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

CLIMA.A2/ETU/2019/0016

Impact Assessment Final Report – ANNEXES

14 March 2022

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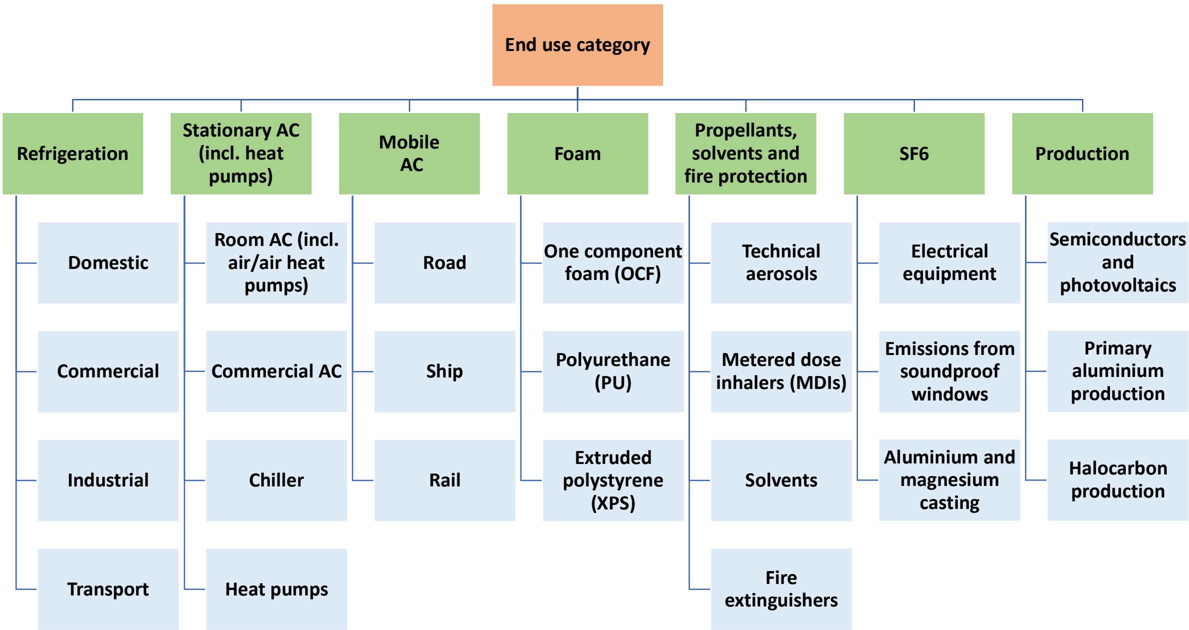
Annex 1: AnaFgas demand and emissions modelling

Annex 1.1: Overview of the model structure

The model AnaFgas was designed as a bottom-up stock model to derive demand and emission scenarios for F-gases in relevant sectors and sub-sectors (Figure 1) for the EU Member States[1].

Figure 1: Overview of the sectors and subsectors covered by the AnaFgas model



Source: Own illustration based on Schwarz et al. (2011)[2]

Certain sub-sectors in Figure 1 are represented in more detail in the model (see Annex to Schwarz et al. 2011):

- **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

[1] For the model application in the 2011 preparatory study, the UK was included in this model, while Croatia was not yet a Member State of the EU and thus not included in the original AnaFgas model. However, Croatia was added in later update of the model in the period 2017 to 2020.

[2] Schwarz, W., et al., 2011, Preparatory study for a review of Regulation (EC) No. 842/2006 on certain fluorinated greenhouse gases. For the EU Commission (DG CLIMA), Final Report.

        - 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

The underlying model logic did not deviate from the previous model in Schwarz et al. (2011) and is described for the different sectors in Annex III to the study[3].

[3] https://ec.europa.eu/clima/sites/clima/files/f-gas/docs/2011_study_annex_en.pdf

For the current projections, 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[4]) and the German Bundesverband Wärmepumpe (bwp[5]). 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)[6] and expert opinion.

For the current projections, the assumptions for the charge size of fluorinated refrigerants in AC units in passenger cars was updated (Table 1). This applies to all scenarios equally.

Table 1: Share and charge of F-gas technologies in MAC in the model

Technology	Unit	2010	2015	2020	2025	2030	2040	2050
HFC-134a-MAC quota of new registered vehicles	%	96%	84%	0%	0%	0%	0%	0%
HFC-1234yf-MAC quota of new registered vehicles	%	0%	12%	95%	91%	86%	82%	77%
R744-MAC quota of new registered vehicles	%	0%	0%	1%	5%	10%	14%	19%
HFC-134a-MAC quota of stock	%	90%	94%	59%	20%	0%	0%	0%
HFC-1234yf-MAC quota of stock	%	0%	2%	37%	75%	91%	84%	79%
R744-MAC quota of stock	%	0%	0%	0%	2%	5%	12%	17%
Charge of new MAC - HFC-134a & HFC-1234yf	kg	0.63	0.50	0.44	0.44	0.44	0.44	0.44
Average charge of MAC in stock - HFC-134a & HFC-1234yf	kg	0.67	0.60	0.53	0.46	0.44	0.44	0.44

Source: AnaFgas modelling

The latest model version features demand for and emissions of HFCs, PFCs and SF_6 as well as unsaturated HFCs and HCFCs 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.

The AnaFgas model is designed to calculate demand and emissions of F-gas gases under different scenarios and will thus be used to derive a baseline, as well as a counterfactual scenario for relevant sectors in the EU. 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.

[4] https://www.ehpa.org/
[5] https://www.waermepumpe.de/
[6] 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

Through these emissions, which occur during the lifetime of the equipment, the lag between use of a chemical and actual emission of this chemical is reproduced. Aggregating emission and use over the different end-uses, the model produces estimates of total year-specific annual demand for, and emissions of each substance expressed in metric or GWP-weighted tonnes.

The stock model requires input regarding the market growth for each of the end-uses, as well as a history of the market penetration of F-gases. To project the use and emissions of F-gases into the future, AnaFgas incorporates the available information about probable evolutions of the end-use market, trends of F-gas substitution and trends of emission factors. It also requires assumptions on future growth trends in different areas such as population development, growth in transport (passenger and freight), change in social structure, consumer habits and lifestyle.

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.

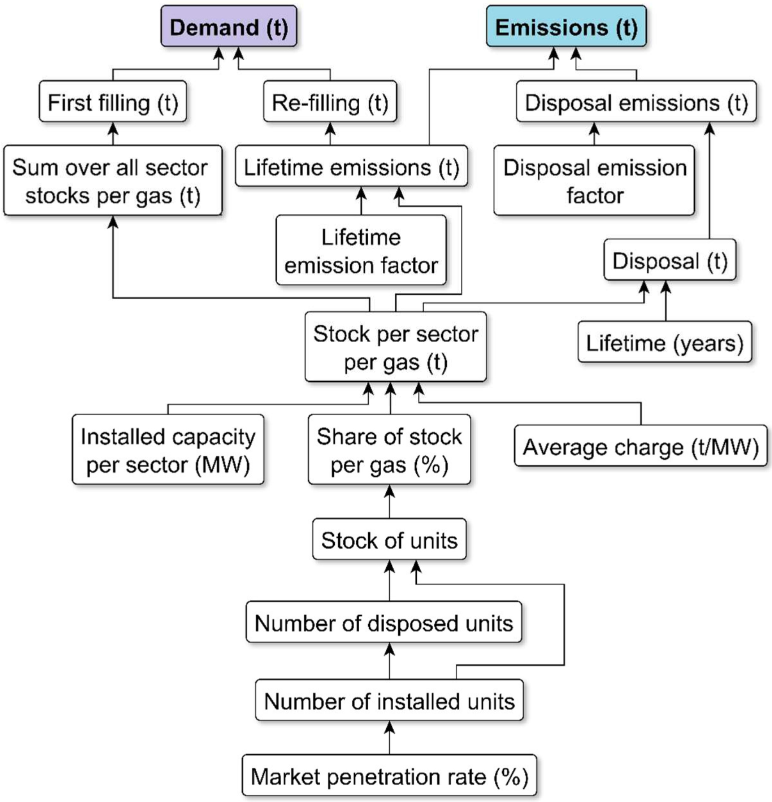
Underlying assumptions for each sector in the model AnaFgas are outlined in detail in the model description in Annex III to the preparatory study (Schwarz et al. 2011). Specific information on each sector for the EU is summarized in the EU sector data sheets.[7] These sector sheets cover economic assessments 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.

Figure 2 gives a very 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 CO_2 eq.

In its latest version, 33 different gases and 12 blends are covered in the model. Those include the most relevant HFCs, PFCs and SF_6 and blends of HFCs.

[7] Examples for EU sector sheets are given in Annex V of the 2011 preparatory study (https://ec.europa.eu/clima/sites/clima/files/f-gas/docs/2011_study_annex_en.pdf)

Figure 2: Simplified overview of the AnaFgas logic to project demand and emissions of F-gases in the EU



Source: Own illustration

Annex 1.2: Emission rates used in the AnaFgas model

The table below shows the annual emission factors applied in the AnaFgas model for the period since 2020 for lifetime, disposal and manufacturing emissions by sector and sub-sector. The assumptions provided in Table 2 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 all scenarios from 2020 used in the model.

There is no difference in the assumed emission rates between scenarios from 2020, because it is not expected that measures under the different scenarios will lead to a further significant reduction in emission rates for the modelled sectors. However, for passenger cars, the model assumes a reduction in charge size until 2020 to 440 g for HFC-1234yf that leads to a further reduction in the average charge of the EU vehicle fleet until 2028. Thus, even with static emission rates, the emissions from the average individual car will decrease until 2028, but this effect is more than compensated by the growing share of vehicles with HFC-1234yf that has its maximum in 2028 with 93 %.

Table 2: 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 (non-food)	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
Propellants, solvents and fire protection			
Aerosols and solvents	100		
Fire extinguishers			
HFC-227ea, HFC-125, HFC-23	2	9	
HFC-134a	4	9	
HFC-236fa	5	9	
SF6			
Electrical equipment	1	5	4
Soundproof windows	1	100	33
Aluminium and magnesium casting			3

Source: AnaFgas modelling

Annex 1.3: F-gas replacement technologies

In the following table, for each sector, F-gas technologies in new equipment in 2020 are shown. Additionally, for the RACHP sectors, natural alternatives are also listed, although they are not represented in the model. Further, replacement F-gas technologies that are assumed in the model for different scenarios, are shown, including, for completeness, natural options.

The current technologies in the model reflect the most important technologies on the market since not all niche applications could be represented. The same applies to the replacement technologies. They represent a selection, based on expert assessment and stakeholder consultations, but do not claim to be exhaustive. This especially applies to later years in the model because assessments of future technologies are increasingly uncertain with time.

Table 3: Technologies used in new equipment in all modelled sectors in 2020 and their potential replacements in the future

Sector	Current technologies	Replacement technologies
Refrigeration		
Commercial		
Domestic	*Isobutane*	
	HFC-134a	
Central systems	HFC-134a	HFC-1234ze(E) with CO_2/CO_2 cascade
	R404A	
	R513A	
	R448A/R449A	
	HCs with secondary liquid and CO_2	
	HCs with CO_2/CO_2 cascade	
	CO_2 transcritical	
Condensing units	HFC-134a	R454C/R455A
	R404A	*Propane with secondary liquid*
	R513A	
	R448A/R449A	
	Propane direct	
	CO_2	
Hermetic units	HFC-134a	
	R454C/R455A	
	Isobutane	
	Propane direct	
Industrial		
Food	R404A	
	HFC-134a	
	R513A	
	Ammonia	
	CO_2	
Non-food	R404A	
	R513A (also with CO_2 cascade)	
	HFC-134ze(E)	
	Ammonia	
Transport		
Vans	R404A	R454C/R455A
	HFC-134a	*CO_2*
	R513A	*HCs*

Sector	Current technologies	Replacement technologies
	R452A	
Trucks and trailers	R404A	R513A
	R452A	R454C/R455A
		CO_2
Fishing vessels	R404A	
	R452A	
	Ammonia	
	CO_2	
Stationary AC		
Moveable units	*Propane*	
Small split units incl. air/air heat pumps	R410A	*Propane*
	HFC-32	
Large split and VRF units	R410A	*Propane*
	HFC-32	*CO_2*
		R454C/R455A
Packaged equipment (incl. rooftop units)	R410A	R454C/R455A
	HFC-32	
	Propane	
Displacement chillers	R410A	*Propane*
	R407C	R454C/R455A
	HFC-134a	
	HFC-32	
	R513A	
	HFC-1234ze(E)	
	Water	
	Ammonia	
	HCs	
Centrifugal chillers	HFC-134a	
	HFC-134ze(E)	
	HCFC-1233zd(E)	
	CO_2	
	Ammonia	
Heat pumps (small)	R410A	
	HFC-134a	
	HFC-32	
	R513A	
	HCs	
Heat pumps (medium)	R410A	HFC-134ze(E)
	HFC-134a	R513A
	HFC-32	R454B
	HCs	
Heat pumps (large)	HFC-134a	HFC-134ze(E)
	Ammonia/R723	
	CO_2	
Mobile AC		
Passenger cars	HFC-1234yf	
	CO_2	
Buses	HFC-134a	R513A
	CO_2	

Sector	Current technologies	Replacement technologies
	HCs	
Trucks N1	HFC-134a	
	HFC-1234yf	
	CO_2	
Trucks N2/N3	HFC-134a	HFC-1234yf
		CO_2
Tram	HFC-134a	R513A
		CO_2
		Air
Metro	HFC-134a	R513A
		CO_2
Train	HFC-134a	R513A
	R407C	
	CO_2	
	Propane	
	Air	
Passenger ships	HFC-134a	*Possibly water or air*
	R513A	
Cargo ships	HFC-134a	*Ammonia/brine*
	R513A	
Foams		
One-component	HFC-134a	
	HFC-1234ze(E)	
	HCs	
Extruded polystyrene (XPS)	HFC-134a	*HCs*
	HFC-152a	
	HFC-1234ze(E)	
	CO_2	
Polyurethane (spray)	HFC-365mfc	HFC-1336mzz(Z)
	HFC-245fa	HCFC-1233zd(E)
	HFC-134a	
	Water	
	CO_2	
Polyurethane (non-spray)	HFC-365mfc (also blended with HFC-227ea)	HFC-1336mzz(Z)
	HFC-245fa	HCFC-1233zd(E)
	HFC-134a	
	HCs	
Propellants, solvents and fire protection (only fluorinated gases)		
Aerosols	HFC-152a	
	HFC-1234ze(E)	
MDIs	HFC-134a	HFC-152a
	HFC-227ea	HFC-1234ze(E)
Solvents	HFC-43-10mee	
	HFC-365mfc	
	C_6F_{14}	
	HCFC-1233zd(E)	
Fire extinguishers	HFC-227ea	
	HFC-125	
	HFC-236fa	
	FK-5-1-12	

Sector	Current technologies	Replacement technologies
SF6 (only fluorinated gases)		
Electrical equipment	SF_6	C_3F_7CN/CO_2
		$CF_3C(O)CF(CF_3)_2$
Emissions from soundproof windows	SF_6	
Aluminium and magnesium casting	SF_6	
	Fluorinated ketone	
Production (only fluorinated gases)		
Semiconductors and photovoltaics	HFC-23	
	HFC-32	
	NF_3	
	SF_6	
	CF_4	
	C_2F_6	
	C_3F_8	
	c-C_4F_8	
Primary aluminium production	CF_4	
	C_2F_6	
Emissions from halocarbon production	HFC-23	
	HFC-134a	
	HFC-143a	
	HFC-32	
	HFC-125	
	HFC-227ea	
	HFC-365mfc	
	CF_4	
	C_3F_8	
	C_4F_{10}	
	C_6F_{14}	

Annex 1.4: 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:

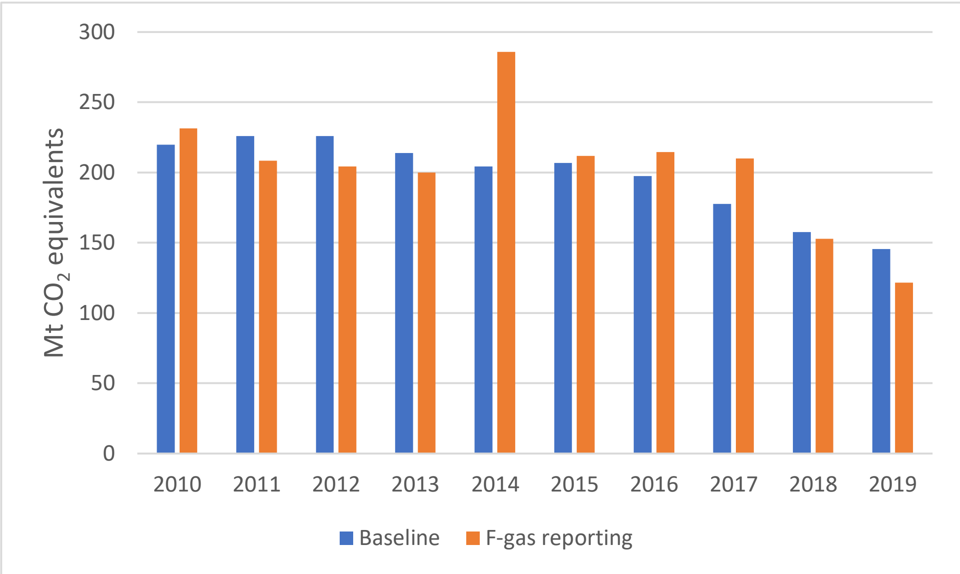
- It must be noted, however, that supply as defined and calculated by the EEA [EEA 2020 public report] is not the same metric as demand used in the AnaFgas modelling. The AnaFgas demand covers the gases which are needed for the operation of equipment in the EU. In the supply metric, additionally, those 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 be 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.

When comparing demand and supply, the metrics do align closely for certain years but deviate for others (Figure 3 and Table 4). Especially in 2014, the supply is substantially higher than the modelled demand, while in 2019 the reverse is the case. The underlying causes cannot be specified precisely but 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 because of the phase-down. Stocks are not part of the derivation of demand, however, and this is the reason why 2014 shows no increase in the modelling.

For the methodological reasons stated above, it is expected that the supply is usually higher than the demand. Looking at Figure 3 this is not always the case. However, there is no direct explanation for the discrepancies between demand and supply in the years 2010 to 2013, 2016 to 2017 and 2019. Some of these differences may be explained by year-to-year carryover effects, in particular the delta changes between negative and positive.

Figure 3: 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, EEA 2020

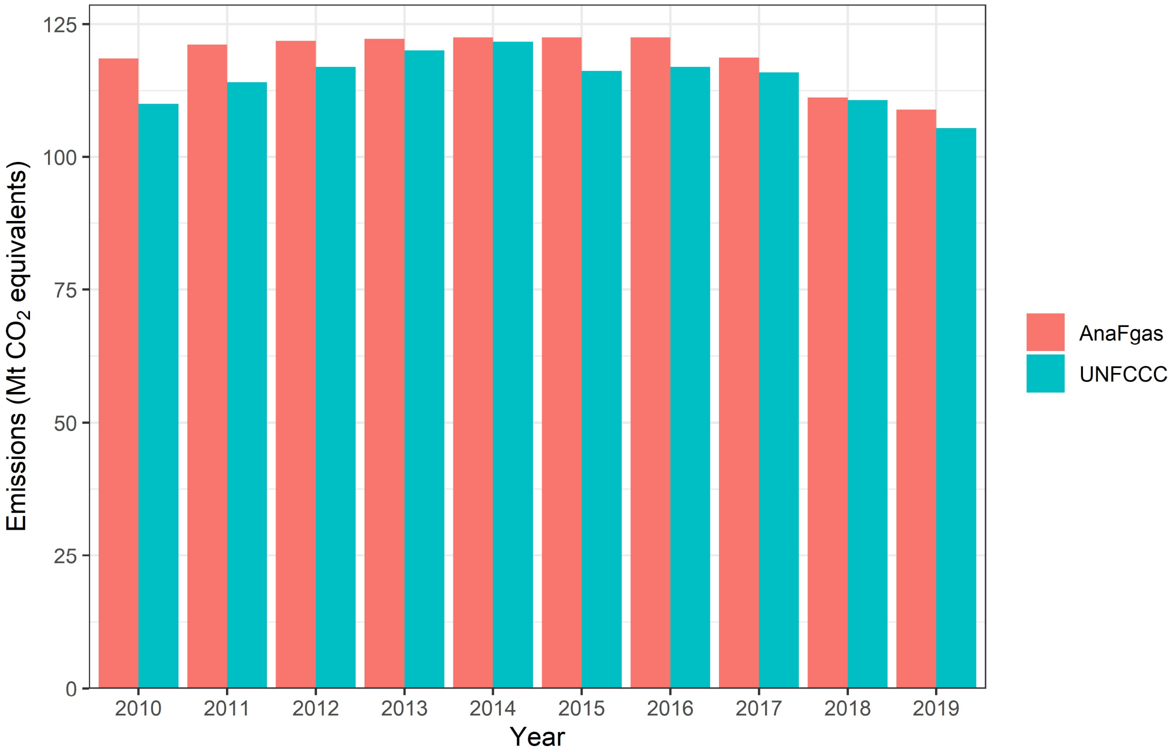
Table 4: Comparison of the modelled baseline F-gas demand and the reported F-gas supply in the EU-28

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 CO_2 eq than stated in the UNFCCC NIR (Figure 4 and Table 5) but the deviations are small (on average 3 %). Since the UNFCCC data is based on estimations, it is not possible to specify reasons for the deviations. Possible explanations could be differences in the assumed emission rates for different sectors and subsectors or charge sizes for different equipment. In any case, the deviations are small and are likely within the uncertainties of both models.

Figure 4: 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)

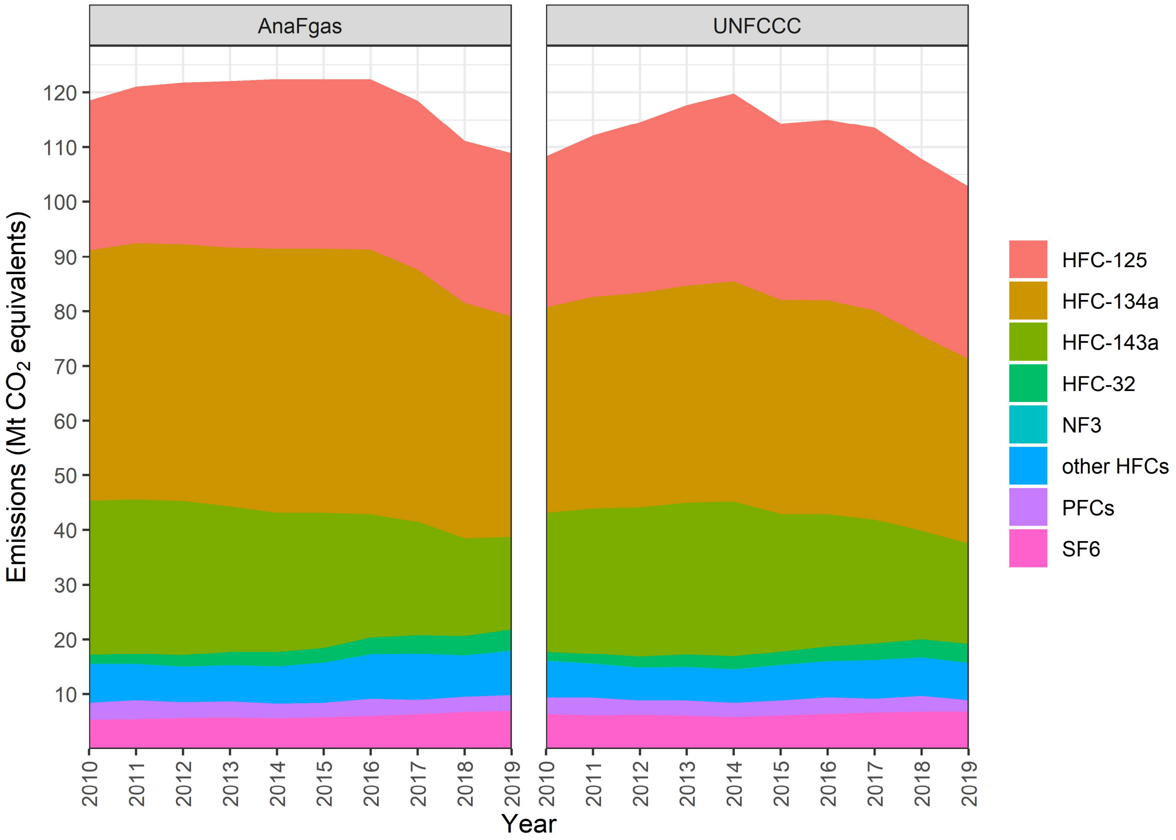
Table 5: Comparison of AnaFgas baseline modelling output with the NIR reported EU-28 F-gas emissions

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 5). 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, assumes are 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 5: 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)

Annex 1.5: Baseline projection of modelled demand and emissions until 2050

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[8], the baseline scenario from the AnaFgas modelling that represents the effect of the current Regulation until 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 assured 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.

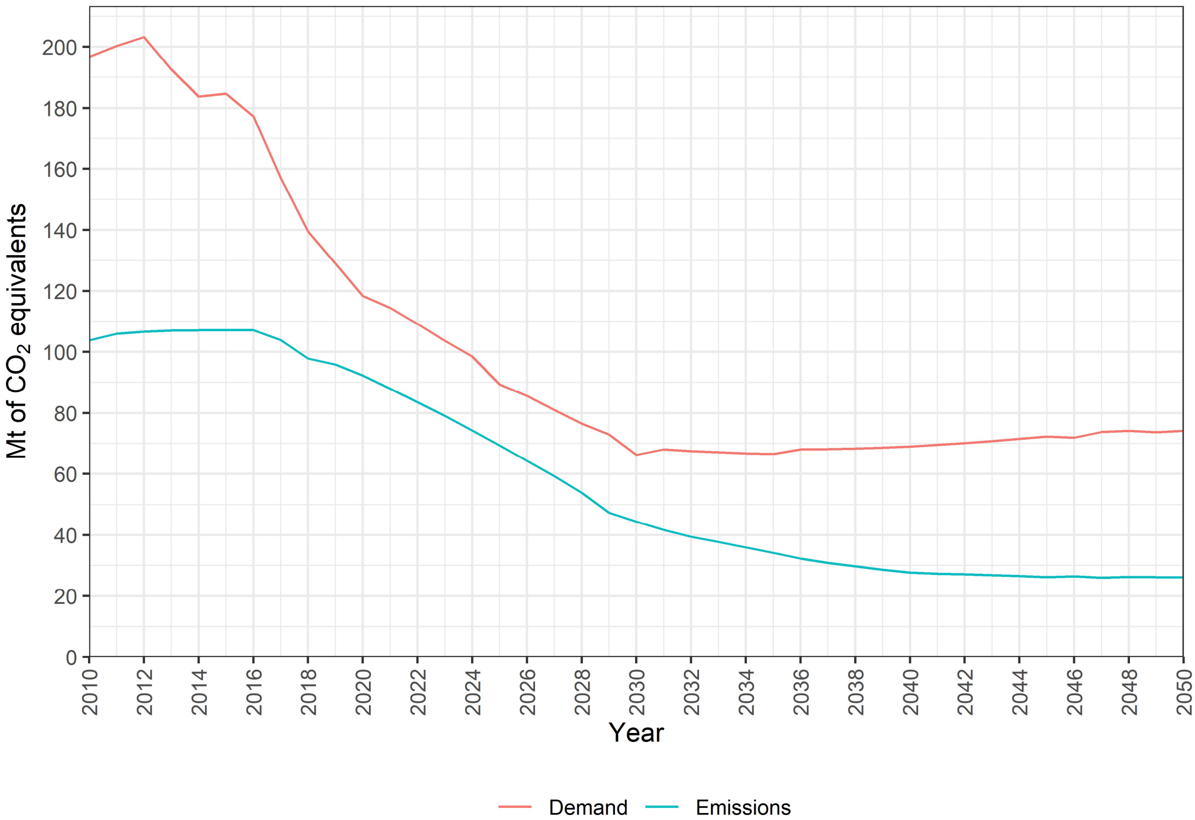
Demand for F-gases is expected to decrease until 2030 to ca. 6 Mt CO_2 eq and then show a moderate increase until 2050 to ca. 74 Mt CO_2 eq (Figure 6). Emissions will also decrease until 2030 to ca. 44 Mt CO_2 eq and, with less acceleration, to ca. 26 Mt CO_2 eq until 2050.

