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PART 1/2

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}

Table of contents

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)	4th, 5th or 6th 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 4th 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.

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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)

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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:

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[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, CO2, 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 CO2, 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

[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]

[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).

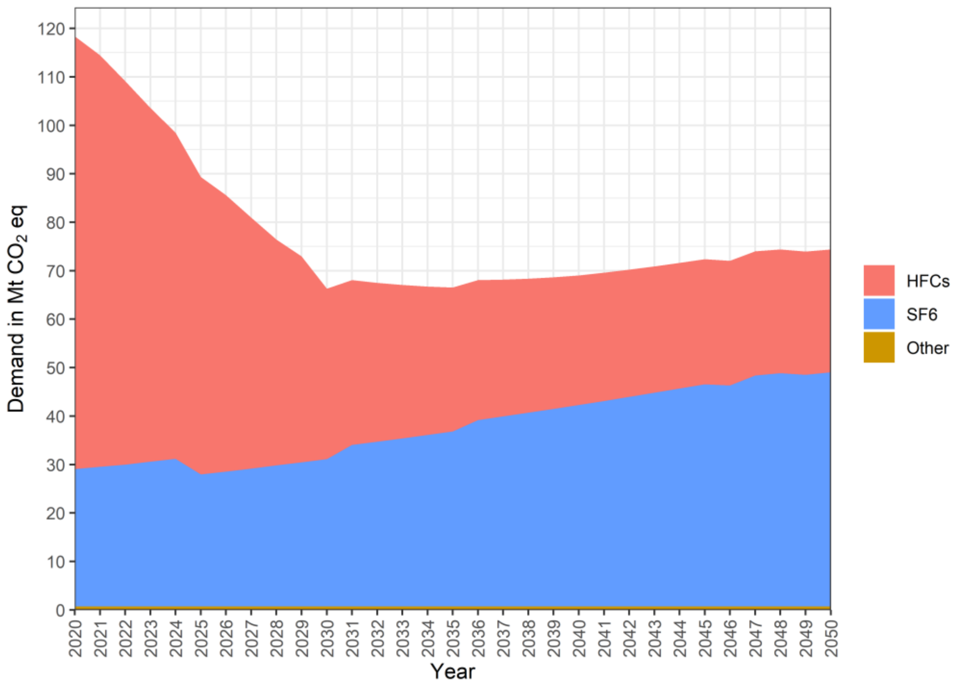

Figure 1. Baseline demand of HFCs, SF_6 and other F-gases in climate terms (MtCO2e)

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.

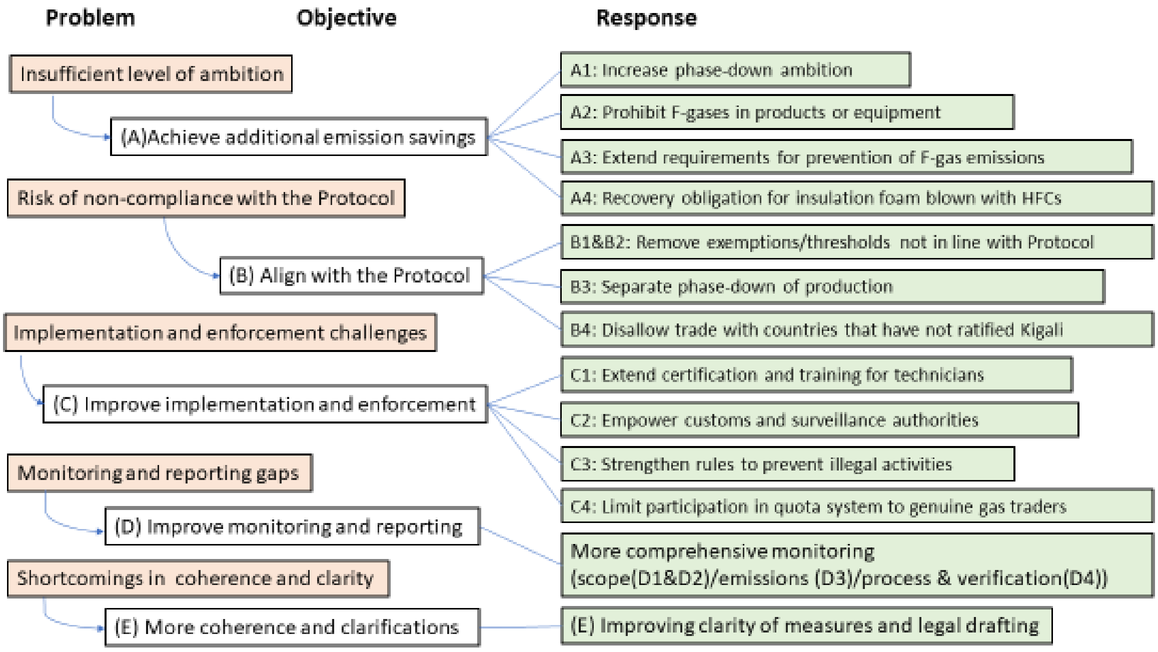

Figure 2. Relationship between the problems, review objectives and policy responses

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

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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.

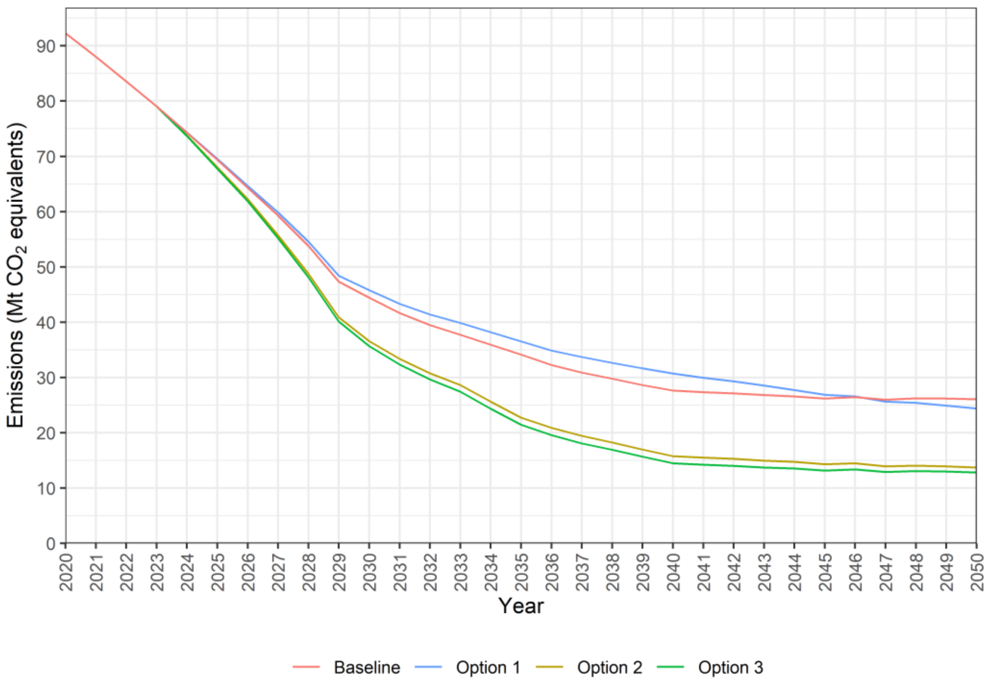

Figure 3: Modelled emissions of F-gases for the different options in the EU27 (based on reductions from the quota system and prohibitions only)

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).

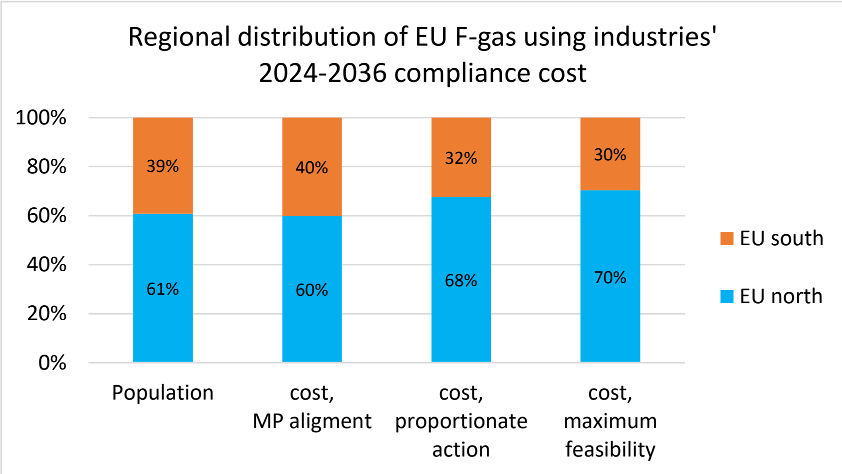

Figure 6: Regional distribution of EU F-gas using industries' 2024-2036 compliance cost

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.

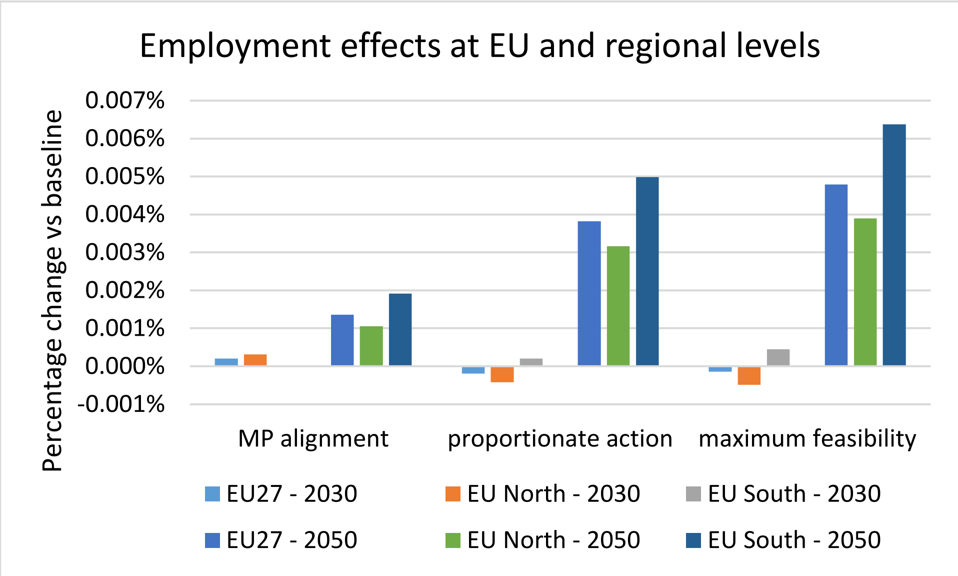

Figure 5: Employment effects

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.

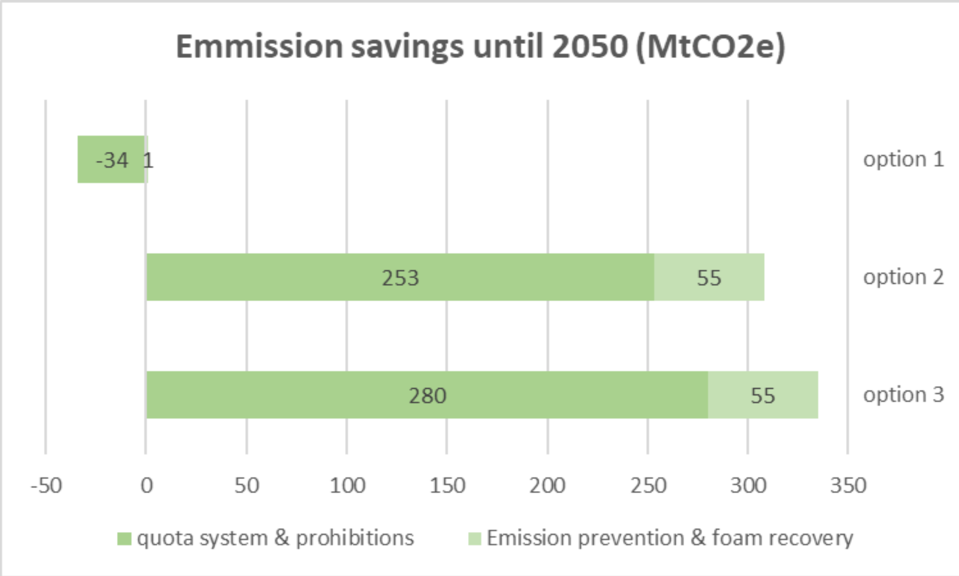

Figure 6: Total additional emission savings vs. the baseline (cumulative) achieved by the three options in the period until 2050.

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): Business	Member States	EC/EEA	Macro-economic effects	Social effects
A	**RAISING AMBITION: Phase-down, Prohibitions, Emission prevention Recovery obligations**	**++(+)** From phase-down & prohibitions: Savings of 27 MtCO2e by 2030; 253 MtCO2e by 2050 In addition: At least 55 MtCO2e savings by 2050 from expanded emission prevention measures and foam collection (13 MtCO2e by 2030) Some energy savings **(-)** Scientific discussion on potential increases of persistent breakdown products of synthetic refrigerants	**(+)** Abatement: Overall €-36/tCO2e technology change cost savings (2024-2036 average); **(-)** Conversion costs up to 336 €/tCO2e (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).

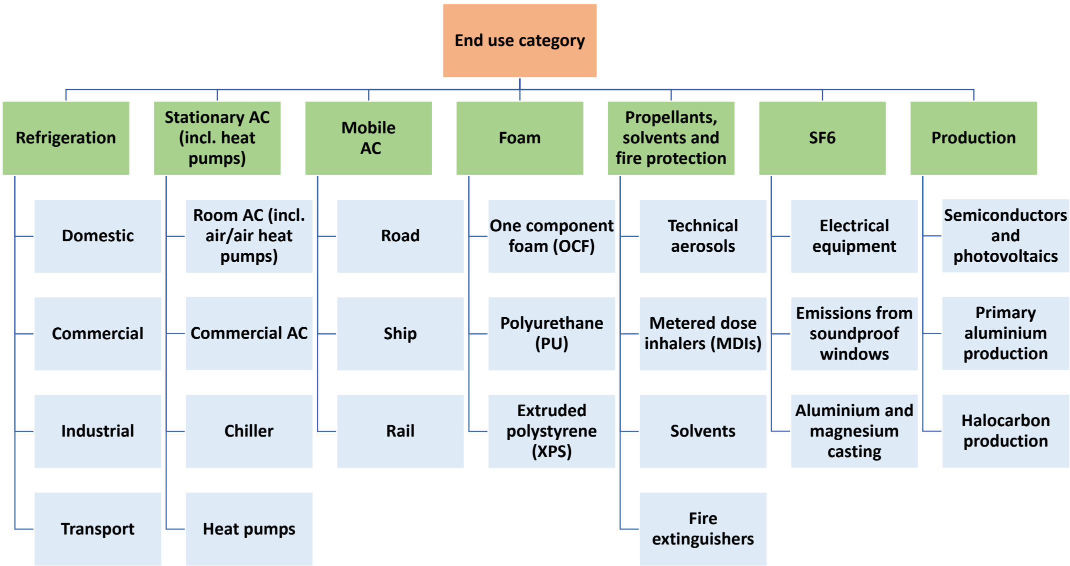

Figure 8: Overview of the sectors and subsectors covered by the AnaFgas model

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)

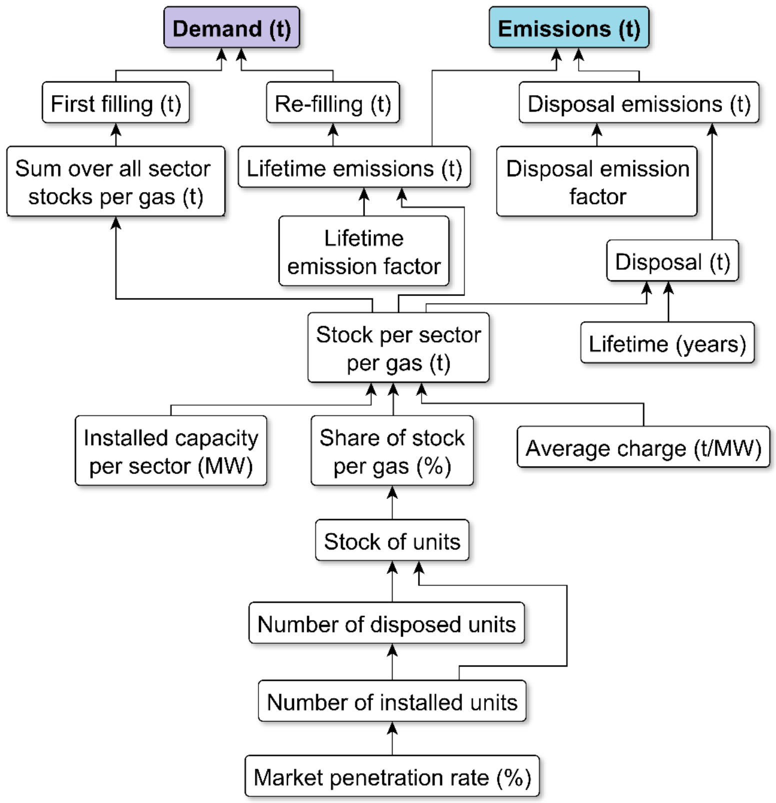

Figure 9: Simplified overview of the AnaFgas logic to project demand and emissions of F-gases in the EU

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.

<u>Input and parametrization</u>

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).

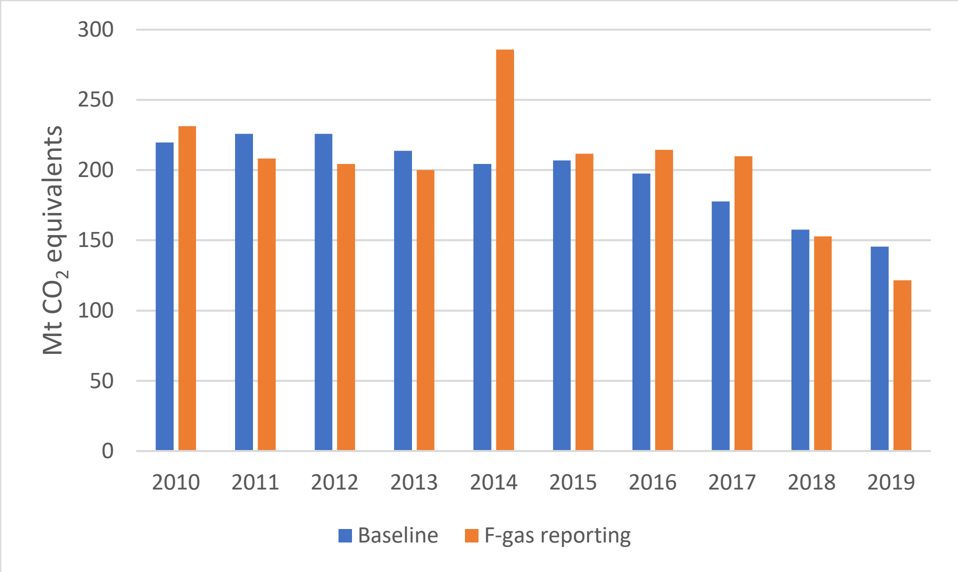

Figure 10: Comparison between the reported F-gas supply for the EU-28 and the results from the AnaFgas baseline modelling for F-gas demand

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.

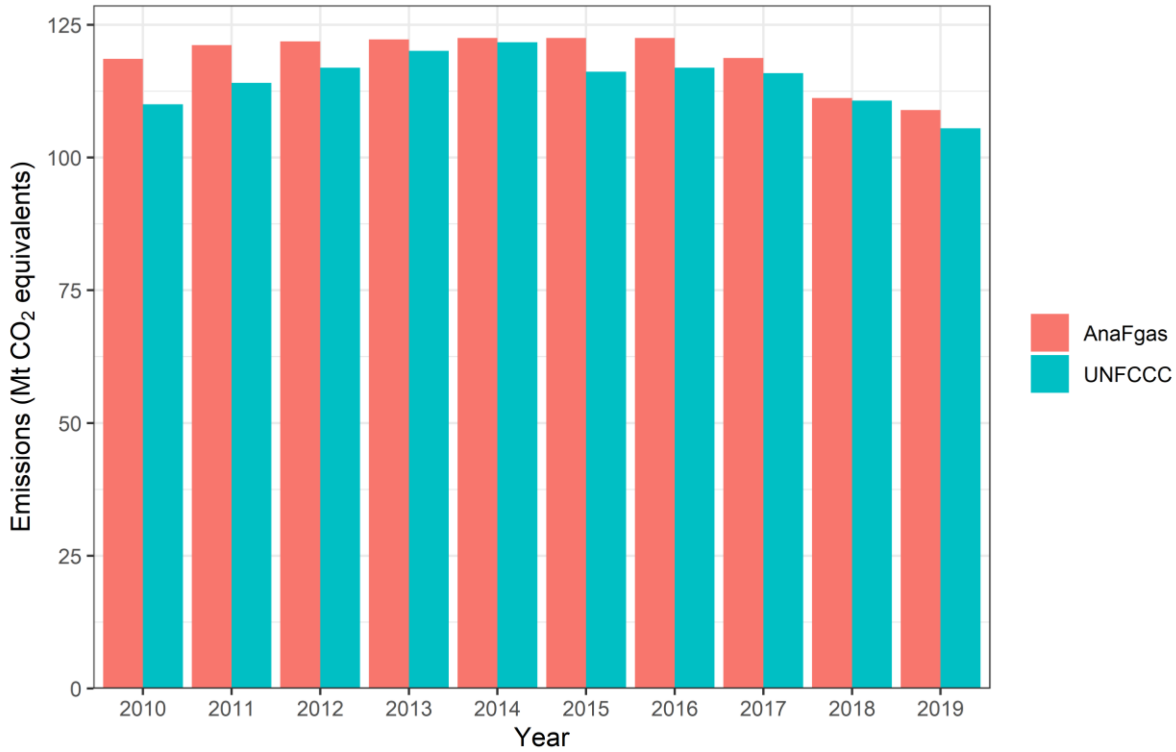

Figure 11: Comparison between the results from the AnaFgas baseline modelling and the reported emissions under UNFCCC (NIR) for the EU-28

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.

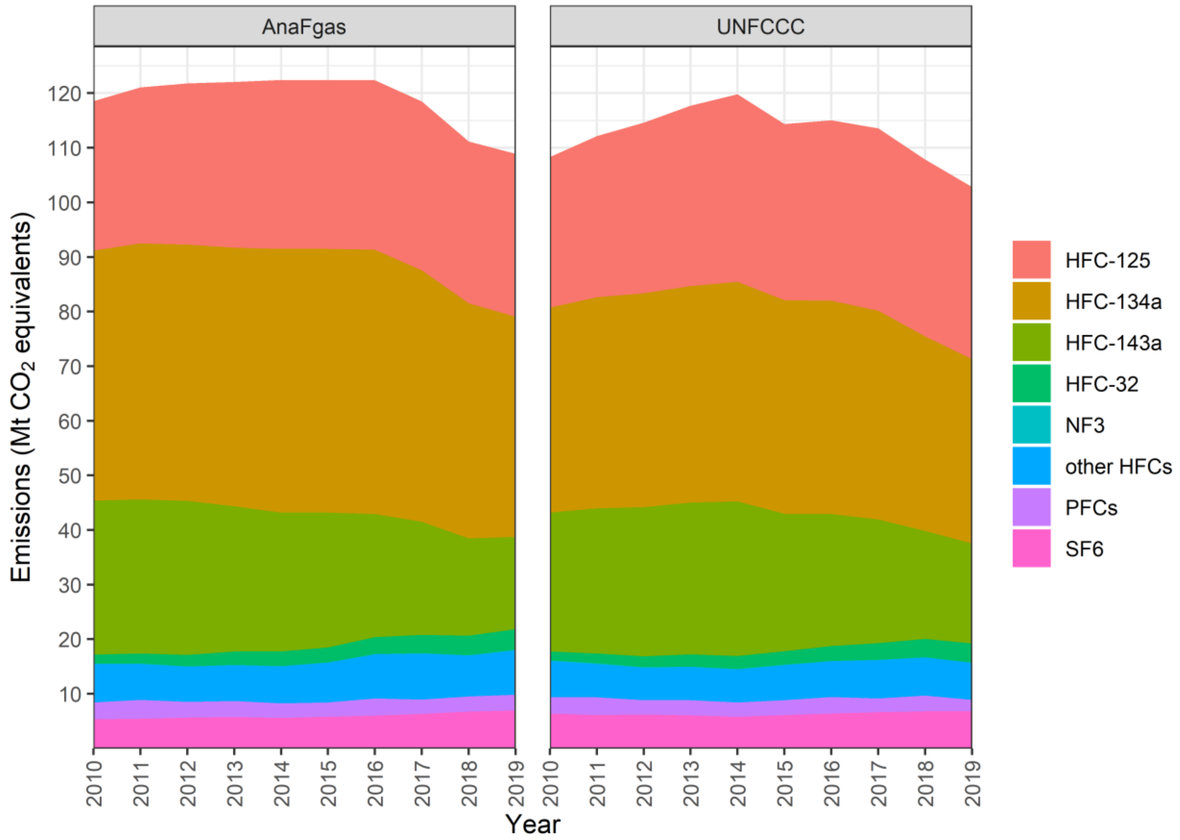

Figure 12: Comparison of the AnaFgas baseline modelling output with the UNFCCC reported EU-28 F-gas emissions by gas/gas group

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).

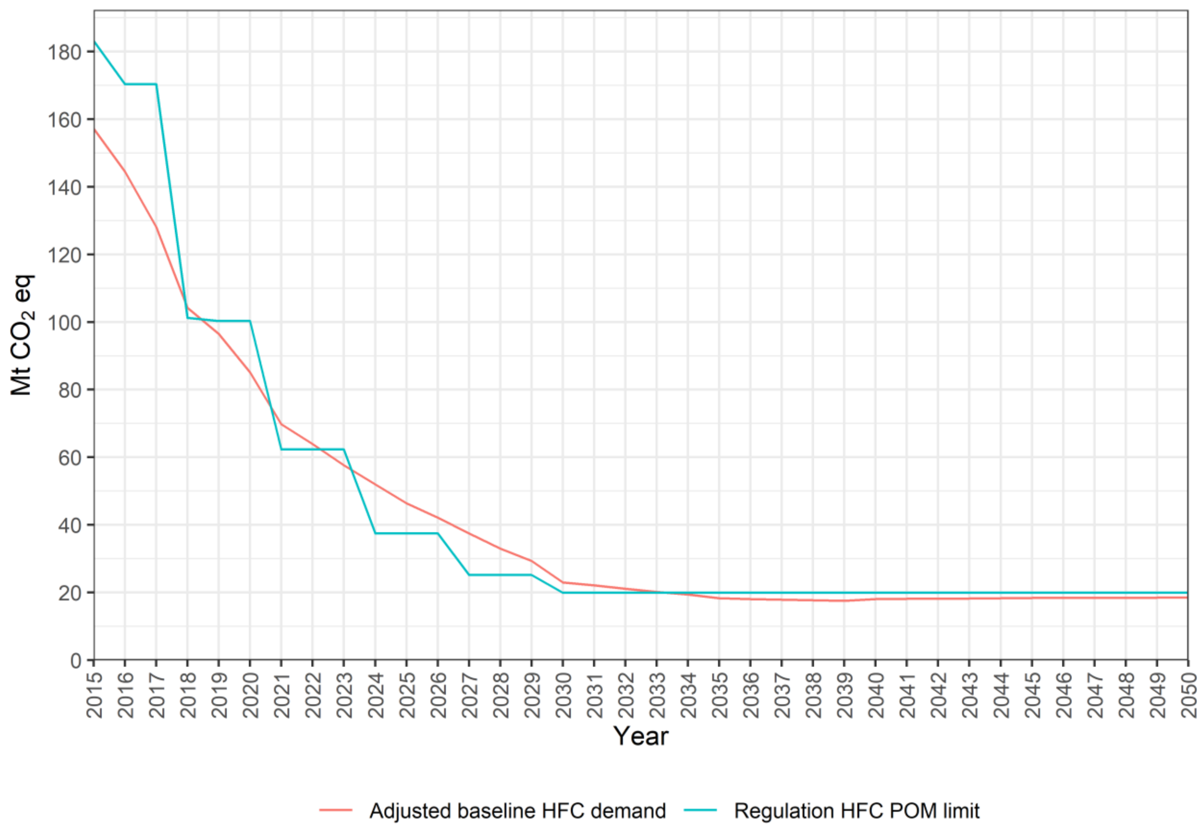

Figure 13. Adjusted HFC demand under the baseline and HFC POM limit under the Regulation

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.

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[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.

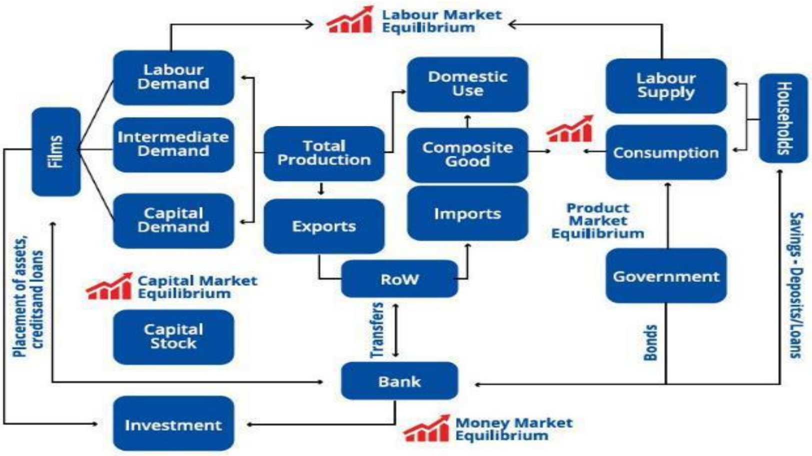

Figure 14. A schematic representation of the JRC-GEM-E3 model
Source: *JRC-GEM-E3 model*

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.