar effort assumed for large and small companies	Large: 1 Medium:1 Small:1	204	-	0.05	-	Administrative burden for those respecting the rules and using best practice as importers will not be impacted as companies should be using re-fillable cylinders for HCFOs already. The number of companies impacted has been based upon the number of bulk importers registered in 2019 based on BDR reporting. It has been estimated that approximately 5% of importers are not currently conducting best practice for HCFOs and will therefore incur additional administrative cost. The admin burden upon these companies is expected to be minimal.
Mandatory certification for bulk gas importers	Only Policy Option 3	Total:1694 Large: 19 Medium: 69 Small:1606	Annual: 0.2 (a couple hours per company only) One Off: Large:10 Medium: 8 Small: 6	847	10378	0.18	2.3	As noted in Commission Implementing Regulation EU 2015/2067 there are currently four categories relating to environment-friendly handling of the system and refrigerant during installation, maintenance, servicing or recovery and leakage checks. The policy option will require company compliance with category III. The number of companies involved in importing HFCs are taken from the Fgas Portal & HFC Licensing System. The administrative costs linked to certification are be based upon data collected through stakeholder engagement for the evaluation of the Regulation.

Policy Measure	Scenario	Number of companies	Days/Year per Company	Total Days (Annual)	Total Days (One-off)	Total Annual Cost (EUR,M)	Total One Off Cost (EUR, M)	Explanation
Add obligation for certification for natural persons and undertakings selling bulk F-gases online	Only Policy Option 3	Total: 500 Large:7 Medium: 20 Small: 473	Annual: 0.2 (a couple hours per company only) One Off: Large:10 Medium: 8 Small: 6	100	3063	0.02	0.7	As noted in Commission Implementing Regulation EU 2015/2067 there are currently four categories relating to environment-friendly handling of the system and refrigerant during installation, maintenance, servicing or recovery and leakage checks. The policy option will require company compliance with category III. The number of companies involved in selling F-gases online has been based upon desk-based research through examining the number of sellers on sites such as Alibaba. The administrative costs linked to certification are be based upon data collected through stakeholder engagement for the evaluation of the Regulation.
Add obligation for documentation for downstream sales for bulk HFC/F-gases (e.g. “declaration of conformity”) and record keeping	Only Policy Option 3	Calculated based upon costs to German industry rather than to specific companies.	n/a	1641	-	0.38	-	The policy option is expected to lead to an increase in administrative costs across all actors in the supply chain, including service companies and gas distributors. As a result of the policy option, additional administrative costs are anticipated as a result of the need for companies to submit further documentation. The estimated costs have been based upon costs estimated for German industry, as this requirement has been previously adopted by the German government. The costs have been attributed to bureaucratic costs from information obligations and estimated to be an annual cost of 70,000 EUR. The costs for the German economy have been extrapolated across the EU based upon population size to give an estimated total annual cost of 377,500 EUR. This is the equivalent of 1,641 days per year a rate of 230 EUR per day.
Add requirement for producers and importers to be registered and hold sufficient quota at the time of release for free circulation/placing on the market / physical entry into territory	All Options	Total: 1694 Large: 19 Medium: 69 Small:1606 Similar effort assumed for large and small companies	Large:1 Medium: 1 Small: 1	1694	-	0.39	-	The policy option will require exporters and importers to schedule trade to ensure that their quotas are not exceeded. This could, for instance, lead to a delay in importing (to ensure the correct amount has been exported) and a subsequent administrative cost will be associated with ensuring this is planned properly. The number of companies impacted has been based upon the number of reporting bulk importers in 2020 as determined through the BDR database. The administrative impact of undertaking the additional planning is expected to be approximately 1 day, regardless of company size.

Policy Measure	Scenario	Number of companies	Days/Year per Company	Total Days (Annual)	Total Days (One-off)	Total Annual Cost (EUR,M)	Total One Off Cost (EUR, M)	Explanation
Add obligation for importers to have quota-exempted quantities labelled during POM/physical entry into territory and that gases must be explicitly labelled as "exempted from quota"	All Options	Total: 65 Similar effort assumed for large and small companies	Large:1 Medium: 1 Small: 1	65	-	0.02	-	The policy option will extend the labelling requirements for importers. As importers are already required to comply with labelling requirements, the policy is expected to lead to only a minimal additional burden for companies based upon additional labelling requirements for exempted gases. The requirement is expected to impact approximately 65 companies dealing with exempted gases (from F-gas Portal & HFC Licensing System)
Strengthen the obligation on destruction of HFC-23 by-production	Options 2 & 3	Total:1694 Large: 19 Medium: 69 Small:1606	Large:2 Medium: 0.5 Small: 0.3	552	-	0.1	-	The policy option will lead to a small additional administrative burden for importers as additional information will be required to be provided. The administrative burden of this policy is however expected to be small to companies compliant with existing rules and will require only outlining additional information to document compliance.
Align the establishment of the annual declaration-based quota allocation with the frequency of the quota allocation based on reference values	All Options	Total: 1800 Large:20 Medium: 73 Small: 1707 Similar effort assumed for large and small companies	Large: 3 Medium: 3 Small: 3	-5,400		-1.2	-	Annual quota application requirements will be required once every three years, leading to a reduction in administrative burden for reporting companies. This will lead to a reduction in administrative for the estimated 1800 current quota holders. Based upon stakeholder and an understanding of the expected cost of the measure a time saving of 3 days per year is expected.
Introduction of a registration fee and/or quota allocation price linked to CO2 equivalents	Options 2 & 3	Total: 2,000 Large: 23 Medium: 81 Small: 1,896	Large:5 Medium: 3 Small: 1`	2,253		0.5		The admin burden is linked to the requirements for companies having to pay for their quota. The number of companies impacted is estimated to be 2000 quota companies. The admin burden is linked to internal administrative work including arrangements to transfer relevant fees.
Registration and reporting obligation for exporters of products and equipment containing	Only Option 3	Total: 2,000 Large: 23 Medium: 81 Small: 1,896	Large:15 Medium: 4 Small:1	1,581	-	0.4	-	Based on expert judgement a significant number of companies are expected be impacted by the policy option, with an estimate of 2000 companies expected to be impacted, similar to importers. The costs of registration and reporting are estimated based on stakeholder feedback indicating the number of days required for

Policy Measure	Scenario	Number of companies	Days/Year per Company	Total Days (Annual)	Total Days (One-off)	Total Annual Cost (EUR,M)	Total One Off Cost (EUR, M)	Explanation
F-gases and other fluorinated substances								reporting under article 19.
Labelling requirements for H(C)FOs, NF3, SO_2F_2, anesthetics; as well as MDIs	Options 2 and 3	Total: 30 Large: 30	Large: Medium: Small Not applicable	60		0.01		Extending the labelling requirements for the gases HFCOs, NF_3, SO_2F_2, anesthetics as well as MDIs will lead to an increase in administrative costs for a small number of producers and importers. The production and importation of these gases is considered relatively uncommon, with, for example, only one producer for SO_2F_2 known to reside within the EU. The additional costs are therefore expected to impact approximately 30 companies, all of which would be expected to be rather large. The administrative cost associated with the labelling requirements has been based upon stakeholder feedback for labelling costs as collected through stakeholder consultation for the evaluation of the Regulation.
Reporting obligation for recipients of quota-exempted HFCs	Options 2 & 3	Total: 65 Large: 45 Medium: 13 Small: 7	Large:4 Medium: 1 Small:0.5	196.5	-	0.04	-	The additional requirement is expected to impact approximately 65 companies based upon reporting assessed in the EEA's BDR database. The administrative burden is expected to be minimal, with a small report required only. The breakdown of companies by size has been based upon expert judgement of the sector, and knowledge that the majority of the companies impacted will be large.
Reporting obligation for undertakings performing reclamation of F-gases	Options 2 & 3	Total: 50 Large:35 Medium:10 Small:5	Large:2 Medium: 1 Small: 0.5	83	-	0.02	-	The policy option will lead to an increased admin burden for both companies reporting on reclamation. In terms of companies reporting on reclamation it is estimated that approximately 50 companies will be affected, based upon expert judgement. An annual administrative cost of approximately 1 day per year is expected to account for the additional reporting for a medium sized company. Reclamation companies can be assumed to have already in place an internal monitoring system on the data to be reported. The breakdown of companies by size has been based upon expert judgement of the sector, and knowledge that the majority of the companies impacted will be large.
Reporting obligation for undertakings performing recycling of F-gases	Only Option 3	Total: 750 Large: 9 Medium: 30	Large:5 Medium: 3 Small: 1	845	-	0.2	-	A larger number of companies reporting on recycling will be impacted (vs. those doing reclamation), with an estimate of 750 companies expected to be impacted, based upon the current number of certified technicians and expert judgement. The

Policy Measure	Scenario	Number of companies	Days/Year per Company	Total Days (Annual)	Total Days (One-off)	Total Annual Cost (EUR,M)	Total One Off Cost (EUR, M)	Explanation
		Small: 711						administrative costs are expected to include both the annual reporting costs and also a small implementation report linked to the collection requirements. The annual cost for recycling companies is expected to be higher than for reclamation and has been based upon expert judgement of the sector.
Reporting obligation for operators of HV switchgear and electrical equipment (< 52 kV) with regard to SF_6 emissions during lifetime and for operators in cooperation with certified personnel of electrical equipment for decommissioning of such equipment	Only Option 3	Total: 2475 Large:28 Medium:100 Small:1016	Large:5 Medium: 3 Small: 1	2788	-	0.6	-	The administrative burden will apply to the switchgear sector and decommissioning companies. In addition, the policy will also impact distribution grid operators. Based on expert judgement there is expected to be a 5 day/year administrative burden associated with this requirement for a large sized company. The administrative burden is primarily associated with the installation of new equipment which will now need to be accounted for. The switchgear sector is estimated to account for approximately 50 - 100 companies, and 2400 distribution grid operators.
Lower the threshold for verification of bulk HFCs placed on the market	All Options	Total: 1,072 Large: 12 Medium: 44 Small: 1,016	Large: 6 Medium: 4 Small: 2	2295	-	0.5	-	The current threshold has been set at >10,000t CO2e, with the threshold set to be lowered to >1,000t CO2e. The current number of companies impacted is estimated to be 19% of quota holders (estimated to be 19% of 1800 companies). Following the reduction of the threshold, the number of companies impacted is expected to increase to 86% of quota holders. It should also be noted that approximately 134 companies are known to be voluntarily reporting in 2020, and therefore the potential additional cost to these companies has been removed as they are already incurring the burden. The additional costs for the companies impacted is estimated to be 1000 - 3000 EUR per year (based on feedback collected through consultation with an auditor) which has been converted into days per year based on a rate of 230 EUR per day.
Add obligation to submit verification reports for bulk HFCs	All Options	Total: 1694 Large: 19 Medium: 69 Small: 1606	Large: 0.5 Medium: 0.5 Small: 0.5	847	-	0.2	-	The obligation to record the information is already included within the current Regulation and therefore the obligation to submit this will only lead to a small increase in administrative burden. Based on current reporting companies this will be estimated to impact approximately 2000 companies.

Policy Measure	Scenario	Number of companies	Days/Year per Company	Total Days (Annual)	Total Days (One-off)	Total Annual Cost (EUR,M)	Total One Off Cost (EUR, M)	Explanation
		Cost are assumed to be similar for large and small companies						
Align reporting and authorization thresholds for placing pre-charged products and equipment on the market	All Options	Total: -358 Large: -4 Medium: -15 Small: -339	Large:5 Medium: 3 Small:1	-404	-	-0.09	-	The reporting threshold is changing from 500 t CO2e of Annex I & II to 100 t CO_2e of HFCs or 500 t CO_2e of Annex I & II. This avoids that use of authorizations are not reported in such cases. This is expected to likely impact a small number of companies which import equipment now captured by the amended threshold. The total number of importers has been based upon data from BDR reporting. The reporting requirements are estimated to be approximately 5 days/year for large companies.
Align reporting and verification dates between bulk and pre-charged products and equipment	All Options	Total: 6,535 Large: 74 Medium: 265 Small: 6,196	Negligible	Negligible	-	Negligible	-	For bulk, the accuracy of the data is verified by an independent auditor by 30 June each year, while reporting is, however, set to take place by 31 March each year. For equipment, it is 31 March for both. The option relaxes the time to deliver the verification to may (for equipment) and anticipates it for bulk. The additional costs for companies is expected to be minimal as companies will undertake the verification shortly after data has been collected (and reported). It will nominally impact time pressures only and will not represent an additional burden for reporting companies.
Relax the verification threshold for placing pre-charged products and equipment on the market	All Options	Total: -1428 Large: - 16 Medium: -58 Small: -1354	Large:10 Medium: 8 Small: 5	-7395	-	-1.7	-	The current threshold is set at >100t CO2e with the policy option set to increase this to >1,000 t CO2. Currently 17% of companies are below the threshold and this number will rise to 52% as the threshold rises. The total number of equipment importers (1024) has been based upon the BDR reporting database.
Add legal basis for electronic verification process (separately for bulk and pre-charged products and equipment)	Only Options 2 & 3	Total: 6,535 Large: 74 Medium: 265 Small: 6,196	Large:1 Medium: 1 Small:1	-6535	-	-1.5	-	As a result of the policy option there is expected to be a slight saving for a number of companies that are compliant with current verification rules once the system has been introduced, which is expected to be approximately 10% of current costs. This is due to the auditor's role and task becoming clearer, and because the relevant data will now be readily available through the electronic process. It is considered inefficient overall for companies to adopt different approaches. Utilising an electronic verification system will enable synergies to be accrued and better help to ensure the availability of auditors. The saving to each company has been

Policy Measure	Scenario	Number of companies	Days/Year per Company	Total Days (Annual)	Total Days (One-off)	Total Annual Cost (EUR,M)	Total One Off Cost (EUR, M)	Explanation
								based upon expert understanding of the system.
Obligation to provide NIL reports for quota holders	All Options	Total: 300 Large: 3 Medium:12 Small:285	Large:0.25 Medium: 0.25 Small:0.25	75	-	0.02	-	The impact upon administrative costs is expected to be very small as the obligation to provide a NIL report will be a straightforward and simple task. Based upon expert judgement and the current number of quota holders this is expected to impact approximately 300 companies.
Require Member States to use electronic reporting systems for collection of F-gas service intervention, technicians, sale of non-hermetic equipment and emissions data	Only Option 3	Total: 65,717 Large: 5915 Medium: 13,143 Small: 46,559 The reduction of burden is assumed to be similar for large and small companies	Large/Medium/Small: 0.25 recurrent/ 1 initial	+/- 0	65,717	0	15,1	The policy will have an impact upon all companies which are required to currently maintain reporting system records. The requirement to use a common electronic tool at national level will be expected to lead to an initial implementation cost of approximately 1 day, based an understanding of the costs to implement the system in Poland and expert judgment. Upon the implementation of the new system the ongoing annual administrative burden is expected to not change significantly, due to the use of the electronic reporting recording tool vs manual recording and storage. Based upon stakeholder consultation it is estimated that approximately one third of Member States already have some sort of system in place, and therefore no further cost is expected. The number of companies impacted has been based upon the number of reporting companies in Slovakia where detailed data is available and extrapolated across the EU, taking into account the Member States for which a system is in place. The breakdown of company size has been based upon a German industrial survey determining the number of employees at German service operators.
Require reporting by companies on new substances	All Options	Total: 100 Large: 10 Medium: 10 Small: 80	Existing company: 0.2 day New company: 1 day	68	-	0.02	-	A number of substances which are fluorinated greenhouse gases, yet are not yet covered by the Regulation. There will be an increase in administrative costs due to an increase in the number of companies require to report on these additional substances. . Reporting requirements will mainly include production, import, export companies. As a result of the policy option there will be new companies that have to report and there will also be existing reporting companies reporting only on additional substances (lower effort).

Table 57. Total additional annual administrative costs to industry (recurrent, in million €)

	Option 1	Option 2	Option 3
Objective A	-	4.4	4.4
Objective B	0.02	0.02	0.02
Objective C	-0.74	5,7	6,2
Objective D	-1.1	-2.5	-1.3
Total Cost	**-1.8**	**7,6**	**9,4**

The table below shows the aggregated change in one-off administrative costs as a result of implementing the policy measures under each of the three ambition scenarios.

Table 58. Total additional administrative costs to industry (one-off, in million €)

	Option 1	Option 2	Option 3
Objective A	-	3	3
Objective B	-	-	-
Objective C	-	-	3
Objective D	-	-	15.1
Total Cost	**-**	**3**	**21.1**

A14.3 Costs to authorities – current Regulation

A14.3.1 At Member State level

Figure 32 shows the range of financial estimates (€) and

Figure 33 presents the range of working day estimates reported by Member States through the targeted interviews associated with ***ongoing annual costs***, split by measure. The tables below each figure show numerically the upper and lower range illustrated. For the measures where only one Member State has provided a value this has been listed as both the upper and lower range.

Figure 32: Financial estimates of recurrent administrative costs per MS per annum, linked to the implementation and enforcement of the Regulation

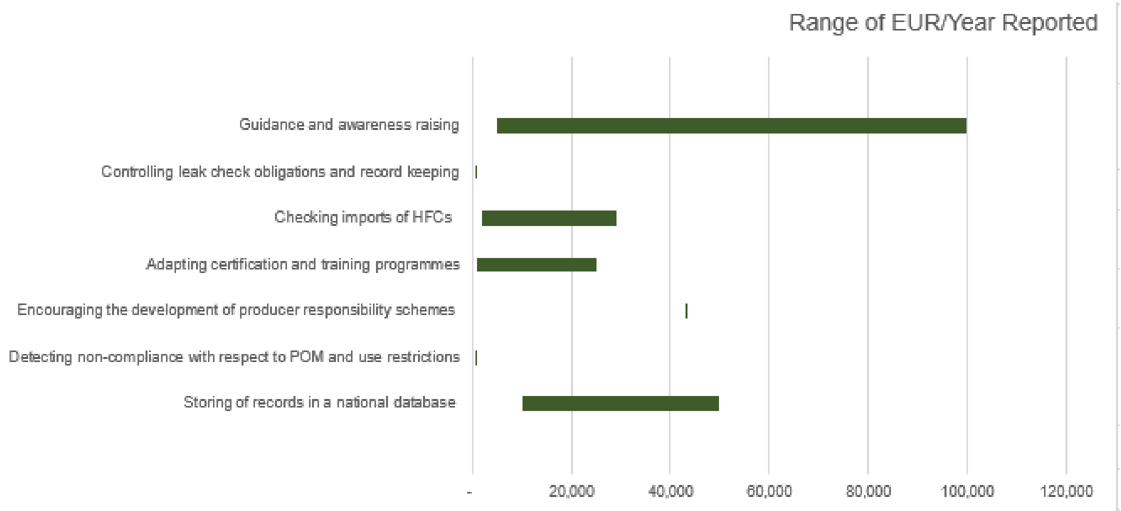


Table 59 Financial estimates of recurrent administrative costs per MS per annum, linked to the implementation and enforcement of the Regulation

Measure	Lower (€)	Median (€)	Upper (€)
Storing of records in a national database	10,000	25,000	50,000
Detecting non-compliance with respect to POM and use restrictions	600	600	600
Encouraging the development of producer responsibility schemes	43,000	43,000	43,000
Adapting certification and training programmes	1,000	5,000	25,000
Checking imports of HFCs	2,000	15,400	29,200
Controlling leak check obligations and record keeping	425	425	425
Guidance and awareness raising	5,000	23,500	100,000

Figure 33: Time estimates of recurrent administrative costs per MS per annum, linked to the implementation and enforcement of the Regulation

Table 60. Time estimates of recurrent administrative costs per MS per annum, linked to the implementation and enforcement of the Regulation

Measure	Lower (days/pa)	Median (days/pa)	Upper (days/pa)
Storing of records in a national database	1	23	180
Encouraging the development of producer responsibility schemes for the recovery, recycling, reclamation and destruction of F-gases	3	25	170
Detecting non-compliance with respect to POM and use restrictions	2	30	120
Detecting non-compliance with respect quota authorisations and HFC phase-down	10	10	100
Checking imports of HFCs	5	5	240
Adapting certification and training programmes	5	5	5
Controlling leak check obligations and record keeping	4	50	40
Controlling end-of-life measures	20	50	20
Guidance and awareness raising	3	40	250

In addition to the annual costs outlined, respondents provided estimates for a range of ***one-off costs***, including: for setting up a database for storing records (Article 6 of the Regulation), establishing a reporting system for emissions data or a joined database. It should be noted, however, that the cost of establishing the reporting system for emissions is not unique to the F-gas Regulation, nor is it fully prescribed, but will also be incurred as a result of the EU Monitoring Mechanism regulation.

In total, €1.5m of one-off upfront costs were reported (figure not extrapolated to all MS). The table below shows the one-off costs or ranges reported by the respondents. Given that Member States had the opportunity to report either financial estimates or working days, the ranges for a measure can vary dependent upon the costs provided by different Member States.

To note:

- Italy reported significant costs (€560,000) for the storing of records in a national database and establishing reporting systems for emissions data. The costs have not been included in the table below as it was noted that the costs also included the ongoing management of the databases.

Table 61: Examples of one-off administrative costs reported by national competent authorities

Measure	Cost (Range Reported)
Reporting to the EU Commission (e.g. Articles 9, 10, 25)	320 – 1,000 (EUR) 2 – 50 (days)
Storing of records in a national database	50,000 (EUR)
Establishing training and certification programmes for service technicians carrying out F-gas related activities	15,000 - 170,000 (EUR) 2.5 – 300 (days)
Establishing reporting systems for emissions data (Article 20) and national database	20,000 - 200,000 (EUR) 2.5 – 180 (days)

Total costs

To arrive at total costs, the costs from those MS that provided cost data were aggregated and extrapolated to an overall total using the number of reporting companies in each Member State[104]. This approach considering the total number of reporting companies has been applied to the majority of measures as this was considered to provide the most accurate basis for extrapolating the costs. However, where appropriate, in some cases the extrapolation has been based upon the number of reporting importers within Member States. This results in the following estimates:

- Using monetary cost data provided, the **total yearly costs across all Member State competent authorities and across all measures is estimated to be €8.8 million**.
- Using working days data provided, the **total yearly costs across all Member State competent authorities and across all measures is estimated to be 58,300 working**

[104] EEA report - 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

days to ensure compliance with the Regulation (including small costs associated with guidance and awareness raising). The latter value would give, based on an illustrative cost per day of €230 per day, a total cost estimate of €13.4 million. Both estimation are therefore giving comparable results, but a larger dataset was gathered for the working days estimations.

Some of the following may be only partially or not included in these totals:

- **Environmental inspections**. This is one of the most significant costs reported. Such inspections are rarely just focusing on Fgas requirements alone, but also check other environmental obligations at the same time. By way of example, the Netherlands reported around €3million per year with only €0.6 million linked to the activities of the national Environmental Inspectorate in relation to illegal trade and leakages. The bulk of the cost is often associated with the need for local authorities to check smaller companies on leakage-related aspects while undertaking other environmental checks. Sweden, for example, reported the involvement of 280 local and 20 regional authorities with a total estimate for inspection work of around 1,450 working days per year, with Poland also estimating a high cost for this measure. In Sweden, these costs comprised of implementation and enforcement activities associated with controlling leak checks obligations, record keeping and controlling end-of-life measures. A respondent from Bavaria suggested that the equivalent of three full time employees (person days) is deployed on F-gas related inspections in this German State. The time requirement per inspection varies by Member State. One of the drivers appears to be the approach to any legal issues arising. Considering this, and given that some Member States only included national costs linked to inspections while others covered local and regional authorities, the enforcement cost category is excluded from the overview in Figure 24 and 25.
- **Existing obligations.** Prior to the 2014 Regulation, requirements existed around some of the measures, such as the controlling leak check obligations, record keeping and controlling end-of-life measures. As such, where Member States report such costs, it may be that not all of these are ‘additional’ relative to the activities they had to undertake under the previous 2006 Regulation. There are also some synergies with Waste regulation, e.g. with respect to encouraging producer responsibility schemes. As such, costs reported by Member States in order to encourage the development of producer responsibility schemes for the recovery, recycling, reclamation and destruction of F-gases (Article 9) may not strictly be attributable to the F-gas Regulation specifically.
- **Customs checking.** Custom costs depend mostly on the risk profiling of the goods, and thus the controls actually carried out. In theory, illegal imports should already be dealt with in an effective way – i.e. confiscation and destruction. Such costs relate to the day-to-day of customs and are likely not fully captured in the numbers above.

A14.3.2 At the European level

An overview of the **administrative costs incurred by the EU Commission** is provided in **Table 62** below. The costs focus on those borne by DG CLIMA and do not cover those of other services, e.g. DG TAXUD and others on illegal trade issues and building CERTEX (EU Single Window for Customs). Also, it does not include the costs of external support to DG CLIMA.

Table 62. Administrative costs incurred by the EU Commission

Measure	Working days per year
Derogation decisions (Article 11)	/
Calculation of reference values / allocation of quota (Article 16)	30 days
IT-related aspects of the HFC Registry (Article 17) (including development & set-up, maintenance, hosting)	330 (1.5 person years) Plus hosting costs (€12.500)
Ensuring smooth functioning of the HFC Registry and the quota system: • Assessing registrations and declarations • Exclusion of illegitimate market actors • Helpdesk ("how do I?" support on using the system)	100 120 60
Enforcement of compliance with bulk quota	80
Enforcement of compliance of equipment importers (authorisations)	20
Publication of reports (Article 21)	20
F-gas Consultation Forum (Article 23)	10
Assuring compliance by EU Member States (e.g. infringement proceedings, EU pilots)	60
Notifications to EU Member State competent authorities (e.g. cases of non-compliance)	20
Providing information on the implementation of the Regulation (including compliance) to stakeholders	230
Illegal Trade incl. Single Window	60
Legal Issues incl. Court cases	160
Reporting	10
Monitoring the phase-down	10
Access to files	20
Committee meetings, implementing acts,	60
Meeting with stakeholders	30
Total	**1100 person days** **EC: 5+ people: 1100 days + 330 days (IT)**

An overview of the **administrative costs incurred by the EEA** is provided in Table 63 below. **The costs** provided also highlight a spike in costs for External IT consultancy support in the year 2018. The EEA have noted that after the 2017 reporting round the old MS Access F-gas database suffered from the increased volume of data from many new companies. It was hence re-developed into MS SQL during 2018, which required a significant number of extra IT-development days.

Table 62Table 61 below. The data provided from the EEA on their costs are based on EEA time recording and invoice information from EEA's contractors. With regard to the BDR helpdesk work, the vast majority of work is related to F-gases (approximately 80 %). The costs provided also highlight a spike in costs for External IT consultancy support in the year 2018. The EEA have noted that after the 2017 reporting round the old MS Access F-gas database suffered from the increased volume of data from many new companies. It was hence re-developed into MS SQL during 2018, which required a significant number of extra IT-development days.

Table 63. Administrative costs incurred by the EEA

	Unit	2012	2013	2014	2015	2016	2017	2018	2019	2020
EEA in-house F-gas thematic project management	**pers on days**	0.25	0.30	0.40	0.50	0.50	0.50	0.50	0.50	0.50
EEA in-house BDR Helpdesk support (both ODS and F-gases)	**pers on days**	0.10	0.10	0.10	0.20	0.20	0.25	0.30	0.30	0.25
EEA in-house IT project management	**pers on days**	0.20	0.20	0.20	0.20	0.20	0.20	0.25	0.25	0.25
European Topic Centre (F-gases thematic consultancy support)	**days**	85	95	89	135	140	116	100	100	103
External IT consultancy support (F-gases webform)	**days**	n.a.	n.a	n.a.	86	133	58	710	121	158
External IT consultancy support for BDR development and maintenance	**days**	n.a.	n.a	n.a.	87	179	191	120	51	148

A14.4 Costs to authorities – policy options

A14.4.1 At the European level

Estimated administrative burden for the European Commission related to the individual measures is given in Table 63. Detail of the calculation and assumptions

Table 64. Detail of the calculation and assumptions for administrative burden of the European Commission

Policy Measure	Scenario	Total Days (Annual)	Total Days (One-off)	Explanation
Increase ambition of the EU HFC phase-down beyond the requirements under the Montreal Protocol by tightening reduction steps until 2030 and introducing additional reduction steps beyond 2030	All Options	28	0	There is a lot of compliance checking also on EC side to ensure compliance with the phase down, alongside support provided to and communications with stakeholders to support compliance. Assume 10% increase in enforcement and support efforts for EC relative to evaluation baseline (expert judgement).
Additional prohibitions Introduce a placing on the market prohibition for small stationary refrigeration hermetic units for commercial and household use that contain or whose functioning relies upon fluorinated greenhouse gases from 1 January 2024 Introduce a placing on the market prohibition for fire protection equipment containing or relying on HFCs, except when required to meet national safety standards from 1 January 2024 Introduce a placing on the market prohibition for RACHP equipment which use PFCs and blends containing PFCs from 1 January 2024 Prohibit placing on the market of skin cooling equipment with F-gases used for purposes that are not required for strictly medical reasons and whose functioning relies upon F-gases	All Options	9	0	For each prohibition, CLIMA incurs costs for communicating with Member States and stakeholders. There will also be additional costs for additional advice and traffic through the Help Desk. Cost data was taken from the evaluation for these items under the existing Regulation, combined with the number of existing prohibitions to calculate a cost per prohibition. It is assumed that half of the costs related to these activities from the evaluation are for prohibitions (expert judgement). In addition, further derogations are anticipated in the future due to more complex rules. Time required per derogation is taken from the ODS IA (40 days per derogation). It is assumed there is roughly one derogation every 3 years, split across the 9 new prohibition proposals.
Additional prohibitions Introduce a placing in the market prohibition for stationary air conditioning and heat pump equipment from 1 January 2025 Remove the existing exemption for servicing	Options 2 and 3	36	0	

Policy Measure	Scenario	Total Days (Annual)	Total Days (One-off)	Explanation
and maintenance of refrigeration equipment with a charge size below 40 tonnes of CO2 eq with virgin fluorinated gases from 1 January 2024 Introduce a placing on the market prohibition for personal care products containing fluorinated greenhouse gases from 1 January 2024 Introduce a placing on the market prohibition for new medium voltage electrical switchgear for primary and secondary distribution, differentiated by voltage level, from 1 January 2030, using SF_6 as insulating or breaking medium; other fluorinated compounds with GWP > 500 can be used; unless evidence is provided that no other suitable alternative is available on technical grounds Introduce a placing on the market prohibition for new high voltage electrical switchgear, differentiated by voltage level, from 1 January 2028 or 2031, respectively , using SF_6 as insulating or breaking medium; other fluorinated compounds with GWP > 1,000 can be used, unless evidence is provided that no other suitable alternative is available on technical grounds Introduce a use prohibition for some inhalation anesthetics containing other fluorinated greenhouse gases listed in Annex II with GWP > 500 from 1 January 2024				
Removal of exemptions and thresholds Remove exemption from placing on the market restrictions under the phase-down for HFCs for use in metered dose inhalers Remove limit of 100 tonnes of CO2 eq for producers or importers that place HFCs on the market Remove the limit for reporting on production, import, export and destruction of F-gases and	All Options	23	0	Measures will incur minor additional costs for CLIMA. Some companies are already receiving quota, but there will be some new companies that require quota. Additional administrative costs will be incurred as more companies come under the reporting requirements. In addition, there will be additional helpdesk traffic and compliance cases. Cost estimates are based on expert judgement uplift from baseline costs calculated in the evaluation. The main cost increases are linked to the MDI exemption as exempted sectors (MDIs, military, semiconductors) comprise > 10%

Policy Measure	Scenario	Total Days (Annual)	Total Days (One-off)	Explanation
other gases listed in Annex II				of the total market (with MDIs representing the vast majority of this exempted proportion). As such it is assumed that phase-down compliance costs (e.g. calculation of reference values, and enforcement of compliance with bulk quota) from the evaluation would increase by around 10%
Removal of exemptions and thresholds Remove POM exemption for military equipment Remove the exemption from placing on the market restrictions under the phase-down for HFCs for etching of semiconductor material or cleaning of chemicals vapour deposition chambers within the semiconductor manufacturing sector	Only Option 3	2.3	0	Measures will incur minor additional costs for CLIMA. Some companies are already receiving quota, but there will be some new companies that require quota. Additional administrative costs will be incurred as more companies come under the reporting requirements. In addition, there will be additional helpdesk traffic and compliance cases. The additional removal of exemptions would add very little additional admin burden, as quantities and companies are low. Cost estimates are based on expert judgement – assume 10% of the costs of other "removals" above.
Implement an EU-wide HFC production phase-down	All Options	10	10	CLIMA would incur additional costs, but these are anticipated to be smaller than for the POM phase down. No yearly allocation would be required. Costs would be driven by compliance with the new rules, awareness raising and discussion with industry. To calculate the costs, we have assumed these are 10% of the evaluation costs of enforcing compliance with the POM phase-down. There would also be initial one-off costs of communicating the phase-down obligations to affected stakeholders (expert judgement – assume same as ongoing cost).
Introduce prohibition for HFC bulk imports to/exports from the EU to any country not Party to the Montreal Protocol (Kigali Amendment)	All Options	Without automisation[105]: 10 With automisation: 248	Without automisation[210]: 0 With automisation: 667	Several measures imply additional costs for CLIMA if controls are to be automised and thus require further development of Certex. There will be additional costs for development and maintenance (assume 100 days/year), plus external assistance per year (assume €100,000), plus a one-time costs to develop the expert function and adjust to the new Regulation (assume €500,000) (all values based on expert judgement). In addition, these changes will also imply additional data security costs. Quantitative estimates (15 days pa) were taken from the
Better control on some special procedures a) Goods released at particular destination custom offices b) Transactions where the minimum of 8-digit CN codes are indicated by the	All Options			

105 I.e. with the CERTEX/European Single Windows for Customs Environment

Policy Measure	Scenario	Total Days (Annual)	Total Days (One-off)	Explanation
importer or exporter				ODS IA). The costs without automising (which is not necessarily required by the Regulation) would be significantly more moderate and do not exceed much current costs (expert judgement suggests 10 days additional p.a.).
Add requirement for producers and importers to be registered and hold sufficient quota at the time of release for free circulation/placing on the market / physical entry into territory	All Options			
Prohibition for (offline and online) sales and possession of HFCs/F-gases that were illegally placed on the market	All Options	10	0	Costs will mainly be for MS enforcement, although in practice some costs may fall on CLIMA (e.g. through OLAF or industry, consulting or providing advice to MS, potential engagement with website hosts). Assume implementation of 5-10 days per annum (expert judgement).
Include minimum penalties to be enforced by EU Member States for quota exceedance, quota authorization deficits, illegal issuance of authorizations, non-compliance with reporting deadlines and verification obligations and transport, storage and use of HFCs not covered by quota	All Options	40	0	Will imply additional costs to CLIMA of around 30-50 days per annum on an ongoing basis to enforce the Regulation (infringement procedures).
Limit issuing quota authorizations to incumbents, i.e. based on reference-based quota	All Options	-1	0	Issuing authorizations to incumbents only may lead to some cost savings through reduced compliance checks (less undertakings to check), although savings will be limited (expert judgement suggests savings of around 5% of 20 days per annum).
Introduction of a registration fee and/or quota allocation price linked to CO2 equivalents	Options 2 & 3	2,200	2,200	This measure could increase costs significantly. Costs would be incurred for collection and distribution of funds, in addition to systems design and construction, registration and tracking, relying on a suitable IT system. Many of these costs may be outsourced, and will be fully offset by revenues collected. But these still imply a significant administrative burden. Expert judgement suggests this may be equivalent to as many as 10 full-time equivalents (i.e. 2200 person days) on an upfront as well as ongoing (annual) basis plus IT costs. This would not include additional IT staff for running the system and ensuring the enhanced data protection and security needed.
Registration and reporting obligation for exporters of products and equipment containing F-gases and other fluorinated substances	Only Option 3	7.1	0	Costs will be linked to advising company on legal obligations. Existing reporting costs for CLIMA are taken from the evaluation and scaled by the number of new companies that would potentially fall under the new requirement. In this case, expert judgement suggests there may be around 1,000 – 2,000 additional companies (relative to around 2,100 existing companies that are

Policy Measure	Scenario	Total Days (Annual)	Total Days (One-off)	Explanation
				obliged to report).
Reporting obligation for recipients of quota-exempted HFCs	Options 2 & 3	0.3	0	Reporting costs for CLIMA (i.e. providing guidance) are taken from the evaluation and scaled by the number of new companies that would potentially fall under the new requirement. In this case, expert judgement suggests there may be around 65 additional companies (relative to around 2,100 existing companies that are obliged to report).
Reporting obligation for undertakings performing reclamation of F-gases	Options 2 & 3	0.2	0	Reporting costs for CLIMA are taken from the evaluation and scaled by the number of new companies that would potentially fall under the new requirement. In this case, expert judgement suggests there may be around 50 additional companies (relative to around 2,100 existing companies that are obliged to report).
Reporting obligation for undertakings performing recycling of F-gases	Only Option 3	3.6	0	Reporting costs for CLIMA are taken from the evaluation and scaled by the number of new companies that would potentially fall under the new requirement. In this case, expert judgement suggests there may be around 750 additional companies (relative to around 2,100 existing companies that are obliged to report).
Reporting obligation for operators of HV switchgear and electrical equipment (< 52 kV) with regard to SF_6 emissions during lifetime and for operators in cooperation with certified personnel of electrical equipment for decommissioning of such equipment	Only Option 3	12	0	Reporting costs for CLIMA are taken from the evaluation and scaled by the number of new companies that would potentially fall under the new requirement. In this case, expert judgement suggests there may be around 50-100 additional companies , in addition to ~50 transmission and 2400 distribution companies (relative to around 2,100 existing companies that are obligated to report).
Align reporting and verification thresholds for placing on the market products and equipment: a) Raising threshold to 1000 tCO2e for equipment b) Verification obligation for POM of HFCs in line with reporting	All Options	-21.1	0	Measure would result in a saving for CLIMA. Raising the threshold from 100 to 1000 tCO2e would reduce the coverage from 83% to either 48% of the 1,500 relevant companies. Analysis scales the costs from the evaluation covering assessment of registrations and declarations (assuming half of these costs are relevant for verification). Clarify verification obligation to apply to both Art 19 report & DoCs implies no additional cost Reporting threshold for product and equipment imports is slightly lower than in the present F-gas Regulation, should lead to slightly higher cost for BDR submission of the report. Additional data collection does not take place as all affected companies are already under the verification obligation.

Policy Measure	Scenario	Total Days (Annual)	Total Days (One-off)	Explanation
Add electronic verification process (separately for bulk and pre-charged products and equipment)	Options 2 & 3	-25	5	Measure would result in a saving for CLIMA. Analysis scales the costs from the evaluation covering compliance checking of verification reports (assuming half of these costs are relevant for verification). Expert judgement assumes a reduction in verification costs of 25% There will also be some costs linked to conceptual development – assume 5 days (expert judgement)
Align quota authorization with reporting thresholds for placing pre-charged products and equipment on the market	All Options	-3.5	0	Measure would result in a saving for CLIMA. Changing the threshold from 100 to 1,000 tCO_2e will reduce the number of companies covered by around 360 (relative to baseline of just over 1,000 companies). Analysis applies this scaling factor to reporting costs captured in the evaluation.
Obligation to provide NIL reports for quota holders	All Options	-5	0	Measure would result in a saving for CLIMA. Analysis scales the costs from the evaluation covering assessment of registrations and declarations (assuming half of these costs are relevant for verification). Expert judgement assumes a reduction in verification costs of 5%
TOTAL COSTS for all measures (Option 3)		**2338 person days** Plus 238 for automation through CERTEX/Single Window	**2215 person days** Plus 667 for automation through CERTEX/Single Window	

Estimated administrative burden for the EEA related to the individual measures is given in Table 64. Detail of calculation and assumptions for administrative burden of the EEA

Table 65. Detail of calculation and assumptions for administrative burden of the EEA

Policy Measure	Scenario	Total Days (Annual)	Total Days (One-off)	Explanation
Remove the limit for reporting on production, import, export and destruction of F-gases and other gases listed in Annex II	All Options	2.2	0	EEA's current F-gas reporting system could fairly easily be adapted at low costs if new reporting thresholds are applied and new substances are added. This may result in a small increase in cost through additional traffic for the BDR Helpdesk (Stakeholder feedback). Expert judgement suggests costs could increase by 5% from costs reported in the evaluation for in house Helpdesk support.
Implement an EU-wide HFC production phase-down in addition to the POM phase-down which would be quantitatively adapted to the Montreal Protocol (same ambition level), quota allocation at entity level based on HFC production 2011-2013 plus 15 % CFC/HCFC production 2011-2013	All Options	0	21	Stakeholder feedback suggests measure would imply additional, one-off costs for making changes to the web reporting form. Costs were collated in the evaluation for development of the new form alongside the 2014 Regulation. Expert judgement assumes costs will be at most 10% relative to these costs.
Registration and reporting obligation for exporters of products and equipment containing F-gases and other fluorinated substances	Only Option 3	157	50	Additional reporting obligations could increase EEA's costs more substantially E.g. for exporters of products and equipment containing F-gases, for recipients of quota-exempted HFCs, and for undertakings performing recycling and reclamation of F-gases, EEA's system could be extended step-wise as in the past at an envisaged annual cost corresponding to the average for 2015-2019. This captures an expected increase in a range of EEA activities, including: greater traffic to the BDR helpdesk, more IT troubleshooting, greater project management and external IT consultancy support. Total costs for EEA are scaled up from existing costs (from the Evaluation), based on the number of companies falling under the new obligations (based on expert judgement) relative to those already reporting to the EEA (around 4,750 in 2019 based on EEA data). Exporters reporting assumes 1500 additional companies, quota exempted 65 additional, reclamation 50 additional and recycling 750 additional companies covered. In addition, there would be a one-off cost associated with the development and implementation of questionnaires to gather the data. No cost estimate was gathered from stakeholders, but expert judgement suggests costs may be around 50 days per new obligation.
Reporting obligation for recipients of quota-exempted HFCs	Option 2 & 3	7	50	
Reporting obligation for undertakings performing reclamation of F-gases	Option 2 & 3	5	50	
Reporting obligation for undertakings performing recycling of F-gases	Only Option 3	78	50	
Reporting obligation for operators of HV switchgear and electrical equipment (< 52 kV) with regard to SF_6 emissions during lifetime and for operators in cooperation with certified personnel of electrical equipment for decommissioning of such equipment	Only Option 3	84	50	
Align reporting and verification thresholds for placing on the market products and equipment: Align reporting and verification dates (separately for bulk and pre-charged products and equipment) Add legal basis for electronic verification process (separately for bulk and pre-charged products and equipment)	All Options	-4	0	Measure could result in cost saving for EEA. Reduced complexity will result in less BDR helpdesk traffic (Stakeholder feedback). No cost estimates were gathered from stakeholders. Expert judgement suggests savings will be small, around 10% reduction in traffic.

Policy Measure	Scenario	Total Days (Annual)	Total Days (One-off)	Explanation
Align reporting and quota authorisation thresholds for placing pre-charged products and equipment on the market Obligation to provide NIL reports for quota holders				
Include new substances in Annex I Include new substances in Annex II and require reporting	All Options	0	21	EEA's current F-gas reporting system could fairly easily be adapted at low costs if new F-gases are added to the current F-gas Regulation (Annex I or II). This would incur a one-off cost to adapt the BDR questionnaire and the QC rules (Stakeholder feedback). No quantitative estimates were put forward by EEA. Expert judgement suggests costs could increase in a similar order of magnitude to measure b3.1.
TOTAL COSTS for all measures (Option 3)		**327**	**292**	

A14.4.2 At Member State level

Estimated administrative burden for the Member States related to the individual measures is given in Table 65.

Table 66. Details of the calculation and assumptions for administrative burden of the Member States

Policy Measure	Scenario	Total Days (Annual)	Total Days (One-off)	Explanation
Increase ambition of the HFC phase-down beyond the requirements under the Montreal Protocol by tightening reduction steps until 2030 and introducing additional reduction steps beyond 2030	All Options	2,134	0	Additional costs for compliance checking of companies. No insights or estimation provided by stakeholders. Expert judgement – assumes 20% increase in costs of checking non-compliance with quota authorizations and phase down (as presented in the evaluation for existing Regulation).
Additional prohibitions Introduce a placing on the market prohibition for small stationary refrigeration hermetic units for commercial and household use that contain or whose functioning relies upon fluorinated greenhouse gases from 1 January 2024 Introduce a placing on the market prohibition for fire protection equipment containing or relying on HFCs, except when required to meet national safety standards from 1	All Options	160	0	Stakeholder feedback suggests costs of new POM prohibitions could range from ‚slight' to ‚very significant'. This would depend on the prohibition. Some resources would be needed for awareness raising alongside compliance. In addition, there may be further costs for derogations. Where prohibitions are time-staggered, as older prohibitions establish themselves, recurrent costs are likely to go down significantly as the prohibition date passes as most actors will learn to respect the new rules. Resources can be re-invested in new prohibitions. No estimation of costs was provided by stakeholders.

Policy Measure	Scenario	Total Days (Annual)	Total Days (One-off)	Explanation
January 2024 Introduce a placing on the market prohibition for RACHP equipment which use PFCs and blends containing PFCs from 1 January 2024 Prohibit placing on the market of skin cooling equipment with F-gases used for purposes that are not required for strictly medical reasons and whose functioning relies upon F-gases				Analysis takes costs of enforcing prohibitions from the evaluation of the existing Regulation, plus the costs of awareness raising. Additional costs are also added for derogations, based on the evidence developed for the ODS IA (23 days per derogation assumed). Some prohibitions will be more impactful than others. Costs are then scaled based on expert judgement, depending on how significant the application is in the market, relative to existing prohibitions.
Additional prohibitions Introduce a placing in the market prohibition for stationary air conditioning and heat pump equipment from 1 January 2025 Remove the existing exemption for servicing and maintenance of refrigeration equipment with a charge size below 40 tonnes of CO2 eq with virgin fluorinated gases from 1 January 2024 Introduce a placing on the market prohibition for personal care products containing fluorinated greenhouse gases from 1 January 2024 POM prohibition for new medium voltage electrical switchgear • for primary distribution, differentiated by voltage level – up to 24 kV from 2026 and 24-52 kV from 2030, using F-gases with GWP > 2000 as insulating or breaking medium; for secondary distribution, differentiated by voltage level – up to 24 kV from 2026 and 24-52 kV from 2030, using F-gases with GWP >2000 as insulating or breaking medium. POM prohibition for new high voltage electrical switchgear • in the range of 52-145 kV and up to 50 kA short circuit current from 2028, using F-gases with GWP >2000 as insulating or	Options 2 & 3	2,475	0	

Policy Measure	Scenario	Total Days (Annual)	Total Days (One-off)	Explanation
breaking medium; • in the range of more than 145 kV or more than 50 kA short circuit current from 2031, using F-gases with GWP >2000 as insulating or breaking medium. Introduce a use prohibition for some inhalation anesthetics containing other fluorinated greenhouse gases listed in Annex II with GWP > 500 from 1 January 2024				
Apply requirements for prevention of emissions of fluorinated gases to substances listed in Annex II	All Options	51	0	No insights or estimation provided by stakeholders. Quantification based on expert judgement. Annex II gases represent around 6% of total supply in 2019, hence scale up MS compliance costs for enforcing containment measures from evaluation by this factor. This measure only relates to Article 3 – data not available for costs of Article 3 specifically. Expert judgement anticipates that the majority of the costs for MS are related to leak checks and reporting (Articles 4-6), with Article 3 presenting only minor costs. Hence assume 10% of reported costs for containment measures from evaluation relate to Article 3.
Apply requirements for prevention of emissions of F-gases to manufacturing, transport, transfer and storage of bulk gases also to non-producers	Options 2 & 3	34	0	No insights or estimation provided by stakeholders. Member States incur additional costs to check and enforce compliance with the extended requirements. Extension is being considered to equipment manufacturers & upstream companies (e.g. gas traders). These costs will be an order far below the number of equipment operators. For industry admin burden, assume additional 1,000 companies. Number of producers and equipment operators (covered by existing requirements) is unknown, estimates for operators suggest this could be around 230,000. Expert judgement, assume 0.4% additional cost for enforcing compliance with containment measures.
Destruction of HFCs from metal-faced panels or reuse, from 2024	All Options	No quantitative estimate	No quantitative estimate	For Member States, costs are expected due to the need for awareness raising, monitoring and enforcement activities (of thousands of demolition projects a year).
Destruction (or reuse) of HFCs in laminated boards in built-up structures and cavities, unless feasibility is proven by the building owner / demolition company, from 2024	Options 2 & 3			
Remove POM exemption for military equipment	Option 3 only	20	0	Quota system is run by DG CLIMA, but in practice MS still incur costs of compliance checking. Stakeholders suggest measure could imply

Policy Measure	Scenario	Total Days (Annual)	Total Days (One-off)	Explanation
				increase in costs, but did not provide estimation. MS spend around 8,000 days pa checking compliance with phase down covering ~2,000 companies – assume 4 days per company. Around 5 military undertakings currently received quota exempted supply
Remove the exemption from placing on the market restrictions under the phase-down for HFCs for etching of semiconductor material or cleaning of chemicals vapour deposition chambers within the semiconductor manufacturing sector	Option 3 only	120	0	Quota system is run by DG CLIMA, but in practice MS still incur costs of compliance checking. Stakeholders suggest measure could imply increase in costs, but did not provide estimation. Analysis scales up costs from evaluation associated with non-compliance with the phase-down. MS spend around 8,000 days pa checking compliance with phase down covering ~2,000 companies – assume 4 days per company. Around 60 semiconductors currently received quota exempted supply. Given activity is concentrated in few MS< expert judgement assumes there may be efficiencies of scale, so costs would be around half if they were spread across many MS.
Remove exemption from placing on the market restrictions under the phase-down for HFCs for use in metered dose inhalers	All Options	100	0	Quota system is run by DG CLIMA, but in practice MS still incur costs of compliance checking. Stakeholders suggest measure could imply increase in costs, but did not provide estimation. MS spend around 8,000 days pa checking compliance with phase down covering ~2,000 companies – assume 4 days per company. Around 25 MDI undertakings currently received quota exempted supply
Implement an EU-wide HFC production phase-down	All Options	30	0	No insights provided by stakeholders. Production has always been centered in few countries which have high expenses. Expert judgement suggests there may be around 5 companies across 2 MS which undertake production at present. Hence additional burden likely to be small. Estimate based on existing costs of non-compliance with POM phase-down, but scaled down by smaller number of companies that will be covered (5 vs 1,800 under POM phase down).
Introduce prohibition for HFC bulk imports to/exports from the EU to any country not Party to the Montreal Protocol (Kigali Amendment)	All Options	109	0	No insights provided by stakeholders. Costs for MS will increase associated with additional import compliance checks. That said, most countries are anticipated to be signatories to Kigali by 2030. Expert judgement: assume 1% increase in costs of checking imports (as reported in the evaluation). Only from 2028 onwards. Can be done automatically with Single Window, which would reduce these costs very significantly
Certification requirement for unsaturated HFCs and H(C)FCs and other F-gas free alternatives, while F-gas certification programmes also to include practical training on all alternatives and add energy efficiency issues to be part of training (stationary	Options 2 & 3	1,924	0	Stakeholder feedback suggested costs would increase, with a range of opinions from ‚no change‘ to ‚significant increase (40%)‘. Scheme is extension of existing programmes. Expert judgement – take mid-point of stakeholder opinion and assume 20% increase in costs of training and certification for MS from evaluation.

Policy Measure	Scenario	Total Days (Annual)	Total Days (One-off)	Explanation
RACHP)				
Installation/servicing/repair/maintenance of equipment that contains fluorinated greenhouse gases or whose functioning relies upon those gases for which certification or attestation is required under Article 10 only by certified personnel	Options 2 & 3	27	0	This measure will imply additional compliance checking cost for MS. No feedback or cost information provided by stakeholders. This measure implies an extension of the requirements of Article 11(4) to include other substances, in particular HCFOs. However, this extension is anticipated to be relatively minor, given many HCFOs are used in blends which are already covered by the Regulation. Pure use of HCFOs is fairly negligible. Assume 1 day per MS additional effort required.
Include specific requirements for customs regarding the treatment of products and equipment illegally placed on the market and illegal F-gas containers once confiscated	All Options	2,174	0	Stakeholder feedback suggested this measure would pace additional administrative burden on customs. Costs estimates by stakeholders ranged from ‚no change' to ‚significant increase' (40%). Costs can be kept low by requiring non-compliant company to cover destruction (standard procedure under customs law) and by auctioning – i.e. costs should be put on the illegal importer, but in practice this might not be possible. Custom costs depend mostly on the risk profiling of the goods, and thus the controls actually carried out. In theory, illegal imports should already be dealt with in an effective way – i.e. confiscation and destruction, but in practice this does not always happen. Hence these costs in theory should already be incurred today, and hence are not truly additional to the option considered here, but are not in practice. Expert judgement – take mid-point of stakeholder opinion and assume 20% increase in costs of checking imports from evaluation.
Better control on some special procedures a) Goods released at particular destination custom offices b) Transactions where the minimum of 8-digit CN codes are indicated by the importer or exporter	All Options	109	0	Administrative costs for Member States may change at customs offices as a result of the changes. If implemented in the CERTEX/Single Window, the SW system may already provide with the procedures that enable better control. If illegal trade reduces, then this may also reduce the use of some customs procedures, resulting in a lower cost. Any additional cost would be associated with follow-up, which would be performed on the basis of risk profiles. Stakeholder comments suggests costs range from ‚no change' to ‚slight increase'. On the basis of evidence provided, a slight increase in costs (1%) has been quantified, scaling up from the costs presented in the evaluation for checking imports. Costs for administrations and business could arise due to bottleneck issues in case transit would, hypothetically, also be limited to certain custom offices.
General prohibition of entry into EU territory of non-refillable F-gas containers and other illegal goods under the Regulation and extend	All Options	544	0	Stakeholder feedback varied around this measure. Some suggested this measure may lead to a cost reduction (due to the introduction of clearer Regulations) to a significant cost increase (due to the need for

Policy Measure	Scenario	Total Days (Annual)	Total Days (One-off)	Explanation
the scope to unsaturated HFCs and unsaturated HCFCs				complementary awareness raising, and greater checking as well as the extension to gases that were not covered so far). Under the existing Regulation, the prohibition relates to placing non-refillable containers on the market. This extends the prohibition into the territory, which in theory is a small change with negligible costs. Given this is a small change, most importers are anticipated to already comply. But a small number (estimated to be approximately 5% of importers are) not currently conducting this practice and will therefore incur additional administrative cost. That said, given these actors should already comply with the Regulation, these costs are not truly additional and associated with this measure. Expert judgement – costs for checking imports will also increase by at most 5%, but generally also depend on risk profiling The second part of this measure is to extend the requirements to HCFOs. However, given the majority of HCFOs are used in blends already covered by the Regulation, these additional costs are anticipated to be negligible.
Prohibition for (offline and online) sales and possession of HFCs/F-gases that were illegally placed on the market	All Options	364	0	Stakeholder feedback suggested that the costs of this measure could range from a slight decrease to a significant increase (with the latter due to the complexity of the checks required, plus additional awareness raising that would be needed). That said, MS should already be monitoring the market for illegal goods to a sufficient degree already. This measure would add more legal certainty around taking enforcement action, and in that way could lead to cost savings. Only additional costs would arise only from enforcement of internet sales. Expert judgement – assume additional (net) cost of around 10 days per MS per annum, in addition to additional costs for awareness raising (10% of those reported in the evaluation associated with existing Regulation).
Add obligation for documentation for downstream sales for bulk HFC/F-gases (e.g. “declaration of conformity”) and record keeping	Option 3 only	No additional costs if implemented with electronic reporting systems on leakage data established by Member States (without, additional days required could be around 3,600)	No additional if implemented with electronic reporting systems	Stakeholder feedback suggests costs could range from no change to significant cost (20-30%). However, expert judgement suggests this measure will incur no additional costs on top of the electronic reporting system developed on leakage data.
Add obligation for importers to have quota-exempted quantities labelled as exempted during POM	All Options	109	0	Stakeholder feedback suggests costs could range from no change to ‚increase‘, but predominant qualitative responses was ‚slight increase‘. No quantitative estimation provided by stakeholders. Quota-exemptions represent around 10% of current quota. That said, not all quota is checked, so controls would not increase by the same amount. Expert judgement assumes costs of checking imports could

Policy Measure	Scenario	Total Days (Annual)	Total Days (One-off)	Explanation
				increase by 1% relative to the baseline (i.e. costs reported in the evaluation) Costs depend greatly on risk profiling.
Strengthen the obligation on destruction of HFC-23 by-production	Options 2 & 3	109	0	No stakeholder feedback or estimation regarding this measure. Expert judgement assumes costs of could be around 1% of overall baseline customs checks (i.e. costs reported in the evaluation)
Include minimum penalties to be enforced by EU Member States for quota exceedance, quota authorization deficits, illegal issuance of authorizations, non-compliance with reporting deadlines and verification obligations and transport, storage and use of HFCs not covered by quota	All Options	0	246	Stakeholder feedback suggested costs could range from ‚no change' to ‚slight increase'. No estimation provided. The majority of Member States should have legislation in place to facilitate the issuance of penalties under the existing Regulation. As such, it is anticipated that to strengthen penalties and/or set a minimum level would imply a minor change to the legislation. Expert judgement suggests could result in one-off costs to change legislation. Assume 1% of baseline compliance costs
Extend labelling requirement to Annex II gases	Options 2 & 3	694	0	Stakeholder feedback suggested costs could range from ‚no change' to ‚increase' – predominant response was ‚slight increase'. Annex II gases represent around 6% of total F-gas supply in 2019. Analysis applies expert judgement to scale up baseline (i.e. from evaluation) labelling costs by this factor
Align reporting and verification thresholds for placing on the market products and equipment	All Options	-2,250	0	No stakeholder feedback provided on this measure. In practice, MS incur costs for follow-up on quota compliance issues. Analysis has applied expert judgement to scale down baseline (i.e. from the evaluation) compliance costs for quota authorizations and Phase-down. Raising the threshold from 100 to 1000 tCO2e would reduce the coverage from 83% to 48% of the 1,500 relevant companies.
Obligation to provide NIL reports for quota holders	All Options	-533	0	No stakeholder feedback provided on this measure. In practice, MS incur costs for follow-up on ‚NIL' reports. CLIMA passes a list to MS to follow-up. Analysis has applied expert judgement to scale down baseline (i.e. from the evaluation) compliance costs for quota authorizations and Phase-down. Costs are scaled down by 5% (expert judgement)
Encourage / require Member States to use electronic reporting systems for collection of F-gas service intervention, technicians, sale of non-hermetic equipment and emissions data	Options 2 & 3	4,140	8,846	The evaluation identified that 4 MS already have electronic reporting systems in place, each collecting different coverage of metrics. A further 2 MS have data collection systems in place, but it unclear if these are electronic. Of these MS, only one MS (PL) provided quantitative cost estimates in the evaluation, both upfront and ongoing. Analysis assumes costs for MS with existing electronic systems are negligible, and applies the costs for PL to the remaining 23 MS. However, it is important to note that implementation costs in PL are generally lower than in other MS, hence using this as a basis from which to scale could produce an underestimation of costs.

Policy Measure	Scenario	Total Days (Annual)	Total Days (One-off)	Explanation
				Full cost is only assumed for Option 3, as use of these systems is not mandated under Option 2. For the latter, costs will scale depending on the number of MS who take up these systems, which is uncertain (in particular given only a small sample of MS have unilaterally taken up systems to date). As such no additional costs are assumed.
TOTAL for all measures (Option 3)		**12644**	**9092**	

A15 Detailed information on foams recovery

A15.1 Feasibility of HFC foam recovery and treatment

It is **more costly to separate, transport and destroy the HFC contained in the foam than standard disposal via landfilling without HFC recovery**. There are a number of constraints that make effective recovery and treatment difficult and/or costly. These include:

- Demolition companies may have difficulties to ascertain whether there is HFCs or not in a panel, and therefore judge how it should be handled (e.g., whether it can be crushed on-site or not). Building audits are expensive and take time, but are required to ascertain level of HFCs present.
- Transportation is expensive per tonne of material handled as HFC foams are considered hazardous materials.[106]
- Foam material with HFCs cannot be crushed on site without emitting the HFC, increasing transportation cost for relatively light materials such as laminated boards panels.
- Costs of waste segregation are high for some materials, especially if contaminated with bitumen. For some laminated boards, segregation is required to avoid contamination by other substances or building materials
- The recycling technology may require significant energy input.
- For metal-faced panels, the capacity of nearby recycling facilities may be too limited to process all metal-faced panels
- National capacity of special waste recycling plants capable of preventing HFC escape is not evenly distributed across Member States.
- Lack of enforcement is a driver for demolition companies to avoid separation of CDW fractions and reduce costs.

On the other hand, **there are strong synergies with ODS policies, where an identical measure is considered under the review of the ODS Regulation (Regulation (EC) No 1005/2009). Foams containing both substance groups (ODS and HFCs) can be collected and destroyed together, without need for separation.** For the short and medium-term, most foams collected may be expected to be ODS foams rather than HFC foams, due to the long lifetimes. Also, most of the overall emission savings would be expected from the destruction/recovery of ODS foams. However, **an identical measure in the F-gas and ODS Regulations is desirable to encourage more generic recycling of foams, without the need to identify the blowing agent during the building audit or in the recycling plant. An identical measure would also prevent the perverse incentive of mislabelling.**

The technical and economic feasibility also strongly depends on the type of foam (e.g. panels, boards, spray or block), and where it is installed (see table A6.1).

[106] Commission notice on technical guidance on the classification of waste (2018/C 124/01)

Table 67. Feasibility of building foams recovery by material

Material	Current feasibility	Justification
Metal-faced panels	Medium-High 	Refurbished recycling facilities that have so far been treating old refrigeration equipment can treat metal-faced panels. And new recycling facilities are already being built that focus on recycling foam panels, with at least two examples in the Netherlands. According to experts interviewed[107], it is **economically and technically feasible to recover Metal-faced panels.** The Metal component accounts for approx. 50-80% by weight (depending on panel thickness) and is easy to segregate and can be treated by existing refrigerant panel recycling plants. In this study, the recovery of the metal component of panels is assumed to already be economically viable, and only the foam component is analysed with respect to additional cost. At the moment, without a mandate for separation of panels and separate disposal of the metal and foam elements, there is low natural demand for the use of refrigerator panel recycling plants for this purpose.
Laminated boards	Medium-Low 	Laminated boards are more difficult and expensive to recover than metal-faced panels. However, **built-up systems[108] could be feasible to recover** since they are easy to segregate and collect, and they can be cut into smaller pieces to transport and process without losing much ODS content.
		Boards in cavity structures[109] could also be feasible to recover. Costs in some Member States like Germany, the Netherlands or Austria, would be lower due to existing waste regulations in place and favourable building practices that reduce the contamination level of the materials. There is a knowledge gap on the feasibility of this beyond these countries.
		Floor insulation boards are not yet economically feasible to recover since they are contaminated with concrete, removal of which requires more innovation. In a board, the foam is under concrete, hence, it is highly contaminated and costly to collect and

[107] Interview with UK-based recycling facility owning several refrigerant plants refurbished for metal-faced panels, and expert knowledge from authors of SKM (2012)

[108] Type of laminated boards easily demountable system primarily used for roofing insulation.

[109] Type of laminated boards that are introduced in empty cavities of existing panels mainly used for wall insulation

			segregate.
Spray foam		Low 	According to the experts interviewed, spray foam recovery is **not feasible in the demolition phase**. Spray foam is mainly used in walls and roofs. It was often used on top of existing structures for e.g. roof insulation, sprayed against surfaces, pumped into cavity holes. When the walls are demolished, foams are trapped in the wreckage and it would require time- and cost-intensive manual segregation.
Block foam		Low 	For block foam, as part of concrete slabs, the recovery is not feasible in the demolition phase as no examples have been identified of successful splitting of this material from the generic demolition waste stream. For block foam part of pipe insulation, recovery opportunities may exist during pipe replacement activities. In particular, block foam used in district heating/cooling system in the pasts is recoverable.

In summary, it is appears feasible to recover about 100% of the waste stream of metal-faced panels. They are the cheapest option given their valuable metal component and because they can be cut into smaller pieces without emitting a significant amount of HFC being released. Thus they can be treated in existing facilities for domestic appliances. It is estimated that approximately 25% of built-up systems and cavity structures (the two sub-types of laminated boards) should also be feasible to recover at the current time given the evidence of suitable construction procedures. Floor insulation boards may still represent too many technical or economic challenges to be a candidate for mandatory recovery because they are trapped into the wreckage in the demolition process and, collection and segregation stage is labour intensive and costly. In floor insulation, the foam is under concrete, hence, it is highly contaminated and costly to collect and segregate. Spray foam is not efficient to recover as it is expected to lose most of its HFC already in the use phase, making the cost-benefit ratio of mandatory recovery very inefficient.

The industry is pro-actively exploring further options to divert end-of-life foam from landfill. Recycling and recovery solutions have been developed and have proven their technical feasibility. Raw material prices have been steadily increasing over the past years and are likely to continue this development. The cost for landfill is also going up. This will contribute to the economic viability of recycling and recovery options.

A15.2 Potential emissions

Table 67 gives potential emissions from the insulation foams blown with HFCs that are presumably taken out of service due to demolition and renovation activities of old buildings. Before 2045 such potential emissions are very low as most foams will contain ODS, rather than HFCs. However, there is a significant potential of avoiding emissions after 2050, with ca. 45 MtCO2e of HFC foams left in buildings. The highest quantities are banked in laminated boards (about two-thirds of the foams).

Table 68. Potential emissions from insulation foams with HFCs reaching end-of-life

Year	Metal-faced panels	Laminated boards	Block foam/ pipe section	All foams
2045	0.011	0.011	0.009	0.031
2046	0.025	0.03	0.021	0.076
2047	0.037	0.106	0.032	0.175
2048	0.067	0.215	0.058	0.340
2049	0.094	0.341	0.081	0.516
2050	0.125	0.521	0.107	0.753
Total	0.359	1.224	0.308	1.891

A15.3 Economic Impacts

Economic impacts have been assessed for ODS-containing foams in a previous study[110], but very similar costs may be expected for HFC-foams. Costs are assessed only for metal-faced panels, built-up system, and cavity structure laminated boards, as these are part of the policy option assessed. New evidence on the cost of recovery is based on data from two case studies and an expert interview from stakeholders engaging with waste streams in Netherlands, Germany, Austria and the United Kingdom. The abatement costs in Table 68 are based on indicative prices (€/CO_2) from the two case studies. The total cost of around 6.4 million are distributed over a high number of building owners and/or real estate developers. As said above, there are important synergies with a similar considered measure for ozone-depleting substances, whose environmental impact is significantly larger as the ones proposed here for HFCs.

Policy Measure	**Scenario**	**Costs**	**Explanation**
Destruction of HFCs in metal-faced panels or reuse from 2024	All Options	EUR 5.37 per	The cost estimation is based upon the economic assumptions used for the analysis of the ODS

[110] Ricardo et al. (2021). Support study for the impact assessment of the Regulation on ozone-depleting substances.

		panel	Regulation. The compliance costs calculated in the ODS have been amended to take into account only HFCs.
Destruction (or reuse) of HFCs in laminated boards in built-up structures and cavities, unless infeasibility is proven by the building owner/demolition company	Options 2 and 3	EUR 35 per board	

Table 69. Overview of the total costs of foam recovery/destruction as envisaged by the policy options[111]

	Policy Option target	Estimate of abatement GHG (kt CO2e)	Total cost (2045 – 2050)	Abatement cost	Unaddressed potential	Estimate of untargeted emissions (2020 - 2050)
			EUR	EUR/t CO2e		GHG (kt CO2e)
Metal-faced panels	100% All options	359	€1.8 MIO	5.1	0%	0
Laminated boards in built-up systems or cavity structures	25% of total boards options 2 & 3	306	€4.6 MIO	15.0	75%	918
Spray & Block foam	0%	0			100%	308
Total		**665**	**€6.4 MIO**	**9.6**		**1,226**

Based on evidence from the stakeholder consultation, for those countries with an available waste treatment stream, technical progress achieved over the last decade resulted in a significant likely decrease in recovery costs. The final cost of the option will however be Member State specific, as not only waste treatment practices, but also building practices differ across the EU Member States. Therefore, these costs may be higher in other Member States than suggested for the Netherlands or Germany (where existing waste separation policy means that less additional cost is borne by the recycling plant or incinerator to obtain foam material, as it is already separated out and classified as a hazardous mono-fraction). As

111 It is assumed that 10% content of blowing agent out of the total foam weight (German Federal Environmental Agency, 2012) excluding the metal cladding.

a way of estimating the absolute worst case scenario and since data for ODS/HFC foams was very difficult to obtain form other countries than the ones mentioned, data on asbestos recovery and destruction from building wastes were collected. Given the health implications of asbestos, there are expensive measures on worker safety to be taken which would not be the case for ODS/HFC foams, and thus these number would indicate how much the recovery and destruction of ODS/HFC will most certainly not cost.

A15.4 Social Impacts

Research and development

According to interviewed experts the recovery of foam banks can be expected to spur innovation since it will create an incentive to reduce costs of reclamation via research and development into demolition and recycling technologies. Based also on the experience related to the mandatory recovery from domestic refrigeration appliances, such a policy is likely to result in better and cheaper ways to ensure recovery. Moreover, given that transport costs are high, research and development is likely to be carried out by domestic companies, creating added value within the European Union.

Consumer prices

The implementation could potentially increase consumer prices, i.e. for consumers renovating or constructing a building. If new construction in a building site must be preceded by incurring in the recovery of ODS/HFC from the decommissioned building, real estate prices could increase slightly as a result. However, there is evidence in the literature suggesting that construction prices have a low influence on the evolution of real estate prices (Martins et al., 2020). New buildings are more expensive on average, and hence mostly bought by households with high purchasing power or by companies as office space. Thus vulnerable consumers are less likely to be affected by price increases. Moreover, richer households pay high premiums (e.g. for “good neighbourhood”) hence the potential increase in consumer prices due to additional costs of recycling, even if realised, would be very marginal compared to the final housing price. The higher demolition costs are expected to be borne by the building owners, as demolition companies would pass these on. However, it is unlikely for consumer prices to increase in a perceptible way due to additional construction costs resulting from the implementation of this policy.

Employment

The policy option may increase employment due to the labour-intensive and complex nature of the demolition and reclamation processes. Currently demolition, segregation and insulation foam recovery processes are largely mechanised and are not labour-intensive activities, although there are differences among Member States. According to the literature[112] it is unlikely that recycling will add labour time (or cost). In fact, in many cases recycling would save time spent on waste management.

[112] Kameswari (2015). Construction and Demolition Waste Management - A Review. International Journal of Advanced Science and Technology, Vol 84.