The increase in demand from 2030 is solely due to the increasing demand for SF_6 in electrical switchgear (Figure 7). This sector shows a comparatively small increase in emissions because the increasing demand is for export to non-EU countries. Thus, emissions of SF_6 from this sector are mainly from

[8] Support contract for an Evaluation and Impact assessment for amending Regulation (EU) No 517/2014 on fluorinated greenhouse gases. CLIMA.A2/ETU/2019/0016. September 2021. Evaluation Final Report by Öko-Recherche, Ricardo and Öko-Institut.

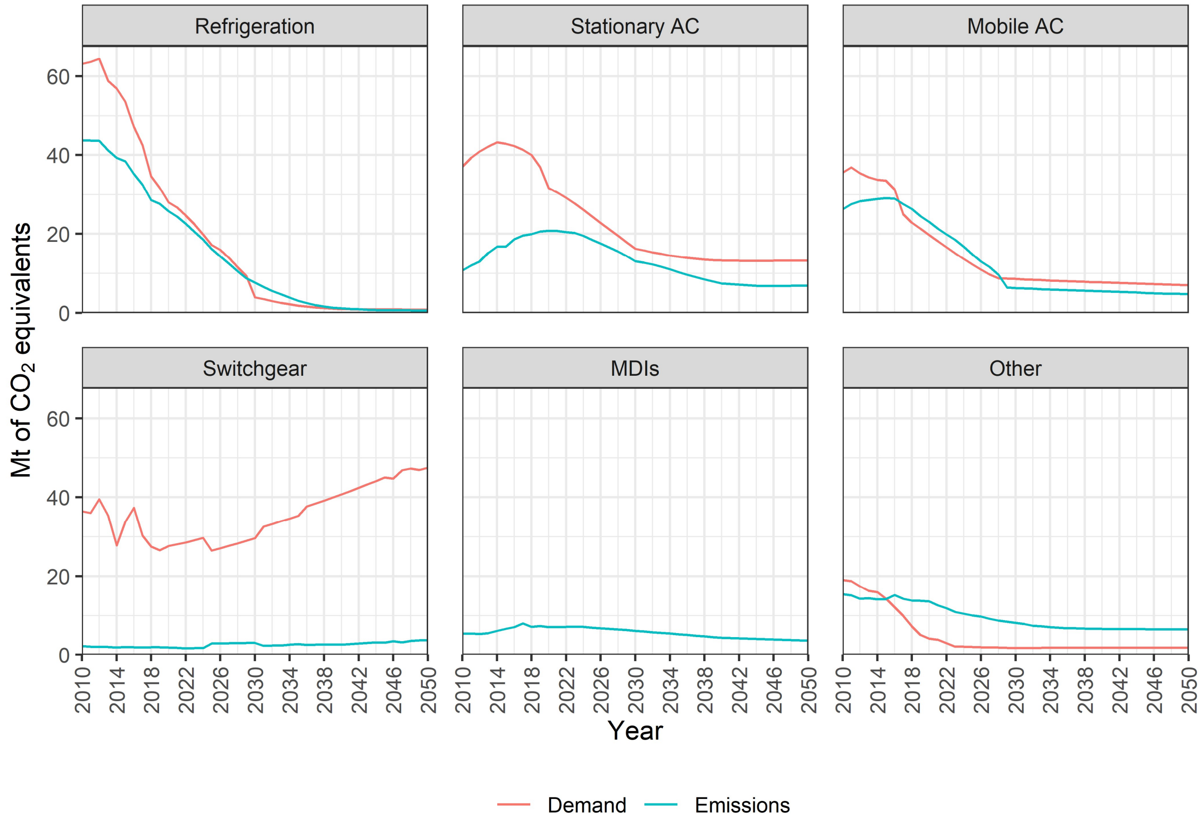
production for export. All other sectors show a decrease in demand and emissions after 2030, but this is only pronounced in refrigeration applications, while other sectors nearly stagnate.

Figure 6: Modelled demand and emissions of F-gases in the EU27 under the baseline scenario



Source: AnaFgas modelling

Figure 7: Modelled demand and emissions of F-gases in the EU27 under the baseline scenario by important sector



Source: AnaFgas modelling

Assumed reclamation of HFCs

For the modelling exercise, future potential reclamation rates are being assessed 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 6 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 MP alignment scenarios show the highest absolute reclamation quantities in Mt CO_2 eq, the more ambitious scenarios (proportionate action and maximum feasibility) show a higher share of reclamation of the demand. Higher ambition leads to a quicker replacement of high-GWP gases in new equipment, which in turn limits the future available quantities for reclamation at EoL of this new equipment This is why the share of reclamation of the demand decreases also for the more ambitious scenarios.

Table 6: Assumed reclamation quantities of HFCs in the EU-27

	Mt CO_2 eq				% of gas in EoL equipment				% of demand			
Year	**BL**	**MP**	**PA**	**MF**	**BL**	**MP**	**PA**	**MF**	**BL**	**MP**	**PA**	**MF**
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%	20%	21%
2030	6	6	5	6	22%	22%	21%	22%	20%	16%	34%	40%
2035	6	6	3	3	32%	31%	19%	24%	24%	20%	26%	41%
2040	4	4	2	2	40%	28%	45%	43%	18%	19%	24%	28%
2045	3	3	1	1	38%	28%	43%	42%	14%	17%	20%	22%
2050	3	3	1	1	33%	35%	38%	45%	12%	16%	20%	25%

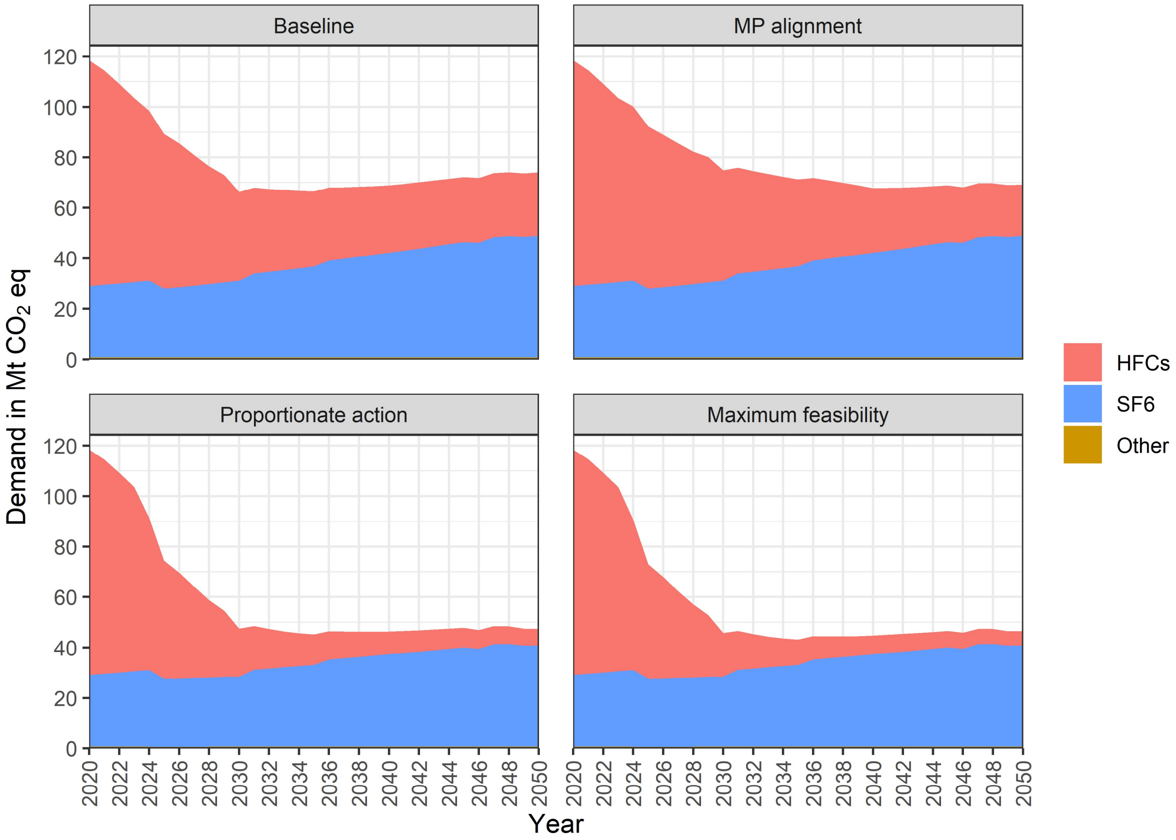
Source: AnaFgas modelling

Generally, an estimation of future reclamation rates is difficult and deviations from the assumed rates are likely, 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.

Demand from 2020 to 2050

Under the baseline scenario, the demand of F-gases in Mt CO_2 eq decreases rapidly until 2030 but increases slightly thereafter until 2050. This latter increase is only driven by the increasing demand for SF_6 (Figure 8 and Table 7). The demand for HFCs decreases from 89 Mt CO_2 eq in 2020 to 25 Mt CO_2 eq in 2050, while the demand for SF_6 increases from 28 to 48 Mt CO_2 eq. Other F-gases include unsaturated HFCs, PFCs and NF_3 and only contribute with less than 1 Mt CO_2 eq per year to the demand between 2020 and 2050.

Figure 8: Modelled demand of F-gases in the EU-27 under the different scenarios



Source: AnaFgas modelling

Table 7: Modelled demand of F-gases in Mt CO_2 eq under the different scenarios in the EU-27

Year	Gas group	BL	MP	PA	MF	MP-BL	PA-BL	MF-BL
2020	**Total**	**118**	**118**	**118**	**118**	**0 (-)**	**0 (-)**	**0 (-)**
	HFCs	89	89	89	89	0 (-)	0 (-)	0 (-)
	SF6	28	28	28	28	0 (-)	0 (-)	0 (-)
	Other	1	1	1	1	0 (-)	0 (-)	0 (-)
2025	**Total**	**89**	**92**	**74**	**73**	**3 (3%)**	**-15 (-17%)**	**-16 (-18%)**
	HFCs	61	64	47	45	3 (5%)	-15 (-24%)	-16 (-26%)
	SF6	27	27	27	27	0 (-)	0 (-1%)	0 (-1%)
	Other	1	1	1	1	0 (0%)	0 (-17%)	0 (-17%)
2030	**Total**	**66**	**75**	**47**	**46**	**9 (13%)**	**-19 (-28%)**	**-21 (-31%)**
	HFCs	35	44	19	17	9 (24%)	-16 (-46%)	-18 (-51%)
	SF6	30	30	28	28	0 (-)	-3 (-9%)	-3 (-9%)
	Other	1	1	1	1	0 (0%)	0 (-12%)	0 (-12%)
2035	**Total**	**66**	**71**	**45**	**43**	**5 (7%)**	**-21 (-32%)**	**-23 (-35%)**
	HFCs	30	34	12	10	5 (16%)	-18 (-59%)	-20 (-66%)
	SF6	36	36	32	32	0 (-)	-4 (-10%)	-4 (-10%)
	Other	1	1	1	1	0 (0%)	0 (-11%)	0 (-11%)
2040	**Total**	**69**	**68**	**46**	**45**	**-1 (-2%)**	**-23 (-33%)**	**-24 (-35%)**

	HFCs	27	25	9	7	-1 (-4%)	-18 (-66%)	-19 (-72%)
	SF6	42	42	37	37	0 (-)	-5 (-12%)	-5 (-12%)
	Other	1	1	1	1	0 (0%)	0 (-10%)	0 (-10%)
2045	**Total**	**72**	**69**	**48**	**47**	**-3 (-5%)**	**-24 (-34%)**	**-26 (-36%)**
	HFCs	26	22	8	6	-3 (-13%)	-18 (-70%)	-19 (-75%)
	SF6	46	46	39	39	0 (-)	-6 (-14%)	-6 (-14%)
	Other	1	1	1	1	0 (0%)	0 (-9%)	0 (-9%)
2050	**Total**	**74**	**69**	**47**	**46**	**-5 (-7%)**	**-27 (-36%)**	**-28 (-37%)**
	HFCs	25	20	6	6	-5 (-19%)	-19 (-74%)	-19 (-78%)
	SF6	48	48	40	40	0 (-)	-8 (-17%)	-8 (-17%)
	Other	1	1	1	1	0 (0%)	0 (-8%)	0 (-8%)

Source: AnaFgas modelling

Note: BL is baseline, MP is MP alignment, PA is proportionate action, MF is maximum feasibility

Under all scenarios, the demand for HFCs in Mt CO_2 eq will decrease strongly for refrigeration equipment. This is mainly driven by the decreasing use of R404A in new equipment and applies to both virgin gas and reclaimed quantities (Figure 9). Since 2020, the use of virgin R404A is prohibited in stationary refrigeration equipment in the temperature range above -50 °C with a charge size above and including 40 tonnes of CO_2 eq (excl. military equipment) but reclaimed gas can still be used. From 2030, the use of reclaimed R404A in this type of refrigeration equipment is also prohibited.

Demand for HFCs in air conditioning applications will decrease until 2030 and then stagnate for both stationary and mobile equipment. The major driver for this change is the replacement of the blend R410A with HFC-32 and HFC-134a with the unsaturated HFC-1234yf in passenger cars. The latter is due to the MAC directive.

Demand of SF_6 for electrical switchgear has the largest share of the total demand and is increasing until 2050. This is due to the assumed growth of the sector of 2 % each year (ZVEI 2020[9]).

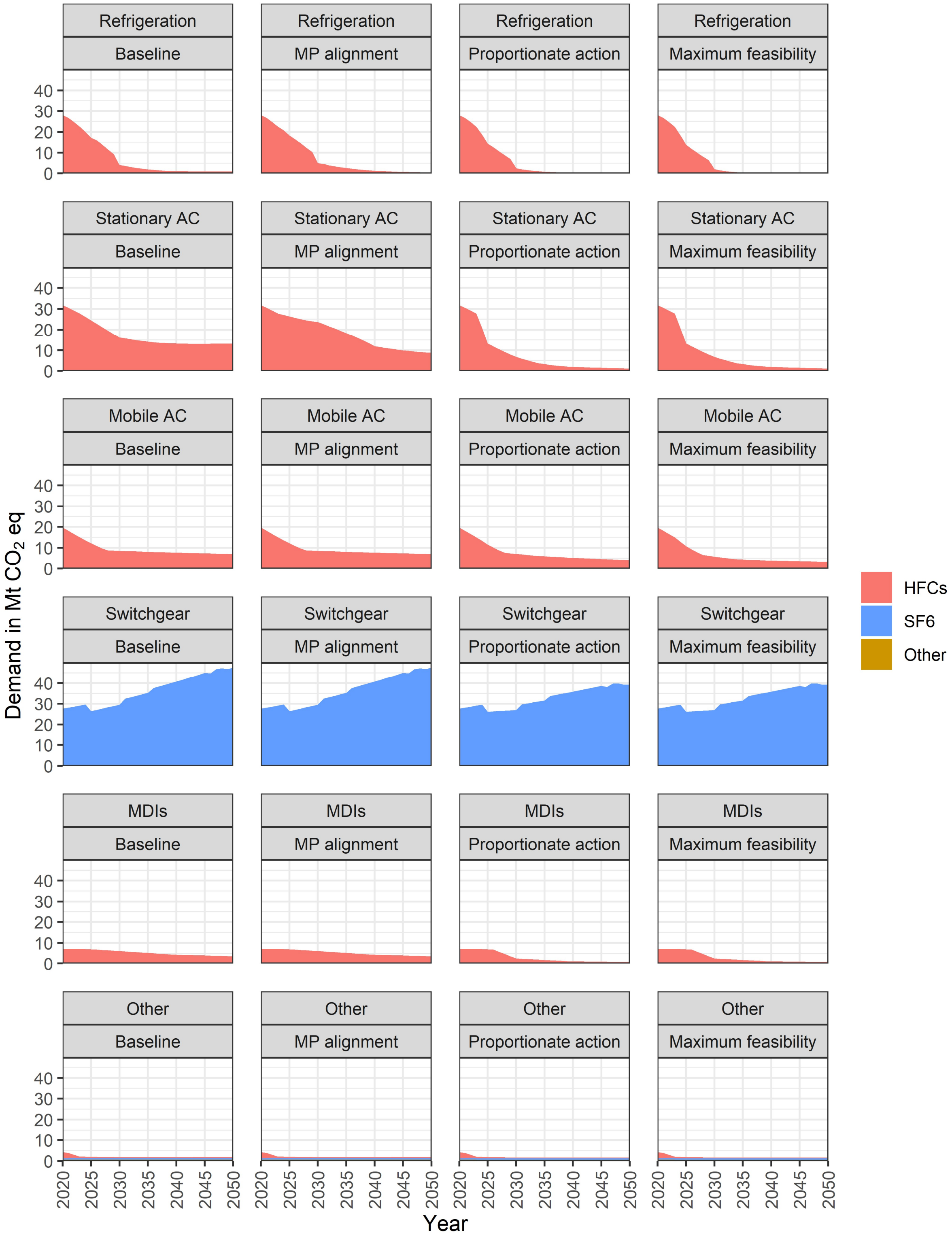
Most of all metered dose inhalers (MDIs) use HFC-134a as a propellant but HFC-227ea is also used, albeit to a lesser degree. As of 2020, there are no alternative propellants available for medical applications but starting in late 2025, HFC-152a (GWP 124) will be introduced on the market after an extensive period of testing[10]. Apart from that, research is currently conducted on the safety of the unsaturated HFC-1234ze (GWP 7)[11]. To date, it is not possible to properly assess the development on the market for this sector. For one, no alternative is of yet on the market and it is not clear in what capacity HFC-134a and HFC-227ea will still be needed for specific medication, due to health benefits that could outweigh environmental concerns.

For the modelling, assumptions were based on industry information and for the baseline scenario, a decrease in the share of HFC-134a in new inhalers from 92 % in 2020 to 48 % in 2050 was assumed. For HFC-227ea, the assumed decrease was from 8 to 2 %. At the same time, an increase in the share in new inhalers with HFC-152a from 1 % in 2026 to 50 % in 2050 was assumed.

All other sectors only contributed relatively little to the overall demand and will be discussed in detail in the following.

[9] 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
[10] Information from Koura
[11] Information from AstraZeneca

Figure 9: Modelled demand of F-gases in the EU-27 under the different scenarios by important sector



Source: AnaFgas modelling

Table 8: Sum of modelled cumulative demand of F-gases in Mt CO_2 eq from 2024 to 2050 for the different scenarios for important sectors in the EU-27

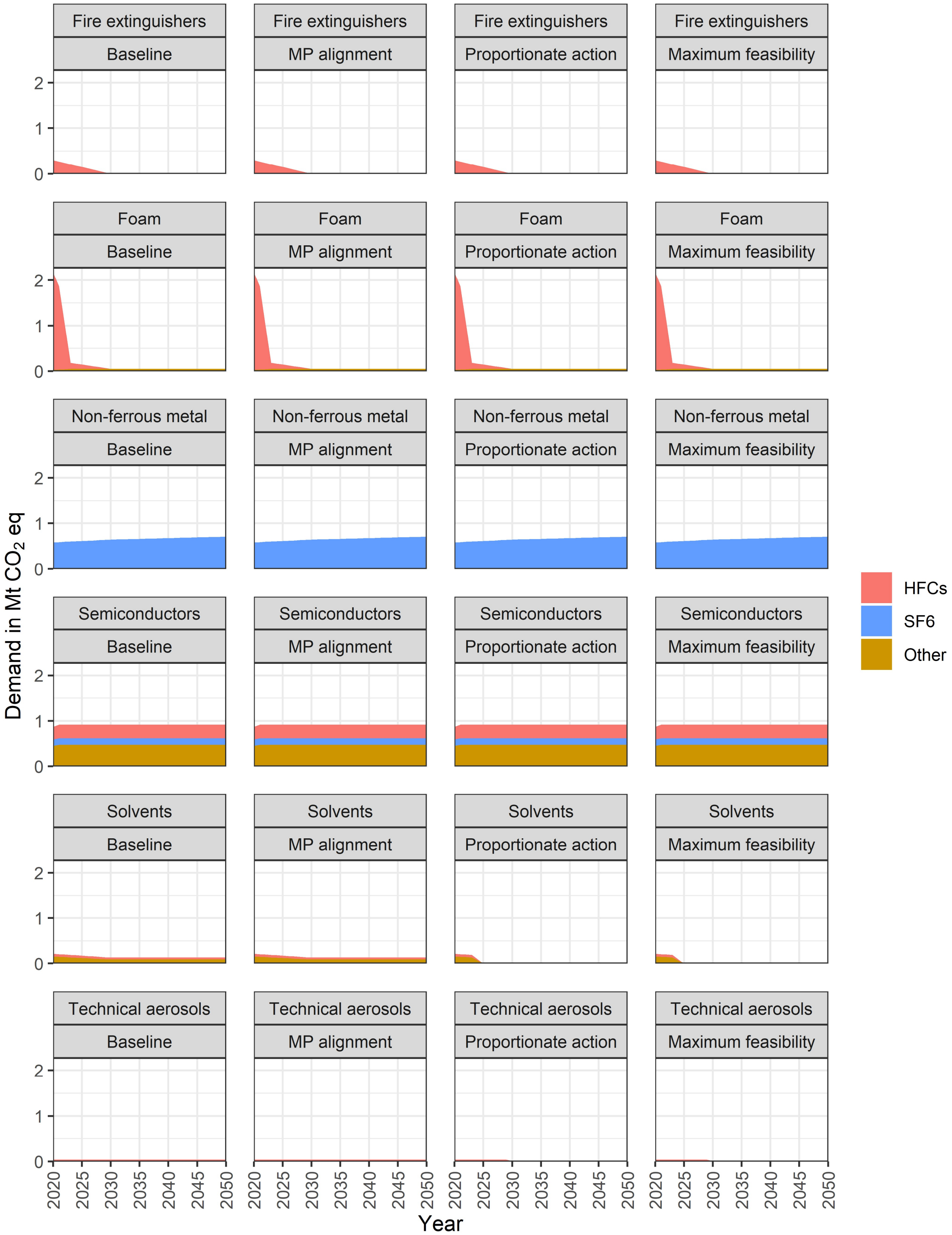
Sector	BL	MP	PA	MF	MP-BL	PA-BL	MF-BL
Refrigeration	120	130	85	76	10 (8%)	-35 (-29%)	-44 (-37%)
Stationary AC	422	452	130	130	29 (7%)	-292 (-69%)	-292 (-69%)
Mobile AC	226	226	171	139	0 (-)	-55 (-24%)	-87 (-38%)
Switchgear	1 013	1 013	901	901	0 (-)	-113 (-11%)	-113 (-11%)
MDIs	138	138	66	66	0 (-)	-72 (-52%)	-72 (-52%)
Other	50	50	46	46	0 (-)	-4 (-9%)	-4 (-9%)
Total	**1 970**	**2 009**	**1 399**	**1 358**	**39 (2%)**	**-571 (-29%)**	**-612 (-31%)**

Source: AnaFgas modelling

Note: BL is baseline, MP is MP alignment, PA is proportionate action, MF is maximum feasibility

The sector “Other” comprises different sectors that contribute less to the overall demand than the other sectors but nonetheless is a significant source of F-gas emissions (Figure 10 and Table 9). While the F-gas demand for fire extinguishers and foam decreases strongly until 2030, all other sectors show mostly continuous or increasing demand until 2050. Between scenarios, only solvents and, to a very small degree, technical aerosols show a difference, with a stronger reduction in the PA and MF scenarios, compared with the baseline and the MP scenario.

Figure 10: Modelled demand of F-gases in the EU-27 under the different scenarios by subsector in the sector “Other”



Source: AnaFgas modelling

Table 9: Sum of modelled cumulative demand of F-gases in Mt CO_2 eq from 2020 to 2050 for the different scenarios for sectors labelled as "Other" in the EU-27

Sector	BL	MP	PA	MF	MP-BL	PA-BL	MF-BL
Fire extinguishers	2	2	2	2	0 (-)	0 (-)	0 (-)
Foam	7	7	7	7	0 (-)	0 (-)	0 (-)
Non-ferrous metal	20	20	20	20	0 (-)	0 (-)	0 (-)
Semiconductors	28	28	28	28	0 (-)	0 (-)	0 (-)
Solvents	5	5	1	1	0 (-)	-4 (-80%)	-4 (-80%)
Technical aerosols	1	1	1	1	0 (-)	0 (-)	0 (-)
Total	**63**	**63**	**59**	**59**	**0 (-)**	**-4 (-6%)**	**-4 (-6%)**

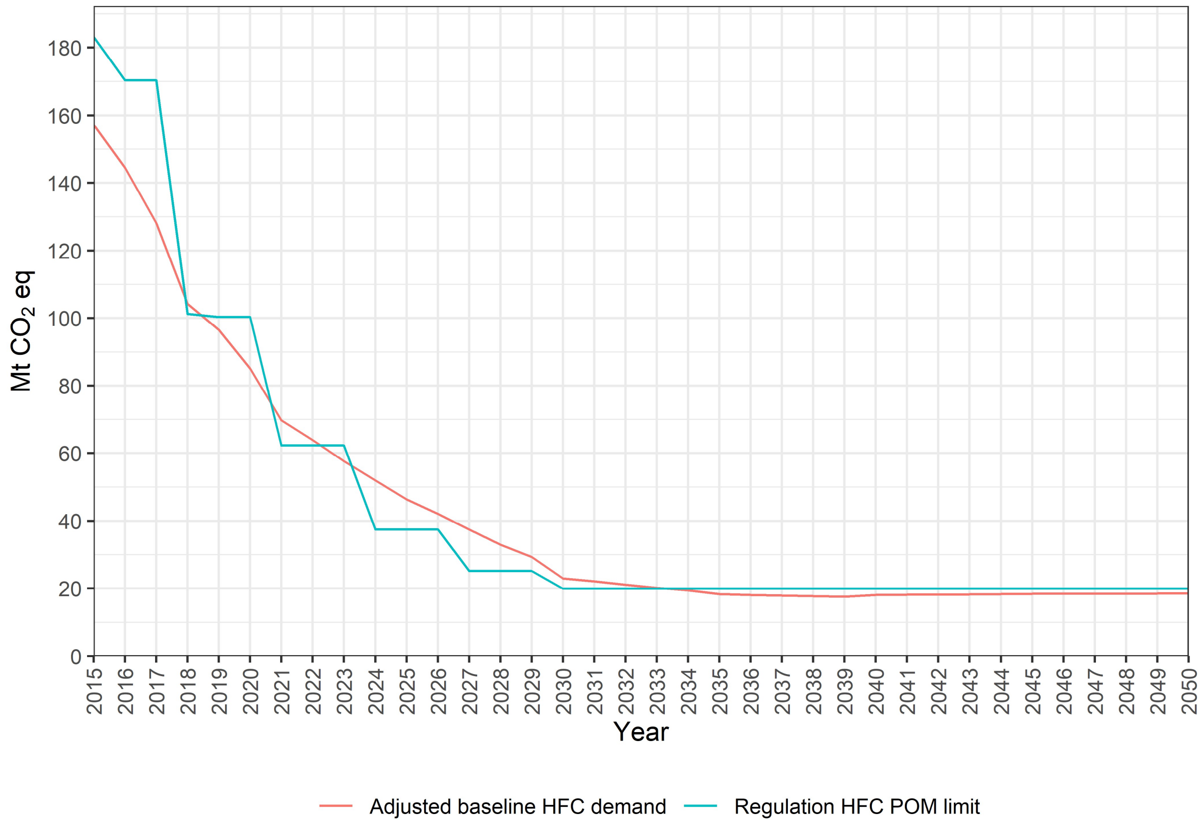
Source: AnaFgas modelling

Note: BL is baseline, MP is MP alignment, PA is proportionate action, MF is maximum feasibility

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 close as possible with 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 6, were subtracted from the demand. **Fehler! Verweisquelle konnte nicht gefunden werden.** 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 11: Adjusted HFC demand under the baseline and HFC POM limit under the Regulation



Source: AnaFgas modelling

Annex 1.6: HFC POM phase-down (measure A1.1)

Modelling scenario definitions

Scenario 1: Montreal Protocol alignment (MP alignment, MP)

The Montreal 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 Montreal Protocol.

As discussed in Annex 6, the ambition of the POM phase-down of FGR 2014/517 is not sufficient to ensure EU compliance with the HFC consumption phase-down after 2033 in the case that EU HFC consumption outside the scope of the FGR POM phase-down remains high. This relates in particular to the HFC demand for use in the quota-exempted MDI sector. On the other hand, a lift of the MDI quota exemption is foreseen for all policy options, including the MP alignment option.

Like the baseline, the MP alignment scenario 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 the MP alignment scenario was calculated by adding a high estimate of HFC demand for MDIs[12] to account for lifting the MDI exemption and introducing additional POM reduction steps in the triennial intervals established under FGR 2014/517, for 2033 and for 2036 in order to meet the consumption ceilings set by the MP for the EU for 2034 and 2036.

[12] 11.5 Mt CO_2eq/year, consistent with the 'high consumption scenario discussed in the MP compliance scenario analysis in Annex 6.

As the 'best guess' HFC demand for MDIs modelled in AnaFgas is lower than the 'worst case' HFC demand for MDIs considered for increase of the POM limit, additional HFC demand from other sectors is possible in the years 2024-2032 under this scenario. In consequence, overall EU HFC demand 2024-2030 in the MP alignment scenario is higher than in the baseline, leading to higher emissions with the respective lead times. After 2033, however, overall HFC demand in the MP alignment scenario is below the baseline and safely meets the MP HFC consumption limits 2034 onwards which were found to be at stake under the baseline.

Scenario 2: Achieve proportionate emission savings and implementation improvements (Proportionate action, PA)

This scenario goes beyond scenario 1 and, while also ensuring Montreal Protocol alignment, it assumes transitioning to low-GWP technologies in all areas where the abatement costs do not exceed 390 € per tonne of CO_2 equivalent, as a proportionate contribution. This is in line with the long-term strategy[13] that sets the carbon value at 390 €/t CO_2 eq[14].

For sectors, in which safety issues can be a concern, mainly due to flammability in combination with charge size, a slower transition to low-GWP alternatives was assumed. For these sectors, building codes and standards, as well as liability issues can present an obstacle that might lead to reluctance in stakeholders to pursue a fast transition to low-GWP technologies.

This scenario includes the following POM prohibitions: A2.1, A2.2, A2.6, A2.7 and A2.8.

Scenario 3: Maximum feasibility and implementation improvements (Maximum feasibility, MF)

The final scenario projects full transitioning to low-GWP technologies in all areas where this transition is technically possible without regarding economic or social aspects. In effect, this means fast and complete replacement of high-GWP F-gases, in sectors where low-GWP alternatives exist. In case of safety requirements prohibiting the use of flammable substances, technological adaptations, such as splitting refrigeration circuits, are assumed where technically possible.

This scenario includes the following POM prohibitions: A2.1, A2.2, A2.6, A2.7 and A2.8.

HFC demand for the different scenarios

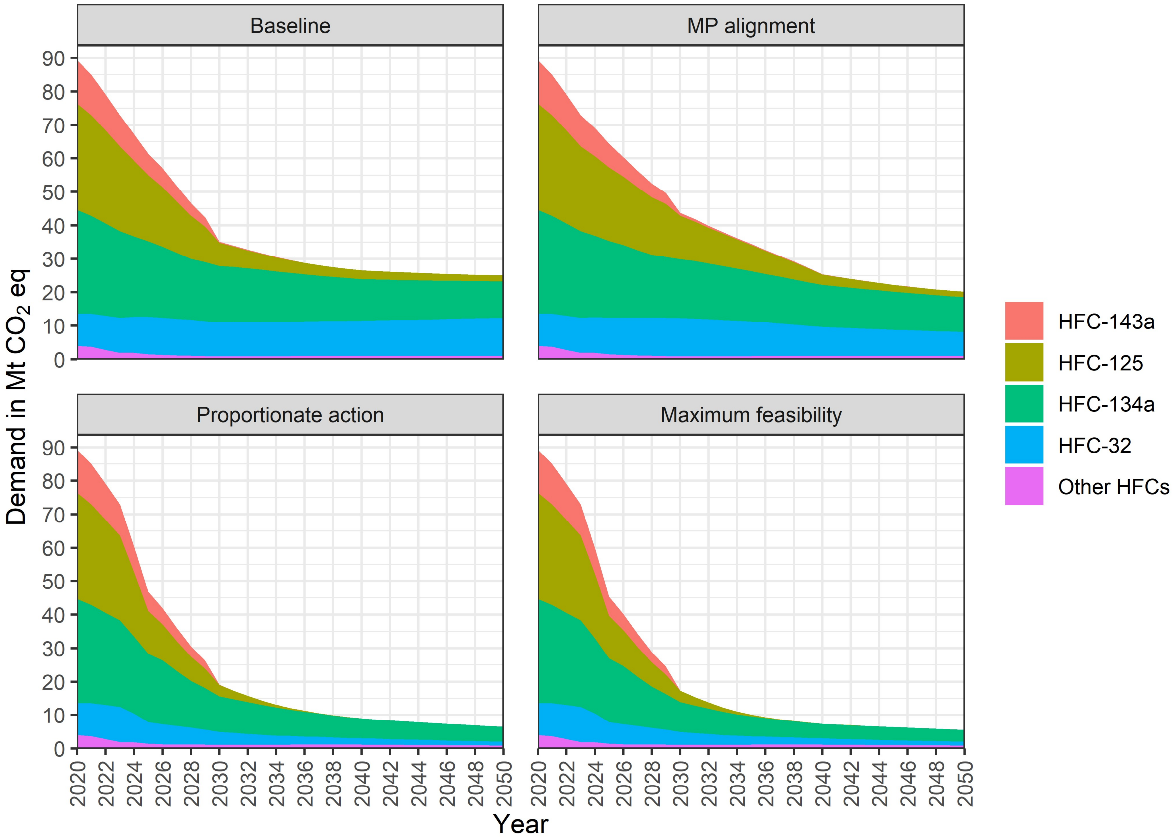
Demand for HFCs in CO_2 equivalents decreases strongly under all scenarios from 2020 to 2050 but the effect is more pronounced under the proportionate action and maximum feasibility scenario (Figure 12 and Table 11). For the MP alignment scenario, HFCs show a higher demand from 2020 to ca. 2035, compared to the baseline, but then fall slightly below the baseline demand beginning in 2036.

Looking at the different HFCs, the more ambitious scenarios PA and MF show a further reduction, especially for HFC-134a and HFC-32, and to a lesser extent HFC-125. This is mainly due to a replacement of R410A with HFC-32, which in turn is replaced by lower-GWP alternatives much quicker than under the baseline or the MP scenario.

[13] Long-term low greenhouse gas emission development strategy of the EU and its Member States, https://ec.europa.eu/clima/policies/strategies/2050_en / https://unfccc.int/sites/default/files/resource/HR-03-06-2020%20EU%20Submission%20on%20Long%20term%20strategy.pdf.

[14] Updated stylised carbon value in 2050 as per the latest MIX modelling exercise for the 'Delivering the European Green Deal' policy package proposed by the Commission in July 2021, https://ec.europa.eu/energy/data-analysis/energy-modelling/policy-scenarios-delivering-european-green-deal_en

Figure 12: Modelled demand HFCs in the EU-27 under the different scenario



Source: AnaFgas modelling

Table 10: Modelled demand of total HFCs in Mt CO_2 eq under the different scenarios in the EU-27

Year	BL	MP	PA	MF	MP-BL	PA-BL	MF-BL
2020	89	89	89	89	0 (-)	0 (-)	0 (-)
2025	61	64	47	45	3 (5%)	-15 (-24%)	-16 (-26%)
2030	35	44	19	17	9 (24%)	-16 (-46%)	-18 (-51%)
2035	30	34	12	10	5 (16%)	-18 (-59%)	-20 (-66%)
2040	27	25	9	7	-1 (-4%)	-18 (-66%)	-19 (-72%)
2045	26	22	8	6	-3 (-13%)	-18 (-70%)	-19 (-75%)
2050	25	20	6	6	-5 (-19%)	-19 (-74%)	-19 (-78%)

Source: AnaFgas modelling

Note: BL is baseline, MP is MP alignment, PA is proportionate action, MF is maximum feasibility

Table 11: Modelled demand of virgin HFCs (without reclaimed quantities) in Mt CO_2 eq under the different scenarios in the EU-27

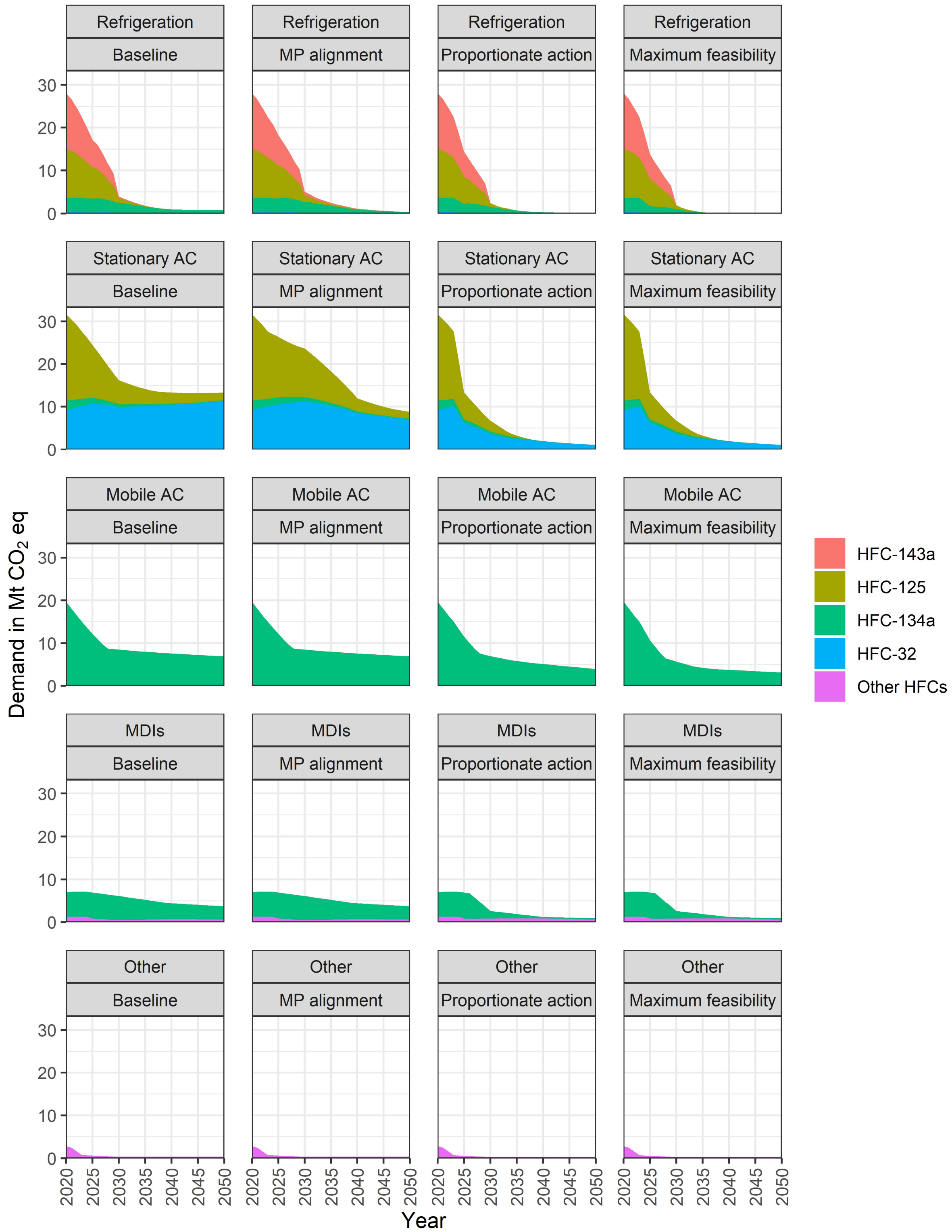
Year	BL	MP	PA	MF	MP-BL	PA-BL	MF-BL
2020	81	81	81	81	0 (-)	0 (-)	0 (-)
2025	53	56	39	37	3 (6%)	-15 (-27%)	-16 (-30%)
2030	29	38	14	11	9 (29%)	-15 (-52%)	-18 (-61%)
2035	24	28	9	7	5 (20%)	-15 (-61%)	-17 (-70%)
2040	23	21	7	5	-1 (-5%)	-16 (-69%)	-17 (-76%)
2045	23	19	7	5	-3 (-15%)	-16 (-71%)	-17 (-76%)
2050	22	17	5	5	-5 (-22%)	-17 (-75%)	-17 (-79%)

Source: AnaFgas modelling

Note: BL is baseline, MP is MP alignment, PA is proportionate action, MF is maximum feasibility

As can be seen in Figure 13, different sectors offer different potentials for further reduction in demand for HFCs, expressed in CO_2 equivalents. When looking at the sum of yearly demand for the different scenarios from 2020 to 2050 (Table 12Table 11), a cumulative reduction in demand compared to the baseline of 222 and 263 Mt CO_2 eq can be achieved in stationary AC applications, for the PA and MF scenario, respectively. For the MP scenario, on the other hand, the cumulative demand exceeds that of the baseline with 33 Mt CO_2 eq.

Figure 13: Modelled demand of HFCs under the different scenarios for important sectors in the EU-27



Source: AnaFgas modelling

Table 12: Sum of modelled cumulative demand of HFCs in Mt CO_2 eq from 2020 to 2050 for the different scenarios for important sectors in the EU-27

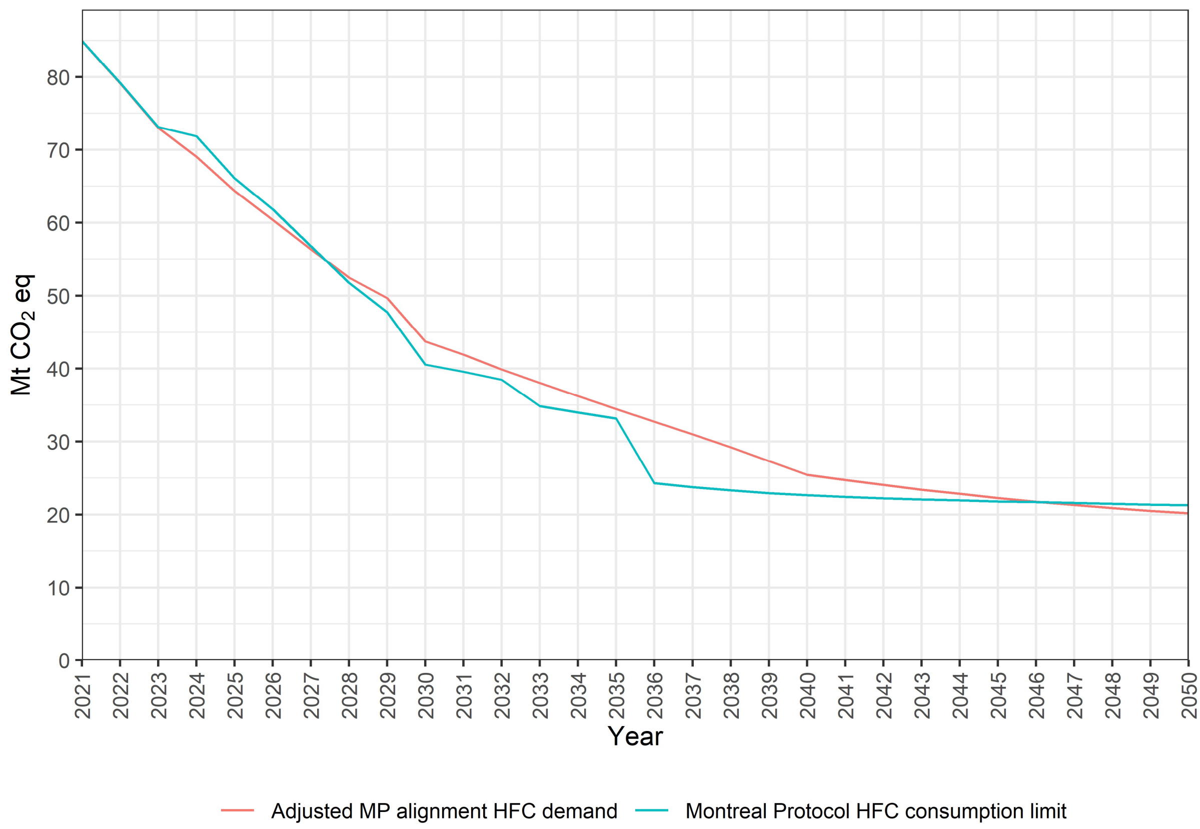
Sector	BL	MP	PA	MF	MP-BL	PA-BL	MF-BL
Refrigeration	221	231	187	178	10 (4%)	-35 (-16%)	-44 (-20%)
Stationary AC	541	570	248	248	29 (5%)	-292 (-54%)	-292 (-54%)
Mobile AC	294	294	239	207	0 (-)	-55 (-19%)	-87 (-30%)
MDIs	167	167	94	94	0 (-)	-72 (-43%)	-72 (-43%)
Other	19	19	17	17	0 (-)	-2 (-9%)	-2 (-9%)
Total	**1 241**	**1 281**	**786**	**744**	**39 (3%)**	**-456 (-37%)**	**-497 (-40%)**

Note: BL is baseline, MP is MP alignment, PA is proportionate action, MF is maximum feasibility

Validation of the MP alignment HFC phasedown scenario

Following the logic from Annex 1.4, the HFC consumption under the MP alignment scenario cannot exceed the HFC consumption limit set out by the Montreal Protocol. To adjust the HFC demand (including MDIs and semiconductors) to fit the consumption metric most closely, reclaimed amounts had to be subtracted. For the MP scenario, the same amounts of reclaimed quantities as under the baseline were assumed. From 2020 to 2050, the area under the curve for the MP scenario exceeds the area for the consumption limit by 45 Mt CO_2 eq. Again, the approximately 69 Mt CO_2 eq of authorisations can be used to compensate this amount.

Figure 14: Adjusted HFC demand under the baseline and HFC consumption limit under the Montreal Protocol



Source: AnaFgas modelling

Annex 1.7: Projected emissions of F-gases from the different sectors and scenarios

Table 13: Emissions of F-gas groups by sector and scenario in Mt CO_2 eq

Sector	Year	Gas group	Baseline	MP alignment	Proportionate action	Maximum feasibility
Refrigeration	2020	HFCs	26	26	26	26
Refrigeration	2020	Other	0	0	0	0
Refrigeration	2025	HFCs	16	16	16	16
Refrigeration	2025	Other	0	0	0	0
Refrigeration	2030	HFCs	8	8	7	7
Refrigeration	2030	Other	0	0	0	0
Refrigeration	2035	HFCs	3	4	2	2
Refrigeration	2035	Other	0	0	0	0
Refrigeration	2040	HFCs	1	2	1	0
Refrigeration	2040	Other	0	0	0	0
Refrigeration	2045	HFCs	1	1	0	0
Refrigeration	2045	Other	0	0	0	0
Refrigeration	2050	HFCs	1	0	0	0
Refrigeration	2050	Other	0	0	0	0
Stationary AC	2020	HFCs	21	21	21	21
Stationary AC	2020	Other	0	0	0	0
Stationary AC	2025	HFCs	19	19	18	18
Stationary AC	2025	Other	0	0	0	0
Stationary AC	2030	HFCs	13	14	10	10
Stationary AC	2030	Other	0	0	0	0
Stationary AC	2035	HFCs	10	12	5	5
Stationary AC	2035	Other	0	0	0	0
Stationary AC	2040	HFCs	7	10	2	2
Stationary AC	2040	Other	0	0	0	0
Stationary AC	2045	HFCs	7	7	1	1
Stationary AC	2045	Other	0	0	0	0
Stationary AC	2050	HFCs	7	5	1	1
Stationary AC	2050	Other	0	0	0	0
Mobile AC	2020	HFCs	23	23	23	23
Mobile AC	2020	Other	0	0	0	0
Mobile AC	2025	HFCs	15	15	15	14
Mobile AC	2025	Other	0	0	0	0
Mobile AC	2030	HFCs	6	6	6	5
Mobile AC	2030	Other	0	0	0	0
Mobile AC	2035	HFCs	6	6	4	3
Mobile AC	2035	Other	0	0	0	0
Mobile AC	2040	HFCs	5	5	4	3
Mobile AC	2040	Other	0	0	0	0

Sector	Year	Gas group	Baseline	MP alignment	Proportionate action	Maximum feasibility
Mobile AC	2045	HFCs	5	5	3	2
Mobile AC	2045	Other	0	0	0	0
Mobile AC	2050	HFCs	5	5	2	1
Mobile AC	2050	Other	0	0	0	0
Switchgear	2020	SF6	2	2	2	2
Switchgear	2025	SF6	3	3	3	3
Switchgear	2030	SF6	3	3	3	3
Switchgear	2035	SF6	3	3	3	3
Switchgear	2040	SF6	3	3	2	2
Switchgear	2045	SF6	3	3	3	3
Switchgear	2050	SF6	4	4	3	3
MDIs	2020	HFCs	7	7	7	7
MDIs	2020	Other	0	0	0	0
MDIs	2025	HFCs	7	7	7	7
MDIs	2025	Other	0	0	0	0
MDIs	2030	HFCs	6	6	3	3
MDIs	2030	Other	0	0	0	0
MDIs	2035	HFCs	5	5	2	2
MDIs	2035	Other	0	0	0	0
MDIs	2040	HFCs	4	4	1	1
MDIs	2040	Other	0	0	0	0
MDIs	2045	HFCs	4	4	1	1
MDIs	2045	Other	0	0	0	0
MDIs	2050	HFCs	4	4	1	1
MDIs	2050	Other	0	0	0	0
Other	2020	HFCs	6	6	6	6
Other	2020	SF6	5	5	5	5
Other	2020	Other	3	3	3	3
Other	2025	HFCs	5	5	5	5
Other	2025	SF6	2	2	2	2
Other	2025	Other	3	3	3	3
Other	2030	HFCs	4	4	4	4
Other	2030	SF6	1	1	1	1
Other	2030	Other	3	3	3	3
Other	2035	HFCs	3	3	3	3
Other	2035	SF6	1	1	1	1
Other	2035	Other	3	3	3	3
Other	2040	HFCs	3	3	3	3
Other	2040	SF6	1	1	1	1
Other	2040	Other	3	3	3	3
Other	2045	HFCs	3	3	3	3
Other	2045	SF6	1	1	1	1

Sector	Year	Gas group	Baseline	MP alignment	Proportionate action	Maximum fea-sibility
Other	2045	Other	3	3	3	3
Other	2050	HFCs	3	3	3	3
Other	2050	SF6	1	1	1	1
Other	2050	Other	3	3	3	3

Table 14: Emissions of F-gas groups by sector contained in the sector 'Other' in Table 13 and scenario in Mt CO_2 eq

Sector	Year	Gas group	Baseline	MP alignment	Proportionate action	Maximum fea-sibility
Fire extinguishers	2020	HFCs	2	2	2	2
Fire extinguishers	2020	Other	0	0	0	0
Fire extinguishers	2025	HFCs	2	2	2	2
Fire extinguishers	2025	Other	0	0	0	0
Fire extinguishers	2030	HFCs	1	1	1	1
Fire extinguishers	2030	Other	0	0	0	0
Fire extinguishers	2035	HFCs	0	0	0	0
Fire extinguishers	2035	Other	0	0	0	0
Fire extinguishers	2040	HFCs	0	0	0	0
Fire extinguishers	2040	Other	0	0	0	0
Fire extinguishers	2045	HFCs	0	0	0	0
Fire extinguishers	2045	Other	0	0	0	0
Fire extinguishers	2050	HFCs	0	0	0	0
Fire extinguishers	2050	Other	0	0	0	0
Foam	2020	HFCs	2	2	2	2
Foam	2020	Other	0	0	0	0
Foam	2025	HFCs	1	1	1	1
Foam	2025	Other	0	0	0	0
Foam	2030	HFCs	1	1	1	1
Foam	2030	Other	0	0	0	0
Foam	2035	HFCs	1	1	1	1
Foam	2035	Other	0	0	0	0
Foam	2040	HFCs	1	1	1	1
Foam	2040	Other	0	0	0	0
Foam	2045	HFCs	1	1	1	1
Foam	2045	Other	0	0	0	0
Foam	2050	HFCs	1	1	1	1
Foam	2050	Other	0	0	0	0
Production	2020	HFCs	2	2	2	2
Production	2020	SF6	0	0	0	0
Production	2020	Other	2	2	2	2
Production	2025	HFCs	2	2	2	2
Production	2025	SF6	0	0	0	0
Production	2025	Other	2	2	2	2

Sector	Year	Gas group	Baseline	MP alignment	Proportionate action	Maximum feasibility
Production	2030	HFCs	2	2	2	2
Production	2030	SF6	0	0	0	0
Production	2030	Other	2	2	2	2
Production	2035	HFCs	2	2	2	2
Production	2035	SF6	0	0	0	0
Production	2035	Other	2	2	2	2
Production	2040	HFCs	2	2	2	2
Production	2040	SF6	0	0	0	0
Production	2040	Other	2	2	2	2
Production	2045	HFCs	2	2	2	2
Production	2045	SF6	0	0	0	0
Production	2045	Other	2	2	2	2
Production	2050	HFCs	2	2	2	2
Production	2050	SF6	0	0	0	0
Production	2050	Other	2	2	2	2
Non-ferrous metal	2020	HFCs	0	0	0	0
Non-ferrous metal	2020	SF6	1	1	1	1
Non-ferrous metal	2020	Other	0	0	0	0
Non-ferrous metal	2025	HFCs	0	0	0	0
Non-ferrous metal	2025	SF6	1	1	1	1
Non-ferrous metal	2025	Other	0	0	0	0
Non-ferrous metal	2030	HFCs	0	0	0	0
Non-ferrous metal	2030	SF6	1	1	1	1
Non-ferrous metal	2030	Other	0	0	0	0
Non-ferrous metal	2035	HFCs	0	0	0	0
Non-ferrous metal	2035	SF6	1	1	1	1
Non-ferrous metal	2035	Other	0	0	0	0
Non-ferrous metal	2040	HFCs	0	0	0	0
Non-ferrous metal	2040	SF6	1	1	1	1
Non-ferrous metal	2040	Other	0	0	0	0
Non-ferrous metal	2045	HFCs	0	0	0	0
Non-ferrous metal	2045	SF6	1	1	1	1
Non-ferrous metal	2045	Other	0	0	0	0
Non-ferrous metal	2050	HFCs	0	0	0	0
Non-ferrous metal	2050	SF6	1	1	1	1
Non-ferrous metal	2050	Other	0	0	0	0
Semiconductors	2020	HFCs	0	0	0	0
Semiconductors	2020	SF6	0	0	0	0
Semiconductors	2020	Other	0	0	0	0
Semiconductors	2025	HFCs	0	0	0	0
Semiconductors	2025	SF6	0	0	0	0
Semiconductors	2025	Other	0	0	0	0

Sector	Year	Gas group	Baseline	MP alignment	Proportionate action	Maximum fea-sibility
Semiconductors	2030	HFCs	0	0	0	0
Semiconductors	2030	SF6	0	0	0	0
Semiconductors	2030	Other	0	0	0	0
Semiconductors	2035	HFCs	0	0	0	0
Semiconductors	2035	SF6	0	0	0	0
Semiconductors	2035	Other	0	0	0	0
Semiconductors	2040	HFCs	0	0	0	0
Semiconductors	2040	SF6	0	0	0	0
Semiconductors	2040	Other	0	0	0	0
Semiconductors	2045	HFCs	0	0	0	0
Semiconductors	2045	SF6	0	0	0	0
Semiconductors	2045	Other	0	0	0	0
Semiconductors	2050	HFCs	0	0	0	0
Semiconductors	2050	SF6	0	0	0	0
Semiconductors	2050	Other	0	0	0	0
Sp windows	2020	SF6	4	4	4	4
Sp windows	2025	SF6	2	2	2	2
Sp windows	2030	SF6	0	0	0	0
Sp windows	2035	SF6	0	0	0	0
Sp windows	2040	SF6	0	0	0	0
Sp windows	2045	SF6	0	0	0	0
Sp windows	2050	SF6	0	0	0	0
Other	2020	HFCs	0	0	0	0
Other	2020	Other	1	1	1	1
Other	2025	HFCs	0	0	0	0
Other	2025	Other	1	1	0	0
Other	2030	HFCs	0	0	0	0
Other	2030	Other	1	1	0	0
Other	2035	HFCs	0	0	0	0
Other	2035	Other	1	1	0	0
Other	2040	HFCs	0	0	0	0
Other	2040	Other	1	1	0	0
Other	2045	HFCs	0	0	0	0
Other	2045	Other	1	1	0	0
Other	2050	HFCs	0	0	0	0
Other	2050	Other	1	1	0	0

Annex 2: AnaFgas Cost Modelling assumptions

Annex 2.1: Gas prices used in the AnaFgas modelling framework

Table 15: Refrigerants prices used in AnaFgas modelling, 2015-2019 averages

Gas	Counterfactual OEM purchase price	Counterfactual service company selling price	Baseline OEM purchase price	Baseline service company selling price	Baseline Reclamation selling price
	€/kg	€/kg	€/kg	€/kg	€/kg
HFC-134a	5.0	10.0	16.4	32.9	35.0
R-404A	5.0	10.0	36.4	72.7	35.0
R-407C	5.0	10.0	19.2	38.4	35.0
R-410A	5.0	10.0	21.7	43.4	35.0
HFC-32	10.0	20.0	15.4	30.8	
R-454C/R-455A	30.0	60.0	31.2	62.4	
R-466A	30.0	60.0	35.9	71.7	
R-452A	25.0	50.0	42.1	84.2	
R-452B	25.0	50.0	30.6	61.2	
R-454B	28.7	57.3	32.4	64.8	
R-513A	30.0	60.0	35.1	70.1	
R-448A/R-449A	30.0	60.0	41.1	82.3	
HFC-1234ze	30.0	60.0	30.0	60.0	
HFC-1234yf	70.0	140.0	70.0	140.0	
HCFC-1233zd	25.0	50.0	25.0	50.0	
HCs	10.0	20.0	10.0	20.0	
CO2	2.5	5.0	2.5	5.0	
NH3	2.0	4.0	2.0	4.0	
Air	2.0	4.0	2.0	4.0	

Note: Counterfactual prices are based on 2014 pre-phase-down prices. Baseline prices 2015-2019 are based on an HFC price increase of 8€/ t CO_2 eq.

Table 16: Fire suppression agent prices used in AnaFgas modelling, 2015-2019 averages

Gas	Counterfactual OEM purchase price	Baseline OEM purchase price	Baseline Reclamation selling price
	€/kg	€/kg	€/kg
HFC-134a	14.0	25.4	
HFC-227ea	14.0	39.8	
HFC-23	14.0	132.4	
HFC-236fa	14.0	92.5	
HFC-125	14.0	42.0	35.0
FK-5-1-12	17.0	17.0	
inert gas for fire suppression: 52% N_2, 40% Ar, 8% CO2	5.0	5.0	

Note: Counterfactual prices are based on 2014 pre-phase-down prices. Baseline prices 2015-2019 are based on an HFC price increase of 8€/ t CO_2 eq.

Table 17: Foam blowing agent prices used in AnaFgas modelling, 2015-2019 averages

Gas	Counterfactual OEM purchase price	Baseline OEM purchase price
	€/kg	€/kg
HFC-134a	5.0	16.4
HFC-152a	5.0	6.0
HFC-245fa	5.0	13.2
HFC-365mfc	6.0	12.4
HFC-43-10mee	5.0	18.1
HFC-1234ze	15.0	15.0
HCFC-1233zd	15.0	15.0
CO2	2.5	2.5

Note: Counterfactual prices are based on 2014 pre-phase-down prices. Baseline prices 2015-2019 are based on an HFC price increase of 8€/ t CO_2 eq.

Table 18: Technical aerosol prices used in AnaFgas modelling, 2015-2019 averages

Gas	Counterfactual OEM purchase price	Baseline OEM purchase price
	€/kg	€/kg
HFC-134a	5.0	16.4
HFC-152a	5.0	6.0
HFC-1234ze	15.0	15.0

Note: Counterfactual prices are based on 2014 pre-phase-down prices. Baseline prices 2015-2019 are based on an HFC price increase of 8€/ t CO_2 eq.

Table 19: MDI aerosol prices used in AnaFgas modelling, 2015-2019 averages

Gas	Counterfactual OEM purchase price	Baseline OEM purchase price
	€/kg	€/kg
HFC-134a	8.0	8.0
HFC-227ea	8.0	8.0

Note: Counterfactual prices are based on 2014 pre-phase-down prices. Baseline prices 2015-2019 equal counterfactual prices as the MDI sector was quota-exempted.

Table 20: Solvent prices used in AnaFgas modelling, 2015-2019 averages

Gas	Counterfactual OEM purchase price	Baseline OEM purchase price
	€/kg	€/kg
HFC-227ea	14.0	39.8
HFC-245fa	5.0	13.2
HFC-365mfc	6.0	12.4
HFC-43-10mee	5.0	18.1
HCFC-1233zd	25.0	25.0

Note: Counterfactual prices are based on 2014 pre-phase-down prices. Baseline prices 2015-2019 are based on an HFC price increase of 8€/ t CO_2 eq.

Annex 2.2 Energy prices used in the AnaFgas modelling framework

Table 21: Final energy prices used in AnaFgas modelling

electricity/fuel type	VAT	€/ kWh final energy used in RAC equipment
electricity commercial	excl.	0.145
electricity household	incl.	0.215
electricity industry	excl.	0.095
electricity rail	excl.	0.080
fuel sea-ships	excl.	0.073
fuel road vehicles private	excl.	0.446
fuel road vehicles commercial	excl.	0.259

Annex 2.3: Assumptions on regional distribution of equipment in F-gas use sectors

Table 22: 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 (<12 kW, excluding small reversable air/air heat pumps covered in the single split subsector)	39%	61%
Heat pumps - medium (12-200kW)	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%
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%

AnaFgas sector	EU 27 south (39% of population)	EU 27 north (61% of population)
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

Annex 2.4: AnaFgas model installation parameters: sector sheets (baseline scenario)

Table 23: AnaFgas sector sheet for the baseline scenario: Domestic Refrigeration

Domestic Refrigeration			
considered gases / technologies:		**HFC-134a**	**R-600a**
GWP AR4 of refrigerant	[1]	1 430	4
refrigerating capacity	kW	0.2	0.2
electric/mechanic capacity	kW	0.13	0.12
installation lifetime	years	15	15
invest cost hardware (first fill excluded)	€	400	392
annual operating hours	h/a	7 200	7 200
final energy cost	€/kWh	0.215	0.215
discount rate (societal view / emission reduction cost)	%	4%	4%
HFC operators' cost for containment & recovery (FGR Art 3-8)	€/a	-	-
additional maintenance cost for non-HFCs	€/a	-	-
refrigerant charge	kg	0.12	0.06
refrigerant cost first fill, average 2024-2036	€/kg	54	10
refrigerant cost first fill, average 2050	€/kg	62.5	10
refrigerant cost first fill, counterfactual scenario, 2014 pre-phase-down prices	€/kg	5	10
installation type is refilled?		no	no
refrigerant cost refill, average 2024-2036	€/kg	-	-
refrigerant cost refill, 2050	€/kg	-	-
refrigerant cost refill, counterfactual scenario, 2014 pre-phase-down prices	€/kg	-	-
leakage rate first fill / refill	kg/kg	0.5%	0.5%
leakage rate operation	1/a	0.3%	0.3%
technologically tolerable refrigerant loss	kg/kg	20%	20%
recovery rate end of life	kg/kg	70%	70%
Penetration rate in new installations, 2024-2036 average	%	-	100.0%
Penetration rate in new installations, 2050	%	-	100.0%

Table 24: AnaFgas sector sheet for the baseline scenario: Commercial refrigeration – Hermetics

Commercial refrigeration - Hermetics				
considered gases / technologies:		**HFC-134a**	**R-600a/290-direct**	**R-454C/R-455A**
GWP AR4 of refrigerant	[1]	1 430	4	148.2
refrigerating capacity	kW	0.6	0.6	0.6
electric/mechanic capacity	kW	0.38	0.36	0.38
installation lifetime	years	10	10	10
invest cost hardware (first fill excluded)	€	1 000	980	1 020
annual operating hours	h/a	6 000	6 000	6 000
final energy cost	€/kWh	0.145	0.145	0.145
discount rate (societal view / emission reduction cost)	%	4%	4%	4%
HFC operators' cost for containment & recovery (FGR Art 3-8)	€/a	3	-	3
additional maintenance cost for non-HFCs	€/a	-	-	-
refrigerant charge	kg	0.4	0.2	0.4
refrigerant cost first fill, average 2024-2036	€/kg	54	10	35.1
refrigerant cost first fill, average 2050	€/kg	62.5	10	36
refrigerant cost first fill, counterfactual scenario, 2014 pre-phase-down prices	€/kg	5	10	30
installation type is refilled?		no	no	no
refrigerant cost refill, average 2024-2036	€/kg	-	-	-
refrigerant cost refill, 2050	€/kg	-	-	-
refrigerant cost refill, counterfactual scenario, 2014 pre-phase-down prices	€/kg	-	-	-
leakage rate first fill / refill	kg/kg	0.5%	0.5%	0.5%
leakage rate operation	1/a	1.0%	1.0%	1.0%
technologically tolerable refrigerant loss	kg/kg	20%	20%	20%
recovery rate end of life	kg/kg	61%	61%	61%
Penetration rate in new installations, 2024-2036 average	%	0.8%	97.6%	1.5%
Penetration rate in new installations, 2050	%	-	100.0%	-

Table 25: AnaFgas sector sheet for the baseline scenario: Commercial refrigeration - Condensing units

Commercial refrigeration - Condensing units									
considered gases / technologies:		**R-404A**	**R-134a DX**	**HC (R-290 DX)**	**R-744 (CO2)**	**HC (R-290 + secondary liquid)**	**R-448A/R-449A**	**R-513A**	**R-454C/R-455A**
GWP AR4 of refrigerant	[1]	3 921.6	1 430	3	1	3	1 392.1	631.4	148.2
refrigerating capacity	kW	4	4	4	4	4	4	4	4
electric/mechanic capacity	kW	2.5	2.5	2.43	2.38	2.38	2.45	2.45	2.53
installation lifetime	years	12	12	12	12	12	12	12	12
invest cost hardware (first fill excluded)	€	3 800	3 800	3 990	4 560	4 560	3 800	3 800	3 876
annual operating hours	h/a	5 840	5 840	5 840	5 840	5 840	5 840	5 840	5 840
final energy cost	€/kWh	0.145	0.145	0.145	0.145	0.145	0.145	0.145	0.145
discount rate (societal view / emission reduction cost)	%	4%	4%	4%	4%	4%	4%	4%	4%
HFC operators' cost for containment & recovery (FGR Art 3-8)	€/a	77	77	-	-	-	77	77	77
additional maintenance cost for non-HFCs	€/a	-	-	55	90	55	-	-	-
refrigerant charge	kg	4	4	2	2.67	0.8	4	4	4
refrigerant cost first fill, average 2024-2036	€/kg	268.5	107.9	20	5	20	155.4	103.3	70.2
refrigerant cost first fill, average 2050	€/kg	313.2	124.8	20	5	20	171.9	110.8	71.9
refrigerant cost first fill, counterfactual scenario, 2014 pre-phase-down prices	€/kg	10	10	20	5	20	60	60	60
installation type is refilled?		yes	yes	yes	yes	yes	yes	yes	yes
refrigerant cost refill, average 2024-2036	€/kg	268.5	107.9	20	5	20	155.4	103.3	70.2
refrigerant cost refill, 2050	€/kg	313.2	124.8	20	5	20	171.9	110.8	71.9
refrigerant cost refill, counterfactual scenario, 2014 pre-phase-down prices	€/kg	10	10	20	5	20	60	60	60
leakage rate first fill / refill	kg/kg	1.0%	1.0%	1.0%	1.0%	1.0%	1.0%	1.0%	1.0%
leakage rate operation	1/a	6.0%	6.0%	6.0%	6.0%	6.0%	6.0%	6.0%	6.0%
technologically tolerable refrigerant loss	kg/kg	25%	25%	25%	25%	25%	25%	25%	25%
recovery rate end of life	kg/kg	71%	71%	71%	71%	71%	71%	71%	71%
Penetration rate in new installations, 2024-2036 average	%	1.8%	9.3%	34.6%	21.1%	8.4%	3.1%	3.1%	18.6%
Penetration rate in new installations, 2050	%	-	-	45.0%	30.0%	10.0%	-	-	15.0%

Table 26: AnaFgas sector sheet for the baseline scenario: Commercial refrigeration - Central systems

Commercial refrigeration - Central systems									
considered gases / technologies:		**R-404A DX**	**R-134a DX**	**HC+CO2+ CO2 cas-cade**	**R-744 transcriti-cal**	**HC+sec. liq-uid+CO2**	**R-448A/R-449A**	**HFC 1234ze + CO2+CO2 cascade**	**R-513A (also in cascade)**
GWP AR4 of refrigerant	[1]	3 921.6	1 430	4	1	4	1 392.1	7	631.4
refrigerating capacity	kW	100	100	100	100	100	100	100	100
electric/mechanic capacity	kW	40	40	37	37	40	39.2	38.8	39.6
installation lifetime	years	12	12	12	12	12	12	12	12
invest cost hardware (first fill excluded)	€	320 000	320 000	368 000	342 400	336 000	320 000	352 000	320 000
annual operating hours	h/a	4 380	4 380	4 380	4 380	4 380	4 380	4 380	4 380
final energy cost	€/kWh	0.145	0.145	0.145	0.145	0.145	0.145	0.145	0.145
discount rate (societal view / emission reduction cost)	%	4%	4%	4%	4%	4%	4%	4%	4%
HFC operators' cost for containment & recovery (FGR Art 3-8)	€/a	655	655	-	-	-	655	-	655
additional maintenance cost for non-HFCs	€/a	-	-	55	255	55	-	-	-
refrigerant charge	kg	230	230	57.5	230	23	230	76.67	230
refrigerant cost first fill, average 2024-2036	€/kg	268.5	107.9	20	5	20	155.4	60	103.3
refrigerant cost first fill, average 2050	€/kg	313.2	124.8	20	5	20	171.9	60	110.8
refrigerant cost first fill, counterfactual scenario, 2014 pre-phase-down prices	€/kg	10	10	20	5	20	60	60	60
installation type is refilled?		yes	yes	yes	yes	yes	yes	yes	yes
refrigerant cost refill, average 2024-2036	€/kg	268.5	107.9	20	5	20	155.4	60	103.3
refrigerant cost refill, 2050	€/kg	313.2	124.8	20	5	20	171.9	60	110.8
refrigerant cost refill, counterfactual scenario, 2014 pre-phase-down prices	€/kg	10	10	20	5	20	60	60	60
leakage rate first fill / refill	kg/kg	1.0%	1.0%	1.0%	1.0%	1.0%	1.0%	1.0%	1.0%
leakage rate operation	1/a	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%
technologically tolerable refrigerant loss	kg/kg	25%	25%	25%	25%	25%	25%	25%	25%
recovery rate end of life	kg/kg	71%	71%	71%	71%	71%	71%	71%	71%
Penetration rate in new installations, 2024-2036 average	%	-	1.6%	15.1%	46.8%	15.1%	2.1%	4.9%	14.4%
Penetration rate in new installations, 2050	%	-	-	17.5%	50.0%	17.5%	-	5.0%	10.0%

Table 27: AnaFgas sector sheet for the baseline scenario: Industrial refrigeration – small

Industrial refrigeration - small						
considered gases / technologies:		**R-404A**	**R-134a**	**R-717**	**CO2 / HC**	**R-513A**
GWP AR4 of refrigerant	[1]	3 921.6	1 430	0	2.5	631.4
refrigerating capacity	kW	270	270	270	270	270
electric/mechanic capacity	kW	168.75	168.75	151.88	160.31	165.38
installation lifetime	years	30	30	30	30	30
invest cost hardware (first fill excluded)	€	425 000	425 000	531 250	552 500	425 000
annual operating hours	h/a	4 500	4 500	4 500	4 500	4 500
final energy cost	€/kWh	0.095	0.095	0.095	0.095	0.095
discount rate (societal view / emission reduction cost)	%	4%	4%	4%	4%	4%
HFC operators' cost for containment & recovery (FGR Art 3-8)	€/a	1 142	1 142	-	-	1 142
additional maintenance cost for non-HFCs	€/a	-	-	1 000	55	-
refrigerant charge	kg	650	650	650	650	650
refrigerant cost first fill, average 2024-2036	€/kg	268.5	107.9	4	12.5	103.3
refrigerant cost first fill, average 2050	€/kg	313.2	124.8	4	12.5	110.8
refrigerant cost first fill, counterfactual scenario, 2014 pre-phase-down prices	€/kg	10	10	4	12.5	60
installation type is refilled?		yes	yes	yes	yes	yes
refrigerant cost refill, average 2024-2036	€/kg	268.5	107.9	4	12.5	103.3
refrigerant cost refill, 2050	€/kg	313.2	124.8	4	12.5	110.8
refrigerant cost refill, counterfactual scenario, 2014 pre-phase-down prices	€/kg	10	10	4	12.5	60
leakage rate first fill / refill	kg/kg	1.0%	1.0%	1.0%	1.0%	1.0%
leakage rate operation	1/a	5.4%	5.4%	5.4%	5.4%	5.4%
technologically tolerable refrigerant loss	kg/kg	30%	30%	30%	30%	30%
recovery rate end of life	kg/kg	65%	65%	65%	65%	65%
Penetration rate in new installations, 2024-2036 average	%	1.6%	1.7%	43.5%	45.2%	8.0%
Penetration rate in new installations, 2050	%	-	-	45.0%	50.0%	5.0%

Table 28: AnaFgas sector sheet for the baseline scenario: Industrial refrigeration – large

Industrial refrigeration - large					
considered gases / technologies:		**R-404A**	**R-717**	**HFC-1234ze**	**R-513A (also as cascade + CO2)**
GWP AR4 of refrigerant	[1]	3 921.6	0	7	631.4
refrigerating capacity	kW	5 000	5 000	5 000	5 000
electric/mechanic capacity	kW	2 000	1 780	1 960	1 960
installation lifetime	years	30	30	30	30
invest cost hardware (first fill excluded)	€	6 000 000	7 800 000	6 120 000	6 000 000
annual operating hours	h/a	4 500	4 500	4 500	4 500
final energy cost	€/kWh	0.095	0.095	0.095	0.095
discount rate (societal view / emission reduction cost)	%	4%	4%	4%	4%
HFC operators' cost for containment & recovery (FGR Art 3-8)	€/a	1 285	-	-	1 285
additional maintenance cost for non-HFCs	€/a	-	2 000	-	-
refrigerant charge	kg	4 000	4 000	4 000	4 000
refrigerant cost first fill, average 2024-2036	€/kg	268.5	4	60	103.3
refrigerant cost first fill, average 2050	€/kg	313.2	4	60	110.8
refrigerant cost first fill, counterfactual scenario, 2014 pre-phase-down prices	€/kg	10	4	60	60
installation type is refilled?		yes	yes	yes	yes
refrigerant cost refill, average 2024-2036	€/kg	268.5	4	60	103.3
refrigerant cost refill, 2050	€/kg	313.2	4	60	110.8
refrigerant cost refill, counterfactual scenario, 2014 pre-phase-down prices	€/kg	10	4	60	60
leakage rate first fill / refill	kg/kg	1.0%	1.0%	1.0%	1.0%
leakage rate operation	1/a	4.0%	4.0%	4.0%	4.0%
technologically tolerable refrigerant loss	kg/kg	0%	0%	0%	0%
recovery rate end of life	kg/kg	70%	70%	70%	70%
Penetration rate in new installations, 2024-2036 average	%	0.2%	87.7%	9.2%	2.8%
Penetration rate in new installations, 2050	%	-	90.0%	10.0%	-

Table 29: AnaFgas sector sheet for the baseline scenario: Transport refrigeration – Vans

Transport refrigeration - Vans							
considered gases / technologies:		**HFC 134a**	**R-404A**	**R-744**	**R-452A**	**R-513A**	**R-454C/R-455A**
GWP AR4 of refrigerant	[1]	1 430	3 921.6	1	2 140.5	631.4	148.2
refrigerating capacity	kW	3	3	3	3	3	3
electric/mechanic capacity	kW	1.5	1.5	1.39	1.5	1.5	1.5
installation lifetime	years	10	10	10	10	10	10
invest cost hardware (first fill excluded)	€	3 000	3 000	3 369	3 000	3 000	3 150
annual operating hours	h/a	1 500	1 500	1 500	1 500	1 500	1 500
final energy cost	€/kWh	0.259	0.259	0.259	0.259	0.259	0.259
discount rate (societal view / emission reduction cost)	%	4%	4%	4%	4%	4%	4%
HFC operators' cost for containment & recovery (FGR Art 3-8)	€/a	77	77	-	77	77	77
additional maintenance cost for non-HFCs	€/a	-	-	55	-	-	-
refrigerant charge	kg	1.5	1.5	1.5	1.5	1.5	1.5
refrigerant cost first fill, average 2024-2036	€/kg	54	139.4	2.5	98.3	51.6	35.1
refrigerant cost first fill, average 2050	€/kg	62.5	162.6	2.5	111	55.4	36
refrigerant cost first fill, counterfactual scenario, 2014 pre-phase-down prices	€/kg	5	5	2.5	25	30	30
installation type is refilled?		yes	yes	yes	yes	yes	yes
refrigerant cost refill, average 2024-2036	€/kg	107.9	268.5	5	196.7	103.3	70.2
refrigerant cost refill, 2050	€/kg	124.8	313.2	5	222.1	110.8	71.9
refrigerant cost refill, counterfactual scenario, 2014 pre-phase-down prices	€/kg	10	10	5	50	60	60
leakage rate first fill / refill	kg/kg	1.0%	1.0%	1.0%	1.0%	1.0%	1.0%
leakage rate operation	1/a	28.0%	28.0%	28.0%	28.0%	28.0%	28.0%
technologically tolerable refrigerant loss	kg/kg	25%	25%	25%	25%	25%	25%
recovery rate end of life	kg/kg	66%	66%	66%	66%	66%	66%
Penetration rate in new installations, 2024-2036 average	%	1.1%	1.6%	76.9%	3.1%	10.4%	6.9%
Penetration rate in new installations, 2050	%	-	-	90.0%	-	-	10.0%

Table 30: AnaFgas sector sheet for the baseline scenario: Transport refrigeration - Trucks & Trailers

Transport refrigeration - Trucks & Trailers						
considered gases / technologies:		**R-404A**	**R-744**	**R-513A**	**R-452A**	**R-454C/R-455A**
GWP AR4 of refrigerant	[1]	3 921.6	1	631.4	2 140.5	148.2
refrigerating capacity	kW	9	9	9	9	9
electric/mechanic capacity	kW	8	7.2	8	8	8
installation lifetime	years	10	10	10	10	10
invest cost hardware (first fill excluded)	€	15 000	17 250	15 000	15 000	15 300
annual operating hours	h/a	4 000	4 000	4 000	4 000	4 000
final energy cost	€/kWh	0.259	0.259	0.259	0.259	0.259
discount rate (societal view / emission reduction cost)	%	4%	4%	4%	4%	4%
HFC operators' cost for containment & recovery (FGR Art 3-8)	€/a	74	-	74	74	74
additional maintenance cost for non-HFCs	€/a	-	90	-	-	-
refrigerant charge	kg	6.5	6.5	6.5	6.5	6.5
refrigerant cost first fill, average 2024-2036	€/kg	139.4	2.5	51.6	98.3	35.1
refrigerant cost first fill, average 2050	€/kg	162.6	2.5	55.4	111	36
refrigerant cost first fill, counterfactual scenario, 2014 pre-phase-down prices	€/kg	5	2.5	30	25	30
installation type is refilled?		yes	yes	yes	yes	yes
refrigerant cost refill, average 2024-2036	€/kg	268.5	5	103.3	196.7	70.2
refrigerant cost refill, 2050	€/kg	313.2	5	110.8	222.1	71.9
refrigerant cost refill, counterfactual scenario, 2014 pre-phase-down prices	€/kg	10	5	60	50	60
leakage rate first fill / refill	kg/kg	1.0%	1.0%	1.0%	1.0%	1.0%
leakage rate operation	1/a	18.0%	18.0%	18.0%	18.0%	18.0%
technologically tolerable refrigerant loss	kg/kg	25%	25%	25%	25%	25%
recovery rate end of life	kg/kg	66%	66%	66%	66%	66%
Penetration rate in new installations, 2024-2036 average	%	1.6%	67.1%	21.5%	2.8%	6.9%
Penetration rate in new installations, 2050	%	-	80.0%	10.0%	-	10.0%

Table 31: AnaFgas sector sheet for the baseline scenario: Transport refrigeration – Ships

Transport refrigeration - Ships				
considered gases / technologies:		**R-404A**	**NH3/CO2**	**R-452A**
GWP AR4 of refrigerant	[1]	3 921.6	0	2 140.5
refrigerating capacity	kW	990	990	990
electric/mechanic capacity	kW	468	439.92	439.92
installation lifetime	years	30	30	30
invest cost hardware (first fill excluded)	€	2 000 000	2 300 000	2 000 000
annual operating hours	h/a	5 000	5 000	5 000
final energy cost	€/kWh	0.073	0.073	0.073
discount rate (societal view / emission reduction cost)	%	4%	4%	4%
HFC operators' cost for containment & recovery (FGR Art 3-8)	€/a	108	-	108
additional maintenance cost for non-HFCs	€/a	-	1 000	-
refrigerant charge	kg	1 000	750	1 000
refrigerant cost first fill, average 2024-2036	€/kg	268.5	4	196.7
refrigerant cost first fill, average 2050	€/kg	313.2	4	222.1
refrigerant cost first fill, counterfactual scenario, 2014 pre-phase-down prices	€/kg	10	4	50
installation type is refilled?		yes	yes	yes
refrigerant cost refill, average 2024-2036	€/kg	268.5	4	196.7
refrigerant cost refill, 2050	€/kg	313.2	4	222.1
refrigerant cost refill, counterfactual scenario, 2014 pre-phase-down prices	€/kg	10	4	50
leakage rate first fill / refill	kg/kg	1.0%	1.0%	1.0%
leakage rate operation	1/a	40.0%	40.0%	40.0%
technologically tolerable refrigerant loss	kg/kg	25%	25%	25%
recovery rate end of life	kg/kg	54%	54%	54%
Penetration rate in new installations, 2024-2036 average	%	0.3%	90.5%	9.2%
Penetration rate in new installations, 2050	%	-	100.0%	-

Table 32: AnaFgas sector sheet for the baseline scenario: Room AC – Moveables

Room AC - Moveables			
considered gases / technologies:		**R-410A direct**	**R-290**
GWP AR4 of refrigerant	[1]	2 087.5	3
refrigerating capacity	kW	3	3
electric/mechanic capacity	kW	0.67	0.67
installation lifetime	years	10	10
invest cost hardware (first fill excluded)	€	300	294
annual operating hours	h/a	500	500
final energy cost	€/kWh	0.215	0.215
discount rate (societal view / emission reduction cost)	%	4%	4%
HFC operators' cost for containment & recovery (FGR Art 3-8)	€/a	3	-
additional maintenance cost for non-HFCs	€/a	-	-
refrigerant charge	kg	0.75	0.38
refrigerant cost first fill, average 2024-2036	€/kg	76.5	10
refrigerant cost first fill, average 2050	€/kg	88.9	10
refrigerant cost first fill, counterfactual scenario, 2014 pre-phase-down prices	€/kg	5	10
installation type is refilled?		no	no
refrigerant cost refill, average 2024-2036	€/kg	-	-
refrigerant cost refill, 2050	€/kg	-	-
refrigerant cost refill, counterfactual scenario, 2014 pre-phase-down prices	€/kg	-	-
leakage rate first fill / refill	kg/kg	0.0%	0.0%
leakage rate operation	1/a	3.0%	3.0%
technologically tolerable refrigerant loss	kg/kg	25%	25%
recovery rate end of life	kg/kg	53%	53%
Penetration rate in new installations, 2024-2036 average	%	-	100.0%
Penetration rate in new installations, 2050	%	-	100.0%

Table 33: AnaFgas sector sheet for the baseline scenario: Room AC - Single split

Room AC - Single split (includes small multi-split <12 kW & reversible air-to-air heat pumps)				
considered gases / technologies:		**R-410A direct**	**R-290**	**HFC-32**
GWP AR4 of refrigerant	[1]	2 087.5	3	675
refrigerating capacity	kW	4.5	4.5	4.5
electric/mechanic capacity	kW	1	1	1
installation lifetime	years	10	10	10
invest cost hardware (first fill excluded)	€	750	803	750
annual operating hours	h/a	1 500	1 500	1 500
final energy cost	€/kWh	0.215	0.215	0.215
discount rate (societal view / emission reduction cost)	%	4%	4%	4%
HFC operators' cost for containment & recovery (FGR Art 3-8)	€/a	9	-	9
additional maintenance cost for non-HFCs	€/a	-	-	-
refrigerant charge	kg	1.5	0.75	1.2
refrigerant cost first fill, average 2024-2036	€/kg	76.5	10	33.1
refrigerant cost first fill, average 2050	€/kg	88.9	10	37.1
refrigerant cost first fill, counterfactual scenario, 2014 pre-phase-down prices	€/kg	5	10	10
installation type is refilled?		yes	yes	yes
refrigerant cost refill, average 2024-2036	€/kg	152.2	20	66.3
refrigerant cost refill, 2050	€/kg	176.9	20	74.3
refrigerant cost refill, counterfactual scenario, 2014 pre-phase-down prices	€/kg	10	20	20
leakage rate first fill / refill	kg/kg	3.5%	3.5%	3.5%
leakage rate operation	1/a	5.0%	5.0%	5.0%
technologically tolerable refrigerant loss	kg/kg	25%	25%	25%
recovery rate end of life	kg/kg	60%	60%	60%
Penetration rate in new installations, 2024-2036 average	%	3.2%	15.3%	81.5%
Penetration rate in new installations, 2050	%	-	20.0%	80.0%

Table 34: AnaFgas sector sheet for the baseline scenario: Room AC – Rooftop

Room AC - Packaged systems (rooftop units), cooling only					
considered gases / technologies:		**R-410A direct**	**HFC-32**	**R-454C/R-455A**	**R-290**
GWP AR4 of refrigerant	[1]	2 087.5	675	148.2	3
refrigerating capacity	kW	30	30	30	30
electric/mechanic capacity	kW	15	14.85	15	14.7
installation lifetime	years	10	10	10	10
invest cost hardware (first fill excluded)	€	10 000	10 200	10 300	10 500
annual operating hours	h/a	3 000	3 000	3 000	3 000
final energy cost	€/kWh	0.145	0.145	0.145	0.145
discount rate (societal view / emission reduction cost)	%	4%	4%	4%	4%
HFC operators' cost for containment & recovery (FGR Art 3-8)	€/a	215	215	215	-
additional maintenance cost for non-HFCs	€/a	-	-	-	55
refrigerant charge	kg	10.5	8.4	10.5	5.25
refrigerant cost first fill, average 2024-2036	€/kg	152.2	66.3	70.2	20
refrigerant cost first fill, average 2050	€/kg	176.9	74.3	71.9	20
refrigerant cost first fill, counterfactual scenario, 2014 pre-phase-down prices	€/kg	10	20	60	20
installation type is refilled?		yes	yes	yes	yes
refrigerant cost refill, average 2024-2036	€/kg	152.2	66.3	70.2	20
refrigerant cost refill, 2050	€/kg	176.9	74.3	71.9	20
refrigerant cost refill, counterfactual scenario, 2014 pre-phase-down prices	€/kg	10	20	60	20
leakage rate first fill / refill	kg/kg	0.0%	0.0%	0.0%	0.0%
leakage rate operation	1/a	3.0%	3.0%	3.0%	3.0%
technologically tolerable refrigerant loss	kg/kg	25%	25%	25%	25%
recovery rate end of life	kg/kg	77%	77%	77%	77%
Penetration rate in new installations, 2024-2036 average	%	25.0%	50.0%	11.6%	13.4%
Penetration rate in new installations, 2050	%	5.0%	50.0%	30.0%	15.0%

Table 35: AnaFgas sector sheet for the baseline scenario: Room AC – VRF

Room AC - VRF cooling only (includes Single-split >3kg VRF Multi-Split)						
considered gases / technologies:		**R-410A direct**	**HFC-32**	**R-454C/R-455A**	**R-290**	**R-290 + evap. Secondary**
GWP AR4 of refrigerant	[1]	2 087.5	675	148.2	3	3
refrigerating capacity	kW	27	27	27	27	27
electric/mechanic capacity	kW	8	8	7.84	7.76	7.6
installation lifetime	years	13	13	13	13	13
invest cost hardware (first fill excluded)	€	9 500	9 738	9 738	12 350	12 920
annual operating hours	h/a	3 000	3 000	3 000	3 000	3 000
final energy cost	€/kWh	0.145	0.145	0.145	0.145	0.145
discount rate (societal view / emission reduction cost)	%	4%	4%	4%	4%	4%
HFC operators' cost for containment & recovery (FGR Art 3-8)	€/a	226	226	226	-	-
additional maintenance cost for non-HFCs	€/a	-	-	-	55	55
refrigerant charge	kg	13.5	10.8	13.5	6.75	6.75
refrigerant cost first fill, average 2024-2036	€/kg	152.2	66.3	70.2	20	20
refrigerant cost first fill, average 2050	€/kg	176.9	74.3	71.9	20	20
refrigerant cost first fill, counterfactual scenario, 2014 pre-phase-down prices	€/kg	10	20	60	20	20
installation type is refilled?		yes	yes	yes	yes	yes
refrigerant cost refill, average 2024-2036	€/kg	152.2	66.3	70.2	20	20
refrigerant cost refill, 2050	€/kg	176.9	74.3	71.9	20	20
refrigerant cost refill, counterfactual scenario, 2014 pre-phase-down prices	€/kg	10	20	60	20	20
leakage rate first fill / refill	kg/kg	0.3%	0.3%	0.3%	0.3%	0.3%
leakage rate operation	1/a	5.6%	5.6%	5.6%	5.6%	5.6%
technologically tolerable refrigerant loss	kg/kg	25%	25%	25%	25%	25%
recovery rate end of life	kg/kg	77%	77%	77%	77%	77%
Penetration rate in new installations, 2024-2036 average	%	25.5%	59.1%	12.0%	1.7%	1.7%
Penetration rate in new installations, 2050	%	5.0%	55.0%	35.0%	2.5%	2.5%

Table 36: AnaFgas sector sheet for the baseline scenario: Minichillers

Minichillers						
considered gases / technologies:		**R-410A**	**R-32**	**HFO-1234ze**	**R-290 direct**	**R-454C/R-455A**
GWP AR4 of refrigerant	[1]	2 087.5	675	7	3	148.2
refrigerating capacity	kW	2	2	2	2	2
electric/mechanic capacity	kW	2	1.98	2	1.94	1.98
installation lifetime	years	12	12	12	12	12
invest cost hardware (first fill excluded)	€	450	459	450	495	473
annual operating hours	h/a	1 860	1 860	1 860	1 860	1 860
final energy cost	€/kWh	0.145	0.145	0.145	0.145	0.145
discount rate (societal view / emission reduction cost)	%	4%	4%	4%	4%	4%
HFC operators' cost for containment & recovery (FGR Art 3-8)	€/a	141	141	-	-	141
additional maintenance cost for non-HFCs	€/a	-	-	-	-	-
refrigerant charge	kg	0.65	0.43	0.72	0.33	0.65
refrigerant cost first fill, average 2024-2036	€/kg	76.5	33.1	30	10	35.1
refrigerant cost first fill, average 2050	€/kg	88.9	37.1	30	10	36
refrigerant cost first fill, counterfactual scenario, 2014 pre-phase-down prices	€/kg	5	10	30	10	30
installation type is refilled?		yes	yes	yes	yes	yes
refrigerant cost refill, average 2024-2036	€/kg	152.2	66.3	60	20	70.2
refrigerant cost refill, 2050	€/kg	176.9	74.3	60	20	71.9
refrigerant cost refill, counterfactual scenario, 2014 pre-phase-down prices	€/kg	10	20	60	20	60
leakage rate first fill / refill	kg/kg	0.5%	0.5%	0.5%	0.5%	0.5%
leakage rate operation	1/a	2.4%	2.4%	2.4%	2.4%	2.4%
technologically tolerable refrigerant loss	kg/kg	20%	20%	20%	20%	20%
recovery rate end of life	kg/kg	78%	78%	78%	78%	78%
Penetration rate in new installations, 2024-2036 average	%	13.1%	52.7%	19.4%	7.4%	7.4%
Penetration rate in new installations, 2050	%	11.1%	44.4%	22.2%	11.1%	11.1%

Table 37: AnaFgas sector sheet for the baseline scenario: Displacement chillers – small

Displacement chillers - small							
considered gases / technologies:		**R-410A**	**H2O (R-718)**	**R-32**	**HFO-1234ze**	**R-290 direct**	**R-454C/R-455A**
GWP AR4 of refrigerant	[1]	2 087.5	0	675	7	3	148.2
refrigerating capacity	kW	80	80	80	80	80	80
electric/mechanic capacity	kW	28	26.32	27.72	27.72	27.16	27.72
installation lifetime	years	15	15	15	15	15	15
invest cost hardware (first fill excluded)	€	18 000	25 200	18 900	18 360	20 700	18 900
annual operating hours	h/a	1 860	1 860	1 860	1 860	1 860	1 860
final energy cost	€/kWh	0.145	0.145	0.145	0.145	0.145	0.145
discount rate (societal view / emission reduction cost)	%	4%	4%	4%	4%	4%	4%
HFC operators' cost for containment & recovery (FGR Art 3-8)	€/a	143	-	143	-	-	143
additional maintenance cost for non-HFCs	€/a	-	-	-	-	-	-
refrigerant charge	kg	26	18	17.33	28.6	13	26
refrigerant cost first fill, average 2024-2036	€/kg	152.2	0.1	66.3	60	20	70.2
refrigerant cost first fill, average 2050	€/kg	176.9	0.1	74.3	60	20	71.9
refrigerant cost first fill, counterfactual scenario, 2014 pre-phase-down prices	€/kg	10	0	20	60	20	60
installation type is refilled?		yes	yes	yes	yes	yes	yes
refrigerant cost refill, average 2024-2036	€/kg	152.2	0.1	66.3	60	20	70.2
refrigerant cost refill, 2050	€/kg	176.9	0.1	74.3	60	20	71.9
refrigerant cost refill, counterfactual scenario, 2014 pre-phase-down prices	€/kg	10	0	20	60	20	60
leakage rate first fill / refill	kg/kg	0.5%	0.5%	0.5%	0.5%	0.5%	0.5%
leakage rate operation	1/a	2.4%	2.4%	2.4%	2.4%	2.4%	2.4%
technologically tolerable refrigerant loss	kg/kg	20%	20%	20%	20%	20%	20%
recovery rate end of life	kg/kg	78%	78%	78%	78%	78%	78%
Penetration rate in new installations, 2024-2036 average	%	6.2%	36.9%	24.3%	8.0%	22.2%	2.6%
Penetration rate in new installations, 2050	%	3.6%	39.8%	14.5%	7.2%	31.2%	3.6%

Table 38: AnaFgas sector sheet for the baseline scenario: Displacement chillers – large

Displacement chillers - large								
considered gases / technologies:		**R-134a**	**R-407C**	**R-410A**	**R-717 / R-718**	**R-32**	**HFO-1234ze**	**R-454C/R-455A**
GWP AR4 of refrigerant	[1]	1 430	1 773.9	2 087.5	0	675	7	148.2
refrigerating capacity	kW	400	400	400	400	400	400	400
electric/mechanic capacity	kW	129	129	129	122.55	127.07	127.71	127.71
installation lifetime	years	15	15	15	15	15	15	15
invest cost hardware (first fill excluded)	€	70 000	70 000	70 000	87 500	73 500	73 500	73 500
annual operating hours	h/a	1 860	1 860	1 860	1 860	1 860	1 860	1 860
final energy cost	€/kWh	0.095	0.095	0.095	0.095	0.095	0.095	0.095
discount rate (societal view / emission reduction cost)	%	4%	4%	4%	4%	4%	4%	4%
HFC operators' cost for containment & recovery (FGR Art 3-8)	€/a	278	278	278	-	278	-	278
additional maintenance cost for non-HFCs	€/a	-	-	-	73	-	-	-
refrigerant charge	kg	150	150	150	75	120	150	150
refrigerant cost first fill, average 2024-2036	€/kg	107.9	128.8	152.2	4	66.3	60	70.2
refrigerant cost first fill, average 2050	€/kg	124.8	149.4	176.9	4	74.3	60	71.9
refrigerant cost first fill, counterfactual scenario, 2014 pre-phase-down prices	€/kg	10	10	10	4	20	60	60
installation type is refilled?		yes	yes	yes	yes	yes	yes	yes
refrigerant cost refill, average 2024-2036	€/kg	107.9	128.8	152.2	4	66.3	60	70.2
refrigerant cost refill, 2050	€/kg	124.8	149.4	176.9	4	74.3	60	71.9
refrigerant cost refill, counterfactual scenario, 2014 pre-phase-down prices	€/kg	10	10	10	4	20	60	60
leakage rate first fill / refill	kg/kg	0.5%	0.5%	0.5%	0.5%	0.5%	0.5%	0.5%
leakage rate operation	1/a	2.4%	2.4%	2.4%	2.4%	2.4%	2.4%	2.4%
technologically tolerable refrigerant loss	kg/kg	20%	20%	20%	20%	20%	20%	20%
recovery rate end of life	kg/kg	78%	78%	78%	78%	78%	78%	78%
Penetration rate in new installations, 2024-2036 average	%	2.1%	1.4%	3.7%	49.6%	29.4%	10.2%	3.6%
Penetration rate in new installations, 2050	%	1.5%	1.0%	2.5%	58.4%	20.9%	10.5%	5.2%

Table 39: AnaFgas sector sheet for the baseline scenario: Centrifugal chillers

Centrifugal chillers					
considered gases / technologies:		**HFC 134a**	**HFO-1234ze**	**HFO-1233zd**	**CO2 / NH3**
GWP AR4 of refrigerant	[1]	1 430	7	4.5	0.5
refrigerating capacity	kW	1 500	1 500	1 500	1 500
electric/mechanic capacity	kW	300	297	297	270
installation lifetime	years	25	25	25	25
invest cost hardware (first fill excluded)	€	140 000	141 400	141 400	154 000
annual operating hours	h/a	3 350	3 350	3 350	3 350
final energy cost	€/kWh	0.095	0.095	0.095	0.095
discount rate (societal view / emission reduction cost)	%	4%	4%	4%	4%
HFC operators' cost for containment & recovery (FGR Art 3-8)	€/a	278	-	-	-
additional maintenance cost for non-HFCs	€/a	-	-	-	-
refrigerant charge	kg	630	630	630	630
refrigerant cost first fill, average 2024-2036	€/kg	107.9	60	50	4.5
refrigerant cost first fill, average 2050	€/kg	124.8	60	50	4.5
refrigerant cost first fill, counterfactual scenario, 2014 pre-phase-down prices	€/kg	10	60	50	4.5
installation type is refilled?		yes	yes	yes	yes
refrigerant cost refill, average 2024-2036	€/kg	107.9	60	50	4.5
refrigerant cost refill, 2050	€/kg	124.8	60	50	4.5
refrigerant cost refill, counterfactual scenario, 2014 pre-phase-down prices	€/kg	10	60	50	4.5
leakage rate first fill / refill	kg/kg	0.5%	0.5%	0.5%	0.5%
leakage rate operation	1/a	2.4%	2.4%	2.4%	2.4%
technologically tolerable refrigerant loss	kg/kg	20%	20%	20%	20%
recovery rate end of life	kg/kg	78%	78%	78%	78%
Penetration rate in new installations, 2024-2036 average	%	2.1%	13.5%	13.5%	71.0%
Penetration rate in new installations, 2050	%	-	15.0%	15.0%	70.0%

Table 40: AnaFgas sector sheet for the baseline scenario: Heat pumps – small

Heat pumps - small (<12 kW, excluding small reversable air/air heat pumps covered in the single split subsector)							
considered gases / technologies:		**R-134a**	**R-410A**	**R-407C**	**HCs**	**R-32**	**R-513A**
GWP AR4 of refrigerant	[1]	1 430	2 087.5	1 773.9	4	675	631.4
refrigerating capacity	kW	11	11	11	11	11	11
electric/mechanic capacity	kW	6.88	6.88	6.88	6.67	6.81	6.81
installation lifetime	years	15	15	15	15	15	15
invest cost hardware (first fill excluded)	€	8 380	8 380	8 380	8 799	8 548	8 380
annual operating hours	h/a	2 000	2 000	2 000	2 000	2 000	2 000
final energy cost	€/kWh	0.215	0.215	0.215	0.215	0.215	0.215
discount rate (societal view / emission reduction cost)	%	4%	4%	4%	4%	4%	4%
HFC operators' cost for containment & recovery (FGR Art 3-8)	€/a	6	6	6	-	6	6
additional maintenance cost for non-HFCs	€/a	-	-	-	-	-	-
refrigerant charge	kg	2.6	2.6	2.6	1.3	2.08	2.6
refrigerant cost first fill, average 2024-2036	€/kg	54	76.5	65.8	10	33.1	51.6
refrigerant cost first fill, average 2050	€/kg	62.5	88.9	76.3	10	37.1	55.4
refrigerant cost first fill, counterfactual scenario, 2014 pre-phase-down prices	€/kg	5	5	5	10	10	30
installation type is refilled?		yes	yes	yes	yes	yes	yes
refrigerant cost refill, average 2024-2036	€/kg	107.9	152.2	128.8	20	66.3	103.3
refrigerant cost refill, 2050	€/kg	124.8	176.9	149.4	20	74.3	110.8
refrigerant cost refill, counterfactual scenario, 2014 pre-phase-down prices	€/kg	10	10	10	20	20	60
leakage rate first fill / refill	kg/kg	0.5%	0.5%	0.5%	0.5%	0.5%	0.5%
leakage rate operation	1/a	3.5%	3.5%	3.5%	3.5%	3.5%	3.5%
technologically tolerable refrigerant loss	kg/kg	30%	30%	30%	30%	30%	30%
recovery rate end of life	kg/kg	59%	59%	59%	59%	59%	59%
Penetration rate in new installations, 2024-2036 average	%	0.1%	3.4%	-	56.1%	38.9%	1.5%
Penetration rate in new installations, 2050	%	-	-	-	70.0%	30.0%	-

Table 41: AnaFgas sector sheet for the baseline scenario: Heat pumps – medium

Heat pumps - medium (12-200kW)									
considered gases / technologies:		**R-134a**	**R-410A**	**R-407C**	**HCs**	**R-32**	**R-513A**	**HFO-1234ze**	**R-454B**
GWP AR4 of refrigerant	[1]	1 430	2 087.5	1 773.9	4	675	631.4	7	466.3
refrigerating capacity	kW	110	110	110	110	110	110	110	110
electric/mechanic capacity	kW	68.75	68.75	68.75	66.69	68.06	68.75	68.06	68.75
installation lifetime	years	15	15	15	15	15	15	15	15
invest cost hardware (first fill excluded)	€	30 000	30 000	30 000	33 000	31 500	30 000	31 500	30 000
annual operating hours	h/a	2 000	2 000	2 000	2 000	2 000	2 000	2 000	2 000
final energy cost	€/kWh	0.145	0.145	0.145	0.145	0.145	0.145	0.145	0.145
discount rate (societal view / emission reduction cost)	%	4%	4%	4%	4%	4%	4%	4%	4%
HFC operators' cost for containment & recovery (FGR Art 3-8)	€/a	283	283	283	-	283	283	-	283
additional maintenance cost for non-HFCs	€/a	-	-	-	55	-	-	-	-
refrigerant charge	kg	26	26	26	13	18	20.8	26	20.8
refrigerant cost first fill, average 2024-2036	€/kg	80.9	114.4	97.3	15	49.7	77.5	45	67
refrigerant cost first fill, average 2050	€/kg	93.6	132.9	112.9	15	55.7	83.1	45	71.2
refrigerant cost first fill, counterfactual scenario, 2014 pre-phase-down prices	€/kg	7.5	7.5	7.5	15	15	45	45	43
installation type is refilled?		yes	yes	yes	yes	yes	yes	yes	yes
refrigerant cost refill, average 2024-2036	€/kg	107.9	152.2	128.8	20	66.3	103.3	60	89.3
refrigerant cost refill, 2050	€/kg	124.8	176.9	149.4	20	74.3	110.8	60	94.9
refrigerant cost refill, counterfactual scenario, 2014 pre-phase-down prices	€/kg	10	10	10	20	20	60	60	57.3
leakage rate first fill / refill	kg/kg	0.5%	0.5%	0.5%	0.5%	0.5%	0.5%	0.5%	0.5%
leakage rate operation	1/a	4.5%	4.5%	4.5%	4.5%	4.5%	4.5%	4.5%	4.5%
technologically tolerable refrigerant loss	kg/kg	30%	30%	30%	30%	30%	30%	30%	30%
recovery rate end of life	kg/kg	59%	59%	59%	59%	59%	59%	59%	59%
Penetration rate in new installations, 2024-2036 average	%	0.1%	7.4%	-	30.6%	32.4%	1.5%	8.4%	19.7%
Penetration rate in new installations, 2050	%	-	5.0%	-	40.0%	25.0%	-	10.0%	20.0%

Table 42: AnaFgas sector sheet for the baseline scenario: Heat pumps – large

Heat pumps - large (>200kW, district heating & industrial)					
considered gases / technologies:		**R-134a**	**HFO-1234ze**	**CO2 (R-744)**	**NH3 / R-723**
GWP AR4 of refrigerant	[1]	1 430	7	1	0
refrigerating capacity	kW	3 173.08	3 173.08	3 173.08	3 173.08
electric/mechanic capacity	kW	1 983.17	1 963.34	1 913.76	1 884.01
installation lifetime	years	20	20	20	20
invest cost hardware (first fill excluded)	€	2 800 000	2 856 000	3 360 000	3 220 000
annual operating hours	h/a	6 000	6 000	6 000	6 000
final energy cost	€/kWh	0.095	0.095	0.095	0.095
discount rate (societal view / emission reduction cost)	%	4%	4%	4%	4%
HFC operators' cost for containment & recovery (FGR Art 3-8)	€/a	283	-	-	-
additional maintenance cost for non-HFCs	€/a	-	-	255	145
refrigerant charge	kg	750	600	500	500
refrigerant cost first fill, average 2024-2036	€/kg	107.9	60	5	4
refrigerant cost first fill, average 2050	€/kg	124.8	60	5	4
refrigerant cost first fill, counterfactual scenario, 2014 pre-phase-down prices	€/kg	10	60	5	4
installation type is refilled?		yes	yes	yes	yes
refrigerant cost refill, average 2024-2036	€/kg	107.9	60	5	4
refrigerant cost refill, 2050	€/kg	124.8	60	5	4
refrigerant cost refill, counterfactual scenario, 2014 pre-phase-down prices	€/kg	10	60	5	4
leakage rate first fill / refill	kg/kg	0.5%	0.5%	0.5%	0.5%
leakage rate operation	1/a	6.0%	6.0%	6.0%	6.0%
technologically tolerable refrigerant loss	kg/kg	30%	30%	30%	30%
recovery rate end of life	kg/kg	76%	76%	76%	76%
Penetration rate in new installations, 2024-2036 average	%	4.8%	25.2%	26.5%	43.5%
Penetration rate in new installations, 2050	%	-	30.0%	25.0%	45.0%

Table 43: AnaFgas sector sheet for the baseline scenario: Mobile AC - Passenger cars

Mobile AC - Passenger cars				
considered gases / technologies:		**R-134a**	**HFO-1234yf**	**R-744**
GWP AR4 of refrigerant	[1]	1 430	4	1
refrigerating capacity	kW	4	4	4
electric/mechanic capacity	kW	4	4	3.6
installation lifetime	years	12	12	12
invest cost hardware (first fill excluded)	€	300	303	450
annual operating hours	h/a	300	300	300
final energy cost	€/kWh	0.446	0.446	0.446
discount rate (societal view / emission reduction cost)	%	4%	4%	4%
HFC operators' cost for containment & recovery (FGR Art 3-8)	€/a	-	-	-
additional maintenance cost for non-HFCs	€/a	-	-	55
refrigerant charge	kg	0.5	0.5	0.34
refrigerant cost first fill, average 2024-2036	€/kg	54	70	2.5
refrigerant cost first fill, average 2050	€/kg	62.5	70	2.5
refrigerant cost first fill, counterfactual scenario, 2014 pre-phase-down prices	€/kg	5	70	2.5
installation type is refilled?		yes	yes	yes
refrigerant cost refill, average 2024-2036	€/kg	107.9	140	5
refrigerant cost refill, 2050	€/kg	124.8	140	5
refrigerant cost refill, counterfactual scenario, 2014 pre-phase-down prices	€/kg	10	140	5
leakage rate first fill / refill	kg/kg	0.5%	0.5%	0.5%
leakage rate operation	1/a	10.0%	10.0%	10.0%
technologically tolerable refrigerant loss	kg/kg	40%	40%	40%
recovery rate end of life	kg/kg	50%	50%	50%
Penetration rate in new installations, 2024-2036 average	%	-	90.8%	9.2%
Penetration rate in new installations, 2050	%	-	80.0%	20.0%

Table 44: AnaFgas sector sheet for the baseline scenario: Mobile AC – Buses

Mobile AC - Buses				
considered gases / technologies:		**R-134a**	**R-744**	**R-513A**
GWP AR4 of refrigerant	[1]	1 430	1	631.4
refrigerating capacity	kW	25	25	25
electric/mechanic capacity	kW	16.7	15.87	16.7
installation lifetime	years	10	10	10
invest cost hardware (first fill excluded)	€	13 000	23 400	13 650
annual operating hours	h/a	2 000	2 000	2 000
final energy cost	€/kWh	0.259	0.259	0.259
discount rate (societal view / emission reduction cost)	%	4%	4%	4%
HFC operators' cost for containment & recovery (FGR Art 3-8)	€/a	-	-	-
additional maintenance cost for non-HFCs	€/a	-	55	-
refrigerant charge	kg	10.4	6.97	10.4
refrigerant cost first fill, average 2024-2036	€/kg	54	2.5	51.6
refrigerant cost first fill, average 2050	€/kg	62.5	2.5	55.4
refrigerant cost first fill, counterfactual scenario, 2014 pre-phase-down prices	€/kg	5	2.5	30
installation type is refilled?		yes	yes	yes
refrigerant cost refill, average 2024-2036	€/kg	107.9	5	103.3
refrigerant cost refill, 2050	€/kg	124.8	5	110.8
refrigerant cost refill, counterfactual scenario, 2014 pre-phase-down prices	€/kg	10	5	60
leakage rate first fill / refill	kg/kg	0.0%	0.0%	0.0%
leakage rate operation	1/a	15.0%	15.0%	15.0%
technologically tolerable refrigerant loss	kg/kg	40%	40%	40%
recovery rate end of life	kg/kg	63%	63%	63%
Penetration rate in new installations, 2024-2036 average	%	23.3%	20.3%	56.4%
Penetration rate in new installations, 2050	%	10.0%	25.0%	65.0%

Table 45: AnaFgas sector sheet for the baseline scenario: Mobile AC - Trucks N1

Mobile AC - Trucks N1				
considered gases / technologies:		**R-134a**	**R-744**	**HFO-1234yf**
GWP AR4 of refrigerant	[1]	1 430	1	4
refrigerating capacity	kW	8	8	8
electric/mechanic capacity	kW	8	7.6	8
installation lifetime	years	10	10	10
invest cost hardware (first fill excluded)	€	300	450	304
annual operating hours	h/a	300	300	300
final energy cost	€/kWh	0.259	0.259	0.259
discount rate (societal view / emission reduction cost)	%	4%	4%	4%
HFC operators' cost for containment & recovery (FGR Art 3-8)	€/a	-	-	-
additional maintenance cost for non-HFCs	€/a	-	55	-
refrigerant charge	kg	1	0.67	1
refrigerant cost first fill, average 2024-2036	€/kg	54	2.5	70
refrigerant cost first fill, average 2050	€/kg	62.5	2.5	70
refrigerant cost first fill, counterfactual scenario, 2014 pre-phase-down prices	€/kg	5	2.5	70
installation type is refilled?		yes	yes	yes
refrigerant cost refill, average 2024-2036	€/kg	107.9	5	140
refrigerant cost refill, 2050	€/kg	124.8	5	140
refrigerant cost refill, counterfactual scenario, 2014 pre-phase-down prices	€/kg	10	5	140
leakage rate first fill / refill	kg/kg	0.0%	0.0%	0.0%
leakage rate operation	1/a	10.0%	10.0%	10.0%
technologically tolerable refrigerant loss	kg/kg	40%	40%	40%
recovery rate end of life	kg/kg	13%	13%	13%
Penetration rate in new installations, 2024-2036 average	%	72.3%	0.8%	26.9%
Penetration rate in new installations, 2050	%	60.0%	10.0%	30.0%

Table 46: AnaFgas sector sheet for the baseline scenario: Mobile AC - Trucks N2

Mobile AC - Trucks N2				
considered gases / technologies:		**R-134a**	**R-744**	**HFO-1234yf**
GWP AR4 of refrigerant	[1]	1 430	1	4
refrigerating capacity	kW	8	8	8
electric/mechanic capacity	kW	8	7.6	8
installation lifetime	years	10	10	10
invest cost hardware (first fill excluded)	€	300	450	304
annual operating hours	h/a	300	300	300
final energy cost	€/kWh	0.259	0.259	0.259
discount rate (societal view / emission reduction cost)	%	4%	4%	4%
HFC operators' cost for containment & recovery (FGR Art 3-8)	€/a	-	-	-
additional maintenance cost for non-HFCs	€/a	-	55	-
refrigerant charge	kg	1	0.67	1
refrigerant cost first fill, average 2024-2036	€/kg	54	2.5	70
refrigerant cost first fill, average 2050	€/kg	62.5	2.5	70
refrigerant cost first fill, counterfactual scenario, 2014 pre-phase-down prices	€/kg	5	2.5	70
installation type is refilled?		yes	yes	yes
refrigerant cost refill, average 2024-2036	€/kg	107.9	5	140
refrigerant cost refill, 2050	€/kg	124.8	5	140
refrigerant cost refill, counterfactual scenario, 2014 pre-phase-down prices	€/kg	10	5	140
leakage rate first fill / refill	kg/kg	0.0%	0.0%	0.0%
leakage rate operation	1/a	15.0%	15.0%	15.0%
technologically tolerable refrigerant loss	kg/kg	40%	40%	40%
recovery rate end of life	kg/kg	13%	13%	13%
Penetration rate in new installations, 2024-2036 average	%	92.7%	3.9%	3.5%
Penetration rate in new installations, 2050	%	85.0%	10.0%	5.0%

Table 47: AnaFgas sector sheet for the baseline scenario: Mobile AC - Trucks N3

Mobile AC - Trucks N3			
considered gases / technologies:		**R-134a**	**R-744**
GWP AR4 of refrigerant	[1]	1 430	1
refrigerating capacity	kW	8	8
electric/mechanic capacity	kW	8	7.6
installation lifetime	years	10	10
invest cost hardware (first fill excluded)	€	300	450
annual operating hours	h/a	300	300
final energy cost	€/kWh	0.259	0.259
discount rate (societal view / emission reduction cost)	%	4%	4%
HFC operators' cost for containment & recovery (FGR Art 3-8)	€/a	-	-
additional maintenance cost for non-HFCs	€/a	-	55
refrigerant charge	kg	1	0.67
refrigerant cost first fill, average 2024-2036	€/kg	54	2.5
refrigerant cost first fill, average 2050	€/kg	62.5	2.5
refrigerant cost first fill, counterfactual scenario, 2014 pre-phase-down prices	€/kg	5	2.5
installation type is refilled?		yes	yes
refrigerant cost refill, average 2024-2036	€/kg	107.9	5
refrigerant cost refill, 2050	€/kg	124.8	5
refrigerant cost refill, counterfactual scenario, 2014 pre-phase-down prices	€/kg	10	5
leakage rate first fill / refill	kg/kg	0.0%	0.0%
leakage rate operation	1/a	15.0%	15.0%
technologically tolerable refrigerant loss	kg/kg	40%	40%
recovery rate end of life	kg/kg	13%	13%
Penetration rate in new installations, 2024-2036 average	%	96.1%	3.9%
Penetration rate in new installations, 2050	%	90.0%	10.0%

Table 48: AnaFgas sector sheet for the baseline scenario: Mobile AC - Passenger ships

Mobile AC - Passenger ships				
considered gases / technologies:		**R-134a**	**R-513A**	**Naturals**
GWP AR4 of refrigerant	[1]	1 430	631.4	0.5
refrigerating capacity	kW	975	975	975
electric/mechanic capacity	kW	180	180	162
installation lifetime	years	30	30	30
invest cost hardware (first fill excluded)	€	123 500	129 675	172 900
annual operating hours	h/a	3 000	3 000	3 000
final energy cost	€/kWh	0.073	0.073	0.073
discount rate (societal view / emission reduction cost)	%	4%	4%	4%
HFC operators' cost for containment & recovery (FGR Art 3-8)	€/a	2 039	2 039	-
additional maintenance cost for non-HFCs	€/a	-	-	-
refrigerant charge	kg	520	520	468
refrigerant cost first fill, average 2024-2036	€/kg	107.9	103.3	4.5
refrigerant cost first fill, average 2050	€/kg	124.8	110.8	4.5
refrigerant cost first fill, counterfactual scenario, 2014 pre-phase-down prices	€/kg	10	60	4.5
installation type is refilled?		yes	yes	yes
refrigerant cost refill, average 2024-2036	€/kg	107.9	103.3	4.5
refrigerant cost refill, 2050	€/kg	124.8	110.8	4.5
refrigerant cost refill, counterfactual scenario, 2014 pre-phase-down prices	€/kg	10	60	4.5
leakage rate first fill / refill	kg/kg	0.0%	0.0%	0.0%
leakage rate operation	1/a	40.0%	40.0%	40.0%
technologically tolerable refrigerant loss	kg/kg	40%	40%	40%
recovery rate end of life	kg/kg	63%	63%	63%
Penetration rate in new installations, 2024-2036 average	%	9.6%	81.3%	9.1%
Penetration rate in new installations, 2050	%	-	-	100.0%

Table 49: AnaFgas sector sheet for the baseline scenario: Mobile AC - Cargo ships

Mobile AC - Cargo ships				
considered gases / technologies:		**R-134a**	**NH3/brine**	**R-513A**
GWP AR4 of refrigerant	[1]	1 430	0	631.4
refrigerating capacity	kW	300	300	300
electric/mechanic capacity	kW	55.3	47.01	55.3
installation lifetime	years	30	30	30
invest cost hardware (first fill excluded)	€	38 000	59 660	39 900
annual operating hours	h/a	3 000	3 000	3 000
final energy cost	€/kWh	0.073	0.073	0.073
discount rate (societal view / emission reduction cost)	%	4%	4%	4%
HFC operators' cost for containment & recovery (FGR Art 3-8)	€/a	778	-	778
additional maintenance cost for non-HFCs	€/a	-	1 000	-
refrigerant charge	kg	160	52.8	160
refrigerant cost first fill, average 2024-2036	€/kg	107.9	4	103.3
refrigerant cost first fill, average 2050	€/kg	124.8	4	110.8
refrigerant cost first fill, counterfactual scenario, 2014 pre-phase-down prices	€/kg	10	4	60
installation type is refilled?		yes	yes	yes
refrigerant cost refill, average 2024-2036	€/kg	107.9	4	103.3
refrigerant cost refill, 2050	€/kg	124.8	4	110.8
refrigerant cost refill, counterfactual scenario, 2014 pre-phase-down prices	€/kg	10	4	60
leakage rate first fill / refill	kg/kg	1.0%	1.0%	1.0%
leakage rate operation	1/a	40.0%	40.0%	40.0%
technologically tolerable refrigerant loss	kg/kg	40%	40%	40%
recovery rate end of life	kg/kg	63%	63%	63%
Penetration rate in new installations, 2024-2036 average	%	15.7%	15.0%	69.3%
Penetration rate in new installations, 2050	%	-	100.0%	-

Table 50: AnaFgas sector sheet for the baseline scenario: Mobile AC – Tram

Mobile AC - Tram					
considered gases / technologies:		**R-134a**	**R-744/CO2**	**R-513A**	**HCs**
GWP AR4 of refrigerant	[1]	1 430	1	631.4	4
refrigerating capacity	kW	35	35	35	35
electric/mechanic capacity	kW	15	13.5	15	14.55
installation lifetime	years	25	25	25	25
invest cost hardware (first fill excluded)	€	25 000	30 000	25 250	27 500
annual operating hours	h/a	2 000	2 000	2 000	2 000
final energy cost	€/kWh	0.08	0.08	0.08	0.08
discount rate (societal view / emission reduction cost)	%	4%	4%	4%	4%
HFC operators' cost for containment & recovery (FGR Art 3-8)	€/a	2	-	2	-
additional maintenance cost for non-HFCs	€/a	-	90	-	-
refrigerant charge	kg	8	6.4	8	8
refrigerant cost first fill, average 2024-2036	€/kg	54	2.5	51.6	10
refrigerant cost first fill, average 2050	€/kg	62.5	2.5	55.4	10
refrigerant cost first fill, counterfactual scenario, 2014 pre-phase-down prices	€/kg	5	2.5	30	10
installation type is refilled?		yes	yes	yes	yes
refrigerant cost refill, average 2024-2036	€/kg	107.9	5	103.3	20
refrigerant cost refill, 2050	€/kg	124.8	5	110.8	20
refrigerant cost refill, counterfactual scenario, 2014 pre-phase-down prices	€/kg	10	5	60	20
leakage rate first fill / refill	kg/kg	0.2%	0.2%	0.2%	0.2%
leakage rate operation	1/a	7.0%	7.0%	7.0%	7.0%
technologically tolerable refrigerant loss	kg/kg	25%	25%	25%	25%
recovery rate end of life	kg/kg	66%	66%	66%	66%
Penetration rate in new installations, 2024-2036 average	%	8.9%	40.5%	45.2%	5.4%
Penetration rate in new installations, 2050	%	-	50.0%	40.0%	10.0%

Table 51: AnaFgas sector sheet for the baseline scenario: Mobile AC – Metro

Mobile AC - Metro				
considered gases / technologies:		**R-134a**	**R-744/CO2**	**R-513A**
GWP AR4 of refrigerant	[1]	1 430	1	631.4
refrigerating capacity	kW	35	35	35
electric/mechanic capacity	kW	15	13.5	15
installation lifetime	years	25	25	25
invest cost hardware (first fill excluded)	€	25 000	30 000	25 250
annual operating hours	h/a	2 000	2 000	2 000
final energy cost	€/kWh	0.08	0.08	0.08
discount rate (societal view / emission reduction cost)	%	4%	4%	4%
HFC operators' cost for containment & recovery (FGR Art 3-8)	€/a	2	-	2
additional maintenance cost for non-HFCs	€/a	-	90	-
refrigerant charge	kg	8	6.4	8
refrigerant cost first fill, average 2024-2036	€/kg	54	2.5	51.6
refrigerant cost first fill, average 2050	€/kg	62.5	2.5	55.4
refrigerant cost first fill, counterfactual scenario, 2014 pre-phase-down prices	€/kg	5	2.5	30
installation type is refilled?		yes	yes	yes
refrigerant cost refill, average 2024-2036	€/kg	107.9	5	103.3
refrigerant cost refill, 2050	€/kg	124.8	5	110.8
refrigerant cost refill, counterfactual scenario, 2014 pre-phase-down prices	€/kg	10	5	60
leakage rate first fill / refill	kg/kg	0.2%	0.2%	0.2%
leakage rate operation	1/a	7.0%	7.0%	7.0%
technologically tolerable refrigerant loss	kg/kg	25%	25%	25%
recovery rate end of life	kg/kg	66%	66%	66%
Penetration rate in new installations, 2024-2036 average	%	7.4%	47.4%	45.2%
Penetration rate in new installations, 2050	%	-	60.0%	40.0%

Table 52: AnaFgas sector sheet for the baseline scenario: Mobile AC – Train

Mobile AC - Train						
considered gases / technologies:		**R-134a**	**R-407C**	**R-744 / HCs**	**R-513A**	**R-729**
GWP AR4 of refrigerant	[1]	1 430	1 773.9	2.5	631.4	0
refrigerating capacity	kW	35	35	35	35	35
electric/mechanic capacity	kW	15	15	13.5	15	13.5
installation lifetime	years	25	25	25	25	25
invest cost hardware (first fill excluded)	€	25 000	25 000	30 000	25 250	50 000
annual operating hours	h/a	2 000	2 000	2 000	2 000	2 000
final energy cost	€/kWh	0.08	0.08	0.08	0.08	0.08
discount rate (societal view / emission reduction cost)	%	4%	4%	4%	4%	4%
HFC operators' cost for containment & recovery (FGR Art 3-8)	€/a	2	2	-	2	-
additional maintenance cost for non-HFCs	€/a	-	-	-	-	-
refrigerant charge	kg	8	8	8	8	8
refrigerant cost first fill, average 2024-2036	€/kg	54	65.8	6.3	51.6	2
refrigerant cost first fill, average 2050	€/kg	62.5	76.3	6.3	55.4	2
refrigerant cost first fill, counterfactual scenario, 2014 pre-phase-down prices	€/kg	5	5	6.3	30	2
installation type is refilled?		yes	yes	yes	yes	yes
refrigerant cost refill, average 2024-2036	€/kg	107.9	128.8	12.5	103.3	4
refrigerant cost refill, 2050	€/kg	124.8	149.4	12.5	110.8	4
refrigerant cost refill, counterfactual scenario, 2014 pre-phase-down prices	€/kg	10	10	12.5	60	4
leakage rate first fill / refill	kg/kg	0.2%	0.2%	0.2%	0.2%	0.2%
leakage rate operation	1/a	7.0%	7.0%	7.0%	7.0%	7.0%
technologically tolerable refrigerant loss	kg/kg	25%	25%	25%	25%	25%
recovery rate end of life	kg/kg	66%	66%	66%	66%	66%
Penetration rate in new installations, 2024-2036 average	%	4.4%	-	33.6%	38.3%	23.7%
Penetration rate in new installations, 2050	%	-	-	40.0%	30.0%	30.0%

Table 53: AnaFgas sector sheet for the baseline scenario: Aerosols – technical

Aerosols - technical				
considered gases / technologies:		**HFC-134a**	**HFC-152a**	**HFC-1234ze**
GWP AR4 of propellant	[1]	1 430	124	7
preparation / canning cost (propellant excluded) per kg propellant	€/kg	20	20	20
propellant charge	kg	0.15	0.15	0.15
propellant cost first fill, average 2024-2036	€/kg	54.0	9.2	15.0
propellant cost first fill, 2050	€/kg	62.5	10.0	15.0
propellant cost first fill, counterfactual scenario, 2014 pre-phase-down prices	€/kg	5.0	5.0	15.0
emission rate on application	kg/kg	100%	100%	100%
Penetration rate (defined on HFC-based niche of sector), 2024-2036 average	%	-	18.9%	81.1%
Penetration rate (defined on HFC-based niche of sector), 2050	%	-	18.9%	81.1%

Table 54: AnaFgas sector sheet for the baseline scenario: Aerosols – MDIs

Aerosols - MDIs				
considered gases / technologies:		**HFC-134a**	**HFC-227ea**	**HFC-152a**
GWP AR4 of propellant	[1]	1 430	3 220	124
preparation / canning cost (propellant excluded) per kg propellant	€/kg	705.88	705.88	705.88
propellant charge	kg	0.005	0.005	0.005
propellant cost first fill, average 2024-2036	€/kg	8.0	8.0	8.0
propellant cost first fill, 2050	€/kg	8.0	8.0	8.0
propellant cost first fill, counterfactual scenario, 2014 pre-phase-down prices	€/kg	8.0	8.0	8.0
emission rate on application	kg/kg	100%	100%	100%
Penetration rate (defined on HFC-based niche of sector), 2024-2036 average	%	84.4%	4.0%	11.6%
Penetration rate (defined on HFC-based niche of sector), 2050	%	48.0%	2.0%	50.0%

Table 55: AnaFgas sector sheet for the baseline scenario: Fire extinguishers

Fire extinguishers							
considered gases / technologies:		**HFC-227ea**	**HFC-23**	**HFC-125**	**HFC-236fa**	**HFC-134a**	**low-GWP alternatives (FK-5-1-12, inert gases)**
GWP AR4 of suppression agent	[1]	3 220	14 800	3 500	9 810	1 430	0.5
room size	m³	200	200	200	200	200	200
required gas concentration (for suppression of class C hazards (energized electrical equipment)	m³ / m³	5.8%	17.4%	9.0%	8.6%	15.3%	21.3%
molar mass of suppression agent	g/mol	170	70	120	152	102	175
molar volume at room temperature	l/mol	24.47	24.47	24.47	24.47	24.47	24.47
installed gas quantity	kg	80.6	99.6	88.3	106.8	127.6	303.9
installation lifetime	years	20	20	20	20	20	20
invest cost hardware (first fill excluded)	€	14 000	11 500	14 000	14 000	14 000	14 000
discount rate (societal view / emission reduction cost)	%	4%	4%	4%	4%	4%	4%
HFC operators' cost for containment & recovery (FGR Art 3-8)	€/a	117	117	117	117	117	-
additional maintenance cost for non-HFCs	€/a	-	-	-	-	-	-
suppression agent cost first fill, average 2024-2036	€/kg	124.3	521.1	133.9	350.1	63	11
suppression agent cost first fill, 2050	€/kg	143.4	608.9	154.7	408.3	71.5	11
suppression agent cost first fill, counterfactual scenario, 2014 pre-phase-down prices	€/kg	14	14	14	14	14	11
installation type is refilled?		yes	yes	yes	yes	yes	yes
suppression agent cost refill, average 2024-2036	€/kg	124.3	521.1	133.1	350.1	63	11
suppression agent cost refill, 2050	€/kg	143.4	608.9	153.8	408.3	71.5	11
suppression agent cost refill, counterfactual scenario, 2014 pre-phase-down prices	€/kg	14	14	14	14	14	11
leakage rate first fill / refill	kg/kg	0.1%	0.1%	0.1%	0.1%	0.1%	0.1%
leakage rate operation	1/a	2.0%	2.0%	2.0%	5.0%	4.0%	2.0%
recovery rate end of life	kg/kg	91%	91%	91%	91%	91%	91%
Penetration rate in new installations (in HFC-based niche of sector), 2024-2036 average	%	-	-	-	-	-	100.0%
Penetration rate in new installations (in HFC-based niche of sector), 2050	%	-	-	-	-	-	100.0%

Table 56: AnaFgas sector sheet for the baseline scenario: Solvents

Solvents					
considered gases / technologies:		**HFC-43-10mee**	**HFC-365mfc**	**HFO-1233zd**	**Novec 7100**
GWP AR4 of propellant	[1]	1 640	794	4.5	297
preparation / canning cost (propellant excluded) per kg propellant	€/kg	20	20	20	20
propellant charge	kg	0.15	0.15	0.15	0.15
propellant cost first fill, average 2024-2036	€/kg	61.2	33.2	25.0	25.0
propellant cost first fill, 2050	€/kg	70.9	37.9	25.0	25.0
propellant cost first fill, counterfactual scenario, 2014 pre-phase-down prices	€/kg	5.0	6.0	25.0	25.0
emission rate on application	kg/kg	100%	100%	100%	100%
Penetration rate (defined on HFC-based niche of sector), 2024-2036 average	%	62.0%	1.8%	27.0%	9.2%
Penetration rate (defined on HFC-based niche of sector), 2050	%	57.9%	1.8%	29.7%	10.6%

Table 57: AnaFgas sector sheet for the baseline scenario: Foam OCF

Foam OCF (one component foam)			
considered gases / technologies:		**HFC-134a**	**HFO-1234ze**
GWP AR4 of blowing agent	[1]	1 430	7
product		OCF cans, 660g, hereof 110g propellant	OCF cans, 660g, hereof 110g propellant
production facility annual output	m^3/a	10 000	10 000
thermal conductivity	mW/ (m * K)	30	30
production facility insulation capacity annual output	m^3/ a * ((m * K) / mW))	333	333
product density	kg/m^3	42	42
blowing agent in formulation	pbw	110	110
total weight of formulation	pbw	660	660
foam product lifetime	years	50	50
invest cost for conversion of production line including development	€	-	22 500
economic lifetime of conversion investment	years	15	15
discount rate (societal view / emission reduction cost)	%	4%	4%
blowing agent cost, average 2024-2036	€/kg	22.7	18.4
blowing agent cost, average 2050	€/kg	23.3	19.0
blowing agent cost, counterfactual scenario, 2014 pre-phase-down prices	€/kg	5.0	15.0
manufacturing emission factor of blowing agent	kg/kg	15%	15%
leakage rate in foam product lifetime, baseline scenario	1/a	1.0%	1.0%
Penetration rate (defined on HFC-based niche of sector), 2024-2036 average	%	-	100.0%
Penetration rate (defined on HFC-based niche of sector), 2050	%	-	100.0%

Table 58: AnaFgas sector sheet for the baseline scenario: Foam XPS

considered gases / technologies:		**XPS / HFC-134a**	**XPS / HFC-152a**	**XPS / HFO-1234ze**	**XPS / CO2**
GWP AR4 of blowing agent	[1]	1 430	124	7	1
product		XPS-134a Panel 1200 x 600 x 1400 mm, density 35	XPS Panel 1200 x 600 x 50 mm, density 35	XPS Panel 1200 x 600 x 1400 mm, density 40	XPS Panel 1200 x 600 x 50 mm, density 35
production facility annual output	m³/a	75 000	87 931	75 000	87 931
thermal conductivity	mW/ (m * K)	29	34	29	34
production facility insulation capacity annual output	m³/ a * ((m * K) / mW))	2 586	2 586	2 586	2 586
product density	kg/m³	35	35	40	35
blowing agent in formulation	pbw	7	10	8	10
total weight of formulation	pbw	100	90	100	90
foam product lifetime	years	50	50	50	50
invest cost for conversion of production line including development	€	-	-	1 000 000	1 500 000
economic lifetime of conversion investment	years	15	15	15	15
discount rate (societal view / emission reduction cost)	%	4%	4%	4%	4%
blowing agent cost, average 2024-2036	€/kg	22.7	9.7	18.4	5.9
blowing agent cost, average 2050	€/kg	23.3	10.3	19.0	6.5
blowing agent cost, counterfactual scenario, 2014 pre-phase-down prices	€/kg	5.0	5.0	15.0	2.5
manufacturing emission factor of blowing agent	kg/kg	30%	100%	30%	30%
leakage rate in foam product lifetime, baseline scenario	1/a	0.8%	0.8%	0.8%	0.8%
Penetration rate (defined on HFC-based niche of sector), 2024-2036 average	%	-	8.4%	91.6%	-
Penetration rate (defined on HFC-based niche of sector), 2050	%	-	-	100.0%	-

Table 59: AnaFgas sector sheet for the baseline scenario: Foam PU spray

Foam PU (polyurethane) spray				
considered gases / technologies:		**HFC-365mfc / HFC-245fa**	**HFO-1233zd / HFO-1336mzz**	**H2O**
GWP AR4 of blowing agent	[1]	864.8	4.5	0
product		spray foam, density 60	spray foam, density 60	spray foam, density 60
production facility annual output	m³/a	1 667	1 583	1 944
thermal conductivity	mW/ (m * K)	30	29	35
production facility insulation capacity annual output	m³/ a * ((m * K) / mW))	56	56	56
product density	kg/m³	60	60	60
blowing agent in formulation	pbw	15	15	15
total weight of formulation	pbw	245	245	245
foam product lifetime	years	50	50	50
invest cost for conversion of production line including development	€	-	22 500	22 500
economic lifetime of conversion investment	years	15	15	15
discount rate (societal view / emission reduction cost)	%	4%	4%	4%
blowing agent cost, average 2024-2036	€/kg	17.8	18.4	3.4
blowing agent cost, average 2050	€/kg	18.4	19.0	4.0
blowing agent cost, counterfactual scenario, 2014 pre-phase-down prices	€/kg	5.7	15.0	0.0
manufacturing emission factor of blowing agent	kg/kg	15%	15%	15%
leakage rate in foam product lifetime, baseline scenario	1/a	1.0%	1.0%	1.0%
Penetration rate (defined on HFC-based niche of sector), 2024-2036 average	%	-	90.0%	10.0%
Penetration rate (defined on HFC-based niche of sector), 2050	%	-	90.0%	10.0%

Table 60: AnaFgas sector sheet for the baseline scenario: Foam PU non-spray

Foam PU (polyurethane) non-spray			
considered gases / technologies:		**HFC-365mfc / HFC-245fa**	**HFO-1233zd / HFO-1336mzz**
GWP AR4 of blowing agent	[1]	864.8	4.5
product		Blockfoam 1 m³, density 60	Blockfoam 1 m³, density 60
production facility annual output	m³/a	10 000	9 500
thermal conductivity	mW/ (m * K)	22	21
production facility insulation capacity annual output	m³/ a * ((m * K) / mW))	455	455
product density	kg/m³	60	60
blowing agent in formulation	pbw	12	14
total weight of formulation	pbw	242	244
foam product lifetime	years	50	50
invest cost for conversion of production line including development	€	-	480 000
economic lifetime of conversion investment	years	15	15
discount rate (societal view / emission reduction cost)	%	4%	4%
blowing agent cost, average 2024-2036	€/kg	17.8	18.4
blowing agent cost, average 2050	€/kg	18.4	19.0
blowing agent cost, counterfactual scenario, 2014 pre-phase-down prices	€/kg	5.7	15.0
manufacturing emission factor of blowing agent	kg/kg	15%	15%
leakage rate in foam product lifetime, baseline scenario	1/a	1.0%	1.0%
Penetration rate (defined on HFC-based niche of sector), 2024-2036 average	%	-	100.0%
Penetration rate (defined on HFC-based niche of sector), 2050	%	-	100.0%

Table 61: AnaFgas sector sheet for the baseline scenario: Electrical switchgear, medium voltage

Electrical switchgear, medium voltage		
considered gases / technologies:		**SF6**
GWP AR4 of insulation gas	[1]	22 800
rated voltage	kW	24
installation lifetime	years	40
invest cost hardware (first fill excluded)	€	15 000
discount rate (societal view / emission reduction cost)	%	4%
maintenance cost	€/a	-
insulation gas charge	kg	5
insulation gas cost first fill, average 2024-2036	€/kg	10
insulation gas cost first fill, average 2050	€/kg	10
insulation gas cost first fill, counterfactual scenario, 2014 pre-phase-down prices	€/kg	10
installation type is refilled?		no
insulation gas cost refill, average 2024-2036	€/kg	-
insulation gas cost refill, 2050	€/kg	-
insulation gas cost refill, counterfactual scenario, 2014 pre-phase-down prices	€/kg	-
leakage rate first fill / refill	kg/kg	0.9%
leakage rate operation	1/a	0.1%
technologically tolerable insulation gas loss	kg/kg	5%
recovery rate end of life	kg/kg	90%
Penetration rate in new installations, 2024-2036 average	%	100.0%
Penetration rate in new installations, 2050	%	100.0%

Table 62: AnaFgas sector sheet for the baseline scenario: Electrical switchgear, high voltage

Electrical switchgear, high voltage		
considered gases / technologies:		**SF6**
GWP AR4 of insulation gas	[1]	22 800
rated voltage	kW	110
installation lifetime	years	40
invest cost hardware (first fill excluded)	€	225 000
discount rate (societal view / emission reduction cost)	%	4%
maintenance cost	€/a	110
insulation gas charge	kg	90
insulation gas cost first fill, average 2024-2036	€/kg	10
insulation gas cost first fill, average 2050	€/kg	10
insulation gas cost first fill, counterfactual scenario, 2014 pre-phase-down prices	€/kg	10
installation type is refilled?		yes
insulation gas cost refill, average 2024-2036	€/kg	10
insulation gas cost refill, 2050	€/kg	10
insulation gas cost refill, counterfactual scenario, 2014 pre-phase-down prices	€/kg	10
leakage rate first fill / refill	kg/kg	0.9%
leakage rate operation	1/a	1.0%
technologically tolerable insulation gas loss	kg/kg	20%
recovery rate end of life	kg/kg	90%
Penetration rate in new installations, 2024-2036 average	%	100.0%
Penetration rate in new installations, 2050	%	100.0%

Annex 2.5: AnaFgas model installation parameters: sector sheets (MP alignment scenario)

Table 63: AnaFgas sector sheet for the MP alignment scenario: Domestic Refrigeration

Domestic Refrigeration			
considered gases / technologies:		**HFC 134a**	**R-600a**
GWP AR4 of refrigerant	[1]	1 430	4
refrigerating capacity	kW	0.2	0.2
electric/mechanic capacity	kW	0.13	0.12
installation lifetime	years	15	15
invest cost hardware (first fill excluded)	€	400	392
annual operating hours	h/a	7 200	7 200
final energy cost	€/kWh	0.215	0.215
discount rate (societal view / emission reduction cost)	%	4%	4%
HFC operators' cost for containment & recovery (FGR Art 3-8)	€/a	-	-
additional maintenance cost for non-HFCs	€/a	-	-
refrigerant charge	kg	0.12	0.06
refrigerant cost first fill, average 2024-2036	€/kg	47.6	10
refrigerant cost first fill, average 2050	€/kg	76.5	10
refrigerant cost first fill, counterfactual scenario, 2014 pre-phase-down prices	€/kg	5	10
installation type is refilled?		no	no
refrigerant cost refill, average 2024-2036	€/kg	-	-
refrigerant cost refill, 2050	€/kg	-	-
refrigerant cost refill, counterfactual scenario, 2014 pre-phase-down prices	€/kg	-	-
leakage rate first fill / refill	kg/kg	0.5%	0.5%
leakage rate operation	1/a	0.3%	0.3%
technologically tolerable refrigerant loss	kg/kg	20%	20%
recovery rate end of life	kg/kg	70%	70%
Penetration rate in new installations, 2024-2036 average	%	-	100.0%
Penetration rate in new installations, 2050	%	-	100.0%

Table 64: AnaFgas sector sheet for the MP alignment scenario: Commercial refrigeration – Hermetics

Commercial refrigeration - Hermetics				
considered gases / technologies:		**HFC 134a**	**R-600a/290-direct**	**R-454C/R-455A**
GWP AR4 of refrigerant	[1]	1 430	4	148.2
refrigerating capacity	kW	0.6	0.6	0.6
electric/mechanic capacity	kW	0.38	0.36	0.38
installation lifetime	years	10	10	10
invest cost hardware (first fill excluded)	€	1 000	980	1 020
annual operating hours	h/a	6 000	6 000	6 000
final energy cost	€/kWh	0.145	0.145	0.145
discount rate (societal view / emission reduction cost)	%	4%	4%	4%
HFC operators' cost for containment & recovery (FGR Art 3-8)	€/a	3	-	3
additional maintenance cost for non-HFCs	€/a	-	-	-
refrigerant charge	kg	0.4	0.2	0.4
refrigerant cost first fill, average 2024-2036	€/kg	47.6	10	34.4
refrigerant cost first fill, average 2050	€/kg	76.5	10	37.4
refrigerant cost first fill, counterfactual scenario, 2014 pre-phase-down prices	€/kg	5	10	30
installation type is refilled?		no	no	no
refrigerant cost refill, average 2024-2036	€/kg	-	-	-
refrigerant cost refill, 2050	€/kg	-	-	-
refrigerant cost refill, counterfactual scenario, 2014 pre-phase-down prices	€/kg	-	-	-
leakage rate first fill / refill	kg/kg	0.5%	0.5%	0.5%
leakage rate operation	1/a	1.0%	1.0%	1.0%
technologically tolerable refrigerant loss	kg/kg	20%	20%	20%
recovery rate end of life	kg/kg	61%	61%	61%
Penetration rate in new installations, 2024-2036 average	%	0.8%	97.6%	1.5%
Penetration rate in new installations, 2050	%	-	100.0%	-

Table 65: AnaFgas sector sheet for the MP alignment scenario: Commercial refrigeration - Condensing units

Commercial refrigeration - Condensing units									
considered gases / technologies:		**R-404A**	**R-134a DX**	**HC (R-290 DX)**	**R-744 (CO2)**	**HC (R-290 + secondary liquid)**	**R-448A/R-449A**	**R-513A**	**R-454C/ R-455A**
GWP AR4 of refrigerant	[1]	3 921.6	1 430	3	1	3	1 392.1	631.4	148.2
refrigerating capacity	kW	4	4	4	4	4	4	4	4
electric/mechanic capacity	kW	2.5	2.5	2.43	2.38	2.38	2.45	2.45	2.53
installation lifetime	years	12	12	12	12	12	12	12	12
invest cost hardware (first fill excluded)	€	3 800	3 800	3 990	4 560	4 560	3 800	3 800	3 876
annual operating hours	h/a	5 840	5 840	5 840	5 840	5 840	5 840	5 840	5 840
final energy cost	€/kWh	0.145	0.145	0.145	0.145	0.145	0.145	0.145	0.145
discount rate (societal view / emission reduction cost)	%	4%	4%	4%	4%	4%	4%	4%	4%
HFC operators' cost for containment & recovery (FGR Art 3-8)	€/a	77	77	-	-	-	77	77	77
additional maintenance cost for non-HFCs	€/a	-	-	55	90	55	-	-	-
refrigerant charge	kg	4	4	2	2.67	0.8	4	4	4
refrigerant cost first fill, average 2024-2036	€/kg	234.7	95.1	20	5	20	142.9	97.6	68.8
refrigerant cost first fill, average 2050	€/kg	387.3	152.9	20	5	20	199.2	123.2	74.8
refrigerant cost first fill, counterfactual scenario, 2014 pre-phase-down prices	€/kg	10	10	20	5	20	60	60	60
installation type is refilled?		yes	yes	yes	yes	yes	yes	yes	yes
refrigerant cost refill, average 2024-2036	€/kg	234.7	95.1	20	5	20	142.9	97.6	68.8
refrigerant cost refill, 2050	€/kg	387.3	152.9	20	5	20	199.2	123.2	74.8
refrigerant cost refill, counterfactual scenario, 2014 pre-phase-down prices	€/kg	10	10	20	5	20	60	60	60
leakage rate first fill / refill	kg/kg	1.0%	1.0%	1.0%	1.0%	1.0%	1.0%	1.0%	1.0%
leakage rate operation	1/a	6.0%	6.0%	6.0%	6.0%	6.0%	6.0%	6.0%	6.0%
technologically tolerable refrigerant loss	kg/kg	25%	25%	25%	25%	25%	25%	25%	25%
recovery rate end of life	kg/kg	71%	71%	71%	71%	71%	71%	71%	71%
Penetration rate in new installations, 2024-2036 average	%	9.8%	11.9%	27.4%	18.5%	8.4%	3.1%	3.1%	17.8%
Penetration rate in new installations, 2050	%	-	-	50.0%	30.0%	10.0%	-	-	10.0%

Table 66: AnaFgas sector sheet for the MP alignment scenario: Commercial refrigeration - Central systems

Commercial refrigeration - Central systems									
considered gases / technologies:		**R-404A DX**	**R-134a DX**	**HC+CO2+ CO2 cas-cade**	**R-744 transcriti-cal**	**HC+sec. liq-uid+CO2**	**R-448A/R-449A**	**HFC 1234ze + CO2+CO2 cascade**	**R-513A (also in cascade)**
GWP AR4 of refrigerant	[1]	3 921.6	1 430	4	1	4	1 392.1	7	631.4
refrigerating capacity	kW	100	100	100	100	100	100	100	100
electric/mechanic capacity	kW	40	40	37	37	40	39.2	38.8	39.6
installation lifetime	years	12	12	12	12	12	12	12	12
invest cost hardware (first fill excluded)	€	320 000	320 000	368 000	342 400	336 000	320 000	352 000	320 000
annual operating hours	h/a	4 380	4 380	4 380	4 380	4 380	4 380	4 380	4 380
final energy cost	€/kWh	0.145	0.145	0.145	0.145	0.145	0.145	0.145	0.145
discount rate (societal view / emission reduction cost)	%	4%	4%	4%	4%	4%	4%	4%	4%
HFC operators' cost for containment & recovery (FGR Art 3-8)	€/a	655	655	-	-	-	655	-	655
additional maintenance cost for non-HFCs	€/a	-	-	55	255	55	-	-	-
refrigerant charge	kg	230	230	57.5	230	23	230	76.67	230
refrigerant cost first fill, average 2024-2036	€/kg	234.7	95.1	20	5	20	142.9	60	97.6
refrigerant cost first fill, average 2050	€/kg	387.3	152.9	20	5	20	199.2	60	123.2
refrigerant cost first fill, counterfactual scenario, 2014 pre-phase-down prices	€/kg	10	10	20	5	20	60	60	60
installation type is refilled?		yes	yes	yes	yes	yes	yes	yes	yes
refrigerant cost refill, average 2024-2036	€/kg	234.7	95.1	20	5	20	142.9	60	97.6
refrigerant cost refill, 2050	€/kg	387.3	152.9	20	5	20	199.2	60	123.2
refrigerant cost refill, counterfactual scenario, 2014 pre-phase-down prices	€/kg	10	10	20	5	20	60	60	60
leakage rate first fill / refill	kg/kg	1.0%	1.0%	1.0%	1.0%	1.0%	1.0%	1.0%	1.0%
leakage rate operation	1/a	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%
technologically tolerable refrigerant loss	kg/kg	25%	25%	25%	25%	25%	25%	25%	25%
recovery rate end of life	kg/kg	71%	71%	71%	71%	71%	71%	71%	71%
Penetration rate in new installations, 2024-2036 average	%	-	8.3%	11.1%	47.0%	11.1%	2.1%	4.9%	15.4%
Penetration rate in new installations, 2050	%	-	-	17.5%	60.0%	17.5%	-	5.0%	-

Table 67: AnaFgas sector sheet for the MP alignment scenario: Industrial refrigeration – small

Industrial refrigeration - small						
considered gases / technologies:		**R-404A**	**R-134a**	**R-717**	**CO2 / HC**	**R-513A**
GWP AR4 of refrigerant	[1]	3 921.6	1 430	0	2.5	631.4
refrigerating capacity	kW	270	270	270	270	270
electric/mechanic capacity	kW	168.75	168.75	151.88	160.31	165.38
installation lifetime	years	30	30	30	30	30
invest cost hardware (first fill excluded)	€	425 000	425 000	531 250	552 500	425 000
annual operating hours	h/a	4 500	4 500	4 500	4 500	4 500
final energy cost	€/kWh	0.095	0.095	0.095	0.095	0.095
discount rate (societal view / emission reduction cost)	%	4%	4%	4%	4%	4%
HFC operators' cost for containment & recovery (FGR Art 3-8)	€/a	1 142	1 142	-	-	1 142
additional maintenance cost for non-HFCs	€/a	-	-	1 000	55	-
refrigerant charge	kg	650	650	650	650	650
refrigerant cost first fill, average 2024-2036	€/kg	234.7	95.1	4	12.5	97.6
refrigerant cost first fill, average 2050	€/kg	387.3	152.9	4	12.5	123.2
refrigerant cost first fill, counterfactual scenario, 2014 pre-phase-down prices	€/kg	10	10	4	12.5	60
installation type is refilled?		yes	yes	yes	yes	yes
refrigerant cost refill, average 2024-2036	€/kg	234.7	95.1	4	12.5	97.6
refrigerant cost refill, 2050	€/kg	387.3	152.9	4	12.5	123.2
refrigerant cost refill, counterfactual scenario, 2014 pre-phase-down prices	€/kg	10	10	4	12.5	60
leakage rate first fill / refill	kg/kg	1.0%	1.0%	1.0%	1.0%	1.0%
leakage rate operation	1/a	5.4%	5.4%	5.4%	5.4%	5.4%
technologically tolerable refrigerant loss	kg/kg	30%	30%	30%	30%	30%
recovery rate end of life	kg/kg	65%	65%	65%	65%	65%
Penetration rate in new installations, 2024-2036 average	%	5.6%	5.7%	40.8%	41.2%	6.7%
Penetration rate in new installations, 2050	%	-	-	45.0%	50.0%	5.0%

Table 68: AnaFgas sector sheet for the MP alignment scenario: Industrial refrigeration – large

Industrial refrigeration - large					
considered gases / technologies:		**R-404A**	**R-717**	**HFC-1234ze**	**R-513A (also as cascade + CO2)**
GWP AR4 of refrigerant	[1]	3 921.6	0	7	631.4
refrigerating capacity	kW	5 000	5 000	5 000	5 000
electric/mechanic capacity	kW	2 000	1 780	1 960	1 960
installation lifetime	years	30	30	30	30
invest cost hardware (first fill excluded)	€	6 000 000	7 800 000	6 120 000	6 000 000
annual operating hours	h/a	4 500	4 500	4 500	4 500
final energy cost	€/kWh	0.095	0.095	0.095	0.095
discount rate (societal view / emission reduction cost)	%	4%	4%	4%	4%
HFC operators' cost for containment & recovery (FGR Art 3-8)	€/a	1 285	-	-	1 285
additional maintenance cost for non-HFCs	€/a	-	2 000	-	-
refrigerant charge	kg	4000	4000	4000	4000
refrigerant cost first fill, average 2024-2036	€/kg	234.7	4	60	97.6
refrigerant cost first fill, average 2050	€/kg	387.3	4	60	123.2
refrigerant cost first fill, counterfactual scenario, 2014 pre-phase-down prices	€/kg	10	4	60	60
installation type is refilled?		yes	yes	yes	yes
refrigerant cost refill, average 2024-2036	€/kg	234.7	4	60	97.6
refrigerant cost refill, 2050	€/kg	387.3	4	60	123.2
refrigerant cost refill, counterfactual scenario, 2014 pre-phase-down prices	€/kg	10	4	60	60
leakage rate first fill / refill	kg/kg	1.0%	1.0%	1.0%	1.0%
leakage rate operation	1/a	4.0%	4.0%	4.0%	4.0%
technologically tolerable refrigerant loss	kg/kg	0%	0%	0%	0%
recovery rate end of life	kg/kg	70%	70%	70%	70%
Penetration rate in new installations, 2024-2036 average	%	0.2%	87.7%	9.2%	2.8%
Penetration rate in new installations, 2050	%	-	90.0%	10.0%	-

Table 69: AnaFgas sector sheet for the MP alignment scenario: Transport refrigeration – Vans

Transport refrigeration - Vans							
considered gases / technologies:		**HFC 134a**	**R-404A**	**R-744**	**R-452A**	**R-513A**	**R-454C/R-455A**
GWP AR4 of refrigerant	[1]	1 430	3 921.6	1	2 140.5	631.4	148.2
refrigerating capacity	kW	3	3	3	3	3	3
electric/mechanic capacity	kW	1.5	1.5	1.39	1.5	1.5	1.5
installation lifetime	years	10	10	10	10	10	10
invest cost hardware (first fill excluded)	€	3 000	3 000	3 369	3 000	3 000	3 150
annual operating hours	h/a	1 500	1 500	1 500	1 500	1 500	1 500
final energy cost	€/kWh	0.259	0.259	0.259	0.259	0.259	0.259
discount rate (societal view / emission reduction cost)	%	4%	4%	4%	4%	4%	4%
HFC operators' cost for containment & recovery (FGR Art 3-8)	€/a	77	77	-	77	77	77
additional maintenance cost for non-HFCs	€/a	-	-	55	-	-	-
refrigerant charge	kg	1.5	1.5	1.5	1.5	1.5	1.5
refrigerant cost first fill, average 2024-2036	€/kg	47.6	121.8	2.5	88.8	48.8	34.4
refrigerant cost first fill, average 2050	€/kg	76.5	201.1	2.5	132.1	61.6	37.4
refrigerant cost first fill, counterfactual scenario, 2014 pre-phase-down prices	€/kg	5	5	2.5	25	30	30
installation type is refilled?		yes	yes	yes	yes	yes	yes
refrigerant cost refill, average 2024-2036	€/kg	95.1	234.7	5	177.5	97.6	68.8
refrigerant cost refill, 2050	€/kg	152.9	387.3	5	264.1	123.2	74.8
refrigerant cost refill, counterfactual scenario, 2014 pre-phase-down prices	€/kg	10	10	5	50	60	60
leakage rate first fill / refill	kg/kg	1.0%	1.0%	1.0%	1.0%	1.0%	1.0%
leakage rate operation	1/a	28.0%	28.0%	28.0%	28.0%	28.0%	28.0%
technologically tolerable refrigerant loss	kg/kg	25%	25%	25%	25%	25%	25%
recovery rate end of life	kg/kg	66%	66%	66%	66%	66%	66%
Penetration rate in new installations, 2024-2036 average	%	1.1%	1.6%	76.9%	3.1%	10.4%	6.9%
Penetration rate in new installations, 2050	%	-	-	90.0%	-	-	10.0%

Table 70: AnaFgas sector sheet for the MP alignment scenario: Transport refrigeration - Trucks & Trailers

Transport refrigeration - Trucks & Trailers						
considered gases / technologies:		**R-404A**	**R-744**	**R-513A**	**R-452A**	**R-454C/R-455A**
GWP AR4 of refrigerant	[1]	3 921.6	1	631.4	2 140.5	148.2
refrigerating capacity	kW	9	9	9	9	9
electric/mechanic capacity	kW	8	7.2	8	8	8
installation lifetime	years	10	10	10	10	10
invest cost hardware (first fill excluded)	€	15 000	17 250	15 000	15 000	15 300
annual operating hours	h/a	4 000	4 000	4 000	4 000	4 000
final energy cost	€/kWh	0.259	0.259	0.259	0.259	0.259
discount rate (societal view / emission reduction cost)	%	4%	4%	4%	4%	4%
HFC operators' cost for containment & recovery (FGR Art 3-8)	€/a	74	-	74	74	74
additional maintenance cost for non-HFCs	€/a	-	90	-	-	-
refrigerant charge	kg	6.5	6.5	6.5	6.5	6.5
refrigerant cost first fill, average 2024-2036	€/kg	121.8	2.5	48.8	88.8	34.4
refrigerant cost first fill, average 2050	€/kg	201.1	2.5	61.6	132.1	37.4
refrigerant cost first fill, counterfactual scenario, 2014 pre-phase-down prices	€/kg	5	2.5	30	25	30
installation type is refilled?		yes	yes	yes	yes	yes
refrigerant cost refill, average 2024-2036	€/kg	234.7	5	97.6	177.5	68.8
refrigerant cost refill, 2050	€/kg	387.3	5	123.2	264.1	74.8
refrigerant cost refill, counterfactual scenario, 2014 pre-phase-down prices	€/kg	10	5	60	50	60
leakage rate first fill / refill	kg/kg	1.0%	1.0%	1.0%	1.0%	1.0%
leakage rate operation	1/a	18.0%	18.0%	18.0%	18.0%	18.0%
technologically tolerable refrigerant loss	kg/kg	25%	25%	25%	25%	25%
recovery rate end of life	kg/kg	66%	66%	66%	66%	66%
Penetration rate in new installations, 2024-2036 average	%	1.6%	67.1%	21.5%	2.8%	6.9%
Penetration rate in new installations, 2050	%	-	80.0%	10.0%	-	10.0%

Table 71: AnaFgas sector sheet for the MP alignment scenario: Transport refrigeration – Ships

Transport refrigeration - Ships				
considered gases / technologies:		**R-404A**	**NH3/CO2**	**R-452A**
GWP AR4 of refrigerant	[1]	3 921.6	0	2 140.5
refrigerating capacity	kW	990	990	990
electric/mechanic capacity	kW	468	439.92	439.92
installation lifetime	years	30	30	30
invest cost hardware (first fill excluded)	€	2 000 000	2 300 000	2 000 000
annual operating hours	h/a	5 000	5 000	5 000
final energy cost	€/kWh	0.073	0.073	0.073
discount rate (societal view / emission reduction cost)	%	4%	4%	4%
HFC operators' cost for containment & recovery (FGR Art 3-8)	€/a	108	-	108
additional maintenance cost for non-HFCs	€/a	-	1 000	-
refrigerant charge	kg	1 000	750	1 000
refrigerant cost first fill, average 2024-2036	€/kg	234.7	4	177.5
refrigerant cost first fill, average 2050	€/kg	387.3	4	264.1
refrigerant cost first fill, counterfactual scenario, 2014 pre-phase-down prices	€/kg	10	4	50
installation type is refilled?		yes	yes	yes
refrigerant cost refill, average 2024-2036	€/kg	234.7	4	177.5
refrigerant cost refill, 2050	€/kg	387.3	4	264.1
refrigerant cost refill, counterfactual scenario, 2014 pre-phase-down prices	€/kg	10	4	50
leakage rate first fill / refill	kg/kg	1.0%	1.0%	1.0%
leakage rate operation	1/a	40.0%	40.0%	40.0%
technologically tolerable refrigerant loss	kg/kg	25%	25%	25%
recovery rate end of life	kg/kg	54%	54%	54%
Penetration rate in new installations, 2024-2036 average	%	0.3%	90.5%	9.2%
Penetration rate in new installations, 2050	%	-	100.0%	-

Table 72: AnaFgas sector sheet for the MP alignment scenario: Room AC – Moveables

Room AC - Moveables			
considered gases / technologies:		**R-410A direct**	**R-290**
GWP AR4 of refrigerant	[1]	2 087.5	3
refrigerating capacity	kW	3	3
electric/mechanic capacity	kW	0.67	0.67
installation lifetime	years	10	10
invest cost hardware (first fill excluded)	€	300	294
annual operating hours	h/a	500	500
final energy cost	€/kWh	0.215	0.215
discount rate (societal view / emission reduction cost)	%	4%	4%
HFC operators' cost for containment & recovery (FGR Art 3-8)	€/a	3	-
additional maintenance cost for non-HFCs	€/a	-	-
refrigerant charge	kg	0.75	0.38
refrigerant cost first fill, average 2024-2036	€/kg	67.2	10
refrigerant cost first fill, average 2050	€/kg	109.4	10
refrigerant cost first fill, counterfactual scenario, 2014 pre-phase-down prices	€/kg	5	10
installation type is refilled?		no	no
refrigerant cost refill, average 2024-2036	€/kg	-	-
refrigerant cost refill, 2050	€/kg	-	-
refrigerant cost refill, counterfactual scenario, 2014 pre-phase-down prices	€/kg	-	-
leakage rate first fill / refill	kg/kg	0.0%	0.0%
leakage rate operation	1/a	3.0%	3.0%
technologically tolerable refrigerant loss	kg/kg	25%	25%
recovery rate end of life	kg/kg	53%	53%
Penetration rate in new installations, 2024-2036 average	%	-	100.0%
Penetration rate in new installations, 2050	%	-	100.0%

Table 73: AnaFgas sector sheet for the MP alignment scenario: Room AC - Single split

Room AC - Single split (includes small multi-split <12 kW & reversible air-to-air heat pumps)				
considered gases / technologies:		**R-410A direct**	**R-290**	**HFC-32**
GWP AR4 of refrigerant	[1]	2 087.5	3	675
refrigerating capacity	kW	4.5	4.5	4.5
electric/mechanic capacity	kW	1	1	1
installation lifetime	years	10	10	10
invest cost hardware (first fill excluded)	€	750	803	750
annual operating hours	h/a	1 500	1 500	1 500
final energy cost	€/kWh	0.215	0.215	0.215
discount rate (societal view / emission reduction cost)	%	4%	4%	4%
HFC operators' cost for containment & recovery (FGR Art 3-8)	€/a	9	-	9
additional maintenance cost for non-HFCs	€/a	-	-	-
refrigerant charge	kg	1.5	0.75	1.2
refrigerant cost first fill, average 2024-2036	€/kg	67.2	10	30.1
refrigerant cost first fill, average 2050	€/kg	109.4	10	43.8
refrigerant cost first fill, counterfactual scenario, 2014 pre-phase-down prices	€/kg	5	10	10
installation type is refilled?		yes	yes	yes
refrigerant cost refill, average 2024-2036	€/kg	133.7	20	60.2
refrigerant cost refill, 2050	€/kg	217.6	20	87.5
refrigerant cost refill, counterfactual scenario, 2014 pre-phase-down prices	€/kg	10	20	20
leakage rate first fill / refill	kg/kg	3.5%	3.5%	3.5%
leakage rate operation	1/a	5.0%	5.0%	5.0%
technologically tolerable refrigerant loss	kg/kg	25%	25%	25%
recovery rate end of life	kg/kg	60%	60%	60%
Penetration rate in new installations, 2024-2036 average	%	8.5%	12.2%	79.3%
Penetration rate in new installations, 2050	%	-	80.0%	20.0%

Table 74: AnaFgas sector sheet for the MP alignment scenario: Room AC – Rooftop

Room AC - Packaged systems (rooftop units), cooling only					
considered gases / technologies:		**R-410A direct**	**HFC-32**	**R-454C/R-455A**	**R-290**
GWP AR4 of refrigerant	[1]	2 087.5	675	148.2	3
refrigerating capacity	kW	30	30	30	30
electric/mechanic capacity	kW	15	14.85	15	14.7
installation lifetime	years	10	10	10	10
invest cost hardware (first fill excluded)	€	10 000	10 200	10 300	10 500
annual operating hours	h/a	3 000	3 000	3 000	3 000
final energy cost	€/kWh	0.145	0.145	0.145	0.145
discount rate (societal view / emission reduction cost)	%	4%	4%	4%	4%
HFC operators' cost for containment & recovery (FGR Art 3-8)	€/a	215	215	215	-
additional maintenance cost for non-HFCs	€/a	-	-	-	55
refrigerant charge	kg	10.5	8.4	10.5	5.25
refrigerant cost first fill, average 2024-2036	€/kg	133.7	60.2	68.8	20
refrigerant cost first fill, average 2050	€/kg	217.6	87.5	74.8	20
refrigerant cost first fill, counterfactual scenario, 2014 pre-phase-down prices	€/kg	10	20	60	20
installation type is refilled?		yes	yes	yes	yes
refrigerant cost refill, average 2024-2036	€/kg	133.7	60.2	68.8	20
refrigerant cost refill, 2050	€/kg	217.6	87.5	74.8	20
refrigerant cost refill, counterfactual scenario, 2014 pre-phase-down prices	€/kg	10	20	60	20
leakage rate first fill / refill	kg/kg	0.0%	0.0%	0.0%	0.0%
leakage rate operation	1/a	3.0%	3.0%	3.0%	3.0%
technologically tolerable refrigerant loss	kg/kg	25%	25%	25%	25%
recovery rate end of life	kg/kg	77%	77%	77%	77%
Penetration rate in new installations, 2024-2036 average	%	34.4%	50.0%	4.0%	11.5%
Penetration rate in new installations, 2050	%	5.0%	50.0%	25.0%	20.0%

Table 75: AnaFgas sector sheet for the MP alignment scenario: Room AC – VRF

Room AC - VRF cooling only (includes Single-split >3kg VRF Multi-Split)						
considered gases / technologies:		**R-410A direct**	**HFC-32**	**R-454C/R-455A**	**R-290**	**R-290 + evap. Secondary**
GWP AR4 of refrigerant	[1]	2 087.5	675	148.2	3	3
refrigerating capacity	kW	27	27	27	27	27
electric/mechanic capacity	kW	8	8	7.84	7.76	7.6
installation lifetime	years	13	13	13	13	13
invest cost hardware (first fill excluded)	€	9 500	9 738	9 738	12 350	12 920
annual operating hours	h/a	3 000	3 000	3 000	3 000	3 000
final energy cost	€/kWh	0.145	0.145	0.145	0.145	0.145
discount rate (societal view / emission reduction cost)	%	4%	4%	4%	4%	4%
HFC operators' cost for containment & recovery (FGR Art 3-8)	€/a	226	226	226	-	-
additional maintenance cost for non-HFCs	€/a	-	-	-	55	55
refrigerant charge	kg	13.5	10.8	13.5	6.75	6.75
refrigerant cost first fill, average 2024-2036	€/kg	133.7	60.2	68.8	20	20
refrigerant cost first fill, average 2050	€/kg	217.6	87.5	74.8	20	20
refrigerant cost first fill, counterfactual scenario, 2014 pre-phase-down prices	€/kg	10	20	60	20	20
installation type is refilled?		yes	yes	yes	yes	yes
refrigerant cost refill, average 2024-2036	€/kg	133.7	60.2	68.8	20	20
refrigerant cost refill, 2050	€/kg	217.6	87.5	74.8	20	20
refrigerant cost refill, counterfactual scenario, 2014 pre-phase-down prices	€/kg	10	20	60	20	20
leakage rate first fill / refill	kg/kg	0.3%	0.3%	0.3%	0.3%	0.3%
leakage rate operation	1/a	5.6%	5.6%	5.6%	5.6%	5.6%
technologically tolerable refrigerant loss	kg/kg	25%	25%	25%	25%	25%
recovery rate end of life	kg/kg	77%	77%	77%	77%	77%
Penetration rate in new installations, 2024-2036 average	%	40.2%	47.7%	6.7%	2.7%	2.7%
Penetration rate in new installations, 2050	%	5.0%	50.0%	35.0%	5.0%	5.0%

Table 76: AnaFgas sector sheet for the MP alignment scenario: Minichillers

Minichillers						
considered gases / technologies:		**R-410A**	**R-32**	**HFO-1234ze**	**R-290 direct**	**R-454C/R-455A**
GWP AR4 of refrigerant	[1]	2 087.5	675	7	3	148.2
refrigerating capacity	kW	2	2	2	2	2
electric/mechanic capacity	kW	2	1.98	2	1.94	1.98
installation lifetime	years	12	12	12	12	12
invest cost hardware (first fill excluded)	€	450	459	450	495	473
annual operating hours	h/a	1 860	1 860	1 860	1 860	1 860
final energy cost	€/kWh	0.145	0.145	0.145	0.145	0.145
discount rate (societal view / emission reduction cost)	%	4%	4%	4%	4%	4%
HFC operators' cost for containment & recovery (FGR Art 3-8)	€/a	141	141	-	-	141
additional maintenance cost for non-HFCs	€/a	-	-	-	-	-
refrigerant charge	kg	0.65	0.43	0.72	0.33	0.65
refrigerant cost first fill, average 2024-2036	€/kg	67.2	30.1	30	10	34.4
refrigerant cost first fill, average 2050	€/kg	109.4	43.8	30	10	37.4
refrigerant cost first fill, counterfactual scenario, 2014 pre-phase-down prices	€/kg	5	10	30	10	30
installation type is refilled?		yes	yes	yes	yes	yes
refrigerant cost refill, average 2024-2036	€/kg	133.7	60.2	60	20	68.8
refrigerant cost refill, 2050	€/kg	217.6	87.5	60	20	74.8
refrigerant cost refill, counterfactual scenario, 2014 pre-phase-down prices	€/kg	10	20	60	20	60
leakage rate first fill / refill	kg/kg	0.5%	0.5%	0.5%	0.5%	0.5%
leakage rate operation	1/a	2.4%	2.4%	2.4%	2.4%	2.4%
technologically tolerable refrigerant loss	kg/kg	20%	20%	20%	20%	20%
recovery rate end of life	kg/kg	78%	78%	78%	78%	78%
Penetration rate in new installations, 2024-2036 average	%	31.2%	41.4%	15.4%	6.0%	6.0%
Penetration rate in new installations, 2050	%	11.1%	44.4%	22.2%	11.1%	11.1%

Table 77: AnaFgas sector sheet for the MP alignment scenario: Displacement chillers – small

Displacement chillers - small							
considered gases / technologies:		**R-410A**	**H2O (R-718)**	**R-32**	**HFO-1234ze**	**R-290 direct**	**R-454C/R-455A**
GWP AR4 of refrigerant	[1]	2 087.5	0	675	7	3	148.2
refrigerating capacity	kW	80	80	80	80	80	80
electric/mechanic capacity	kW	28	26.32	27.72	27.72	27.16	27.72
installation lifetime	years	15	15	15	15	15	15
invest cost hardware (first fill excluded)	€	18 000	25 200	18 900	18 360	20 700	18 900
annual operating hours	h/a	1 860	1 860	1 860	1 860	1 860	1 860
final energy cost	€/kWh	0.145	0.145	0.145	0.145	0.145	0.145
discount rate (societal view / emission reduction cost)	%	4%	4%	4%	4%	4%	4%
HFC operators' cost for containment & recovery (FGR Art 3-8)	€/a	143	-	143	-	-	143
additional maintenance cost for non-HFCs	€/a	-	-	-	-	-	-
refrigerant charge	kg	26	18	17.33	28.6	13	26
refrigerant cost first fill, average 2024-2036	€/kg	133.7	0.1	60.2	60	20	68.8
refrigerant cost first fill, average 2050	€/kg	217.6	0.1	87.5	60	20	74.8
refrigerant cost first fill, counterfactual scenario, 2014 pre-phase-down prices	€/kg	10	0	20	60	20	60
installation type is refilled?		yes	yes	yes	yes	yes	yes
refrigerant cost refill, average 2024-2036	€/kg	133.7	0.1	60.2	60	20	68.8
refrigerant cost refill, 2050	€/kg	217.6	0.1	87.5	60	20	74.8
refrigerant cost refill, counterfactual scenario, 2014 pre-phase-down prices	€/kg	10	0	20	60	20	60
leakage rate first fill / refill	kg/kg	0.5%	0.5%	0.5%	0.5%	0.5%	0.5%
leakage rate operation	1/a	2.4%	2.4%	2.4%	2.4%	2.4%	2.4%
technologically tolerable refrigerant loss	kg/kg	20%	20%	20%	20%	20%	20%
recovery rate end of life	kg/kg	78%	78%	78%	78%	78%	78%
Penetration rate in new installations, 2024-2036 average	%	16.6%	29.1%	22.1%	7.5%	22.1%	2.6%
Penetration rate in new installations, 2050	%	3.6%	39.8%	14.5%	7.2%	31.2%	3.6%

Table 78: AnaFgas sector sheet for the MP alignment scenario: Displacement chillers – large

Displacement chillers - large								
considered gases / technologies:		**R-134a**	**R-407C**	**R-410A**	**R-717 / R-718**	**R-32**	**HFO-1234ze**	**R-454C/R-455A**
GWP AR4 of refrigerant	[1]	1 430	1 773.9	2 087.5	0	675	7	148.2
refrigerating capacity	kW	400	400	400	400	400	400	400
electric/mechanic capacity	kW	129	129	129	122.55	127.07	127.71	127.71
installation lifetime	years	15	15	15	15	15	15	15
invest cost hardware (first fill excluded)	€	70 000	70 000	70 000	87 500	73 500	73 500	73 500
annual operating hours	h/a	1 860	1 860	1 860	1 860	1 860	1 860	1 860
final energy cost	€/kWh	0.095	0.095	0.095	0.095	0.095	0.095	0.095
discount rate (societal view / emission reduction cost)	%	4%	4%	4%	4%	4%	4%	4%
HFC operators' cost for containment & recovery (FGR Art 3-8)	€/a	278	278	278	-	278	-	278
additional maintenance cost for non-HFCs	€/a	-	-	-	73	-	-	-
refrigerant charge	kg	150	150	150	75	120	150	150
refrigerant cost first fill, average 2024-2036	€/kg	95.1	113.3	133.7	4	60.2	60	68.8
refrigerant cost first fill, average 2050	€/kg	152.9	183.4	217.6	4	87.5	60	74.8
refrigerant cost first fill, counterfactual scenario, 2014 pre-phase-down prices	€/kg	10	10	10	4	20	60	60
installation type is refilled?		yes	yes	yes	yes	yes	yes	yes
refrigerant cost refill, average 2024-2036	€/kg	95.1	113.3	133.7	4	60.2	60	68.8
refrigerant cost refill, 2050	€/kg	152.9	183.4	217.6	4	87.5	60	74.8
refrigerant cost refill, counterfactual scenario, 2014 pre-phase-down prices	€/kg	10	10	10	4	20	60	60
leakage rate first fill / refill	kg/kg	0.5%	0.5%	0.5%	0.5%	0.5%	0.5%	0.5%
leakage rate operation	1/a	2.4%	2.4%	2.4%	2.4%	2.4%	2.4%	2.4%
technologically tolerable refrigerant loss	kg/kg	20%	20%	20%	20%	20%	20%	20%
recovery rate end of life	kg/kg	78%	78%	78%	78%	78%	78%	78%
Penetration rate in new installations, 2024-2036 average	%	6.0%	4.0%	10.1%	39.5%	27.2%	9.7%	3.6%
Penetration rate in new installations, 2050	%	1.5%	1.0%	2.5%	58.4%	20.9%	10.5%	5.2%

Table 79: AnaFgas sector sheet for the MP alignment scenario: Centrifugal chillers

Centrifugal chillers					
considered gases / technologies:		**HFC 134a**	**HFO-1234ze**	**HFO-1233zd**	**CO2 / NH3**
GWP AR4 of refrigerant	[1]	1 430	7	4.5	0.5
refrigerating capacity	kW	1 500	1 500	1 500	1 500
electric/mechanic capacity	kW	300	297	297	270
installation lifetime	years	25	25	25	25
invest cost hardware (first fill excluded)	€	140 000	141 400	141 400	154 000
annual operating hours	h/a	3 350	3 350	3 350	3 350
final energy cost	€/kWh	0.095	0.095	0.095	0.095
discount rate (societal view / emission reduction cost)	%	4%	4%	4%	4%
HFC operators' cost for containment & recovery (FGR Art 3-8)	€/a	278	-	-	-
additional maintenance cost for non-HFCs	€/a	-	-	-	-
refrigerant charge	kg	630	630	630	630
refrigerant cost first fill, average 2024-2036	€/kg	95.1	60	50	4.5
refrigerant cost first fill, average 2050	€/kg	152.9	60	50	4.5
refrigerant cost first fill, counterfactual scenario, 2014 pre-phase-down prices	€/kg	10	60	50	4.5
installation type is refilled?		yes	yes	yes	yes
refrigerant cost refill, average 2024-2036	€/kg	95.1	60	50	4.5
refrigerant cost refill, 2050	€/kg	152.9	60	50	4.5
refrigerant cost refill, counterfactual scenario, 2014 pre-phase-down prices	€/kg	10	60	50	4.5
leakage rate first fill / refill	kg/kg	0.5%	0.5%	0.5%	0.5%
leakage rate operation	1/a	2.4%	2.4%	2.4%	2.4%
technologically tolerable refrigerant loss	kg/kg	20%	20%	20%	20%
recovery rate end of life	kg/kg	78%	78%	78%	78%
Penetration rate in new installations, 2024-2036 average	%	2.1%	13.5%	13.5%	71.0%
Penetration rate in new installations, 2050	%	-	15.0%	15.0%	70.0%

Table 80: AnaFgas sector sheet for the MP alignment scenario: Heat pumps – small

Heat pumps - small (<12 kW, excluding small reversable air/air heat pumps covered in the single split subsector)							
considered gases / technologies:		**R-134a**	**R-410A**	**R-407C**	**HCs**	**R-32**	**R-513A**
GWP AR4 of refrigerant	[1]	1 430	2 087.5	1 773.9	4	675	631.4
refrigerating capacity	kW	11	11	11	11	11	11
electric/mechanic capacity	kW	6.88	6.88	6.88	6.67	6.81	6.81
installation lifetime	years	15	15	15	15	15	15
invest cost hardware (first fill excluded)	€	8 380	8 380	8 380	8 799	8 548	8 380
annual operating hours	h/a	2 000	2 000	2 000	2 000	2 000	2 000
final energy cost	€/kWh	0.215	0.215	0.215	0.215	0.215	0.215
discount rate (societal view / emission reduction cost)	%	4%	4%	4%	4%	4%	4%
HFC operators' cost for containment & recovery (FGR Art 3-8)	€/a	6	6	6	-	6	6
additional maintenance cost for non-HFCs	€/a	-	-	-	-	-	-
refrigerant charge	kg	2.6	2.6	2.6	1.3	2.08	2.6
refrigerant cost first fill, average 2024-2036	€/kg	47.6	67.2	57.8	10	30.1	48.8
refrigerant cost first fill, average 2050	€/kg	76.5	109.4	93.7	10	43.8	61.6
refrigerant cost first fill, counterfactual scenario, 2014 pre-phase-down prices	€/kg	5	5	5	10	10	30
installation type is refilled?		yes	yes	yes	yes	yes	yes
refrigerant cost refill, average 2024-2036	€/kg	95.1	133.7	113.3	20	60.2	97.6
refrigerant cost refill, 2050	€/kg	152.9	217.6	183.4	20	87.5	123.2
refrigerant cost refill, counterfactual scenario, 2014 pre-phase-down prices	€/kg	10	10	10	20	20	60
leakage rate first fill / refill	kg/kg	0.5%	0.5%	0.5%	0.5%	0.5%	0.5%
leakage rate operation	1/a	3.5%	3.5%	3.5%	3.5%	3.5%	3.5%
technologically tolerable refrigerant loss	kg/kg	30%	30%	30%	30%	30%	30%
recovery rate end of life	kg/kg	59%	59%	59%	59%	59%	59%
Penetration rate in new installations, 2024-2036 average	%	0.6%	8.2%	-	35.9%	51.1%	4.2%
Penetration rate in new installations, 2050	%	-	-	-	80.0%	20.0%	-

Table 81: AnaFgas sector sheet for the MP alignment scenario: Heat pumps – medium

Heat pumps - medium (12-200kW)									
considered gases / technologies:		**R-134a**	**R-410A**	**R-407C**	**HCs**	**R-32**	**R-513A**	**HFO-1234ze**	**R-454B**
GWP AR4 of refrigerant	[1]	1 430	2 087.5	1 773.9	4	675	631.4	7	466.3
refrigerating capacity	kW	110	110	110	110	110	110	110	110
electric/mechanic capacity	kW	68.75	68.75	68.75	66.69	68.06	68.75	68.06	68.75
installation lifetime	years	15	15	15	15	15	15	15	15
invest cost hardware (first fill excluded)	€	30 000	30 000	30 000	33 000	31 500	30 000	31 500	30 000
annual operating hours	h/a	2 000	2 000	2 000	2 000	2 000	2 000	2 000	2 000
final energy cost	€/kWh	0.145	0.145	0.145	0.145	0.145	0.145	0.145	0.145
discount rate (societal view / emission reduction cost)	%	4%	4%	4%	4%	4%	4%	4%	4%
HFC operators' cost for containment & recovery (FGR Art 3-8)	€/a	283	283	283	-	283	283	-	283
additional maintenance cost for non-HFCs	€/a	-	-	-	55	-	-	-	-
refrigerant charge	kg	26	26	26	13	18	20.8	26	20.8
refrigerant cost first fill, average 2024-2036	€/kg	71.3	100.4	85.6	15	45.2	73.2	45	63.8
refrigerant cost first fill, average 2050	€/kg	114.7	163.5	138.6	15	65.6	92.4	45	78
refrigerant cost first fill, counterfactual scenario, 2014 pre-phase-down prices	€/kg	7.5	7.5	7.5	15	15	45	45	43
installation type is refilled?		yes	yes	yes	yes	yes	yes	yes	yes
refrigerant cost refill, average 2024-2036	€/kg	95.1	133.7	113.3	20	60.2	97.6	60	85.1
refrigerant cost refill, 2050	€/kg	152.9	217.6	183.4	20	87.5	123.2	60	104
refrigerant cost refill, counterfactual scenario, 2014 pre-phase-down prices	€/kg	10	10	10	20	20	60	60	57.3
leakage rate first fill / refill	kg/kg	0.5%	0.5%	0.5%	0.5%	0.5%	0.5%	0.5%	0.5%
leakage rate operation	1/a	4.5%	4.5%	4.5%	4.5%	4.5%	4.5%	4.5%	4.5%
technologically tolerable refrigerant loss	kg/kg	30%	30%	30%	30%	30%	30%	30%	30%
recovery rate end of life	kg/kg	59%	59%	59%	59%	59%	59%	59%	59%
Penetration rate in new installations, 2024-2036 average	%	0.6%	23.4%	-	20.6%	28.8%	0.9%	8.1%	17.5%
Penetration rate in new installations, 2050	%	-	5.0%	-	65.0%	10.0%	-	10.0%	10.0%

Table 82: AnaFgas sector sheet for the MP alignment scenario: Heat pumps – large

Heat pumps - large (>200kW, district heating & industrial)					
considered gases / technologies:		**R-134a**	**HFO-1234ze**	**CO2 (R-744)**	**NH3 / R-723**
GWP AR4 of refrigerant	[1]	1 430	7	1	0
refrigerating capacity	kW	3 173.08	3 173.08	3 173.08	3 173.08
electric/mechanic capacity	kW	1 983.17	1 963.34	1 913.76	1 884.01
installation lifetime	years	20	20	20	20
invest cost hardware (first fill excluded)	€	2 800 000	2 856 000	3 360 000	3 220 000
annual operating hours	h/a	6 000	6 000	6 000	6 000
final energy cost	€/kWh	0.095	0.095	0.095	0.095
discount rate (societal view / emission reduction cost)	%	4%	4%	4%	4%
HFC operators' cost for containment & recovery (FGR Art 3-8)	€/a	283	-	-	-
additional maintenance cost for non-HFCs	€/a	-	-	255	145
refrigerant charge	kg	750	600	500	500
refrigerant cost first fill, average 2024-2036	€/kg	95.1	60	5	4
refrigerant cost first fill, average 2050	€/kg	152.9	60	5	4
refrigerant cost first fill, counterfactual scenario, 2014 pre-phase-down prices	€/kg	10	60	5	4
installation type is refilled?		yes	yes	yes	yes
refrigerant cost refill, average 2024-2036	€/kg	95.1	60	5	4
refrigerant cost refill, 2050	€/kg	152.9	60	5	4
refrigerant cost refill, counterfactual scenario, 2014 pre-phase-down prices	€/kg	10	60	5	4
leakage rate first fill / refill	kg/kg	0.5%	0.5%	0.5%	0.5%
leakage rate operation	1/a	6.0%	6.0%	6.0%	6.0%
technologically tolerable refrigerant loss	kg/kg	30%	30%	30%	30%
recovery rate end of life	kg/kg	76%	76%	76%	76%
Penetration rate in new installations, 2024-2036 average	%	4.8%	25.2%	26.5%	43.5%
Penetration rate in new installations, 2050	%	-	30.0%	25.0%	45.0%

Table 83: AnaFgas sector sheet for the MP alignment scenario: Mobile AC - Passenger cars

Mobile AC - Passenger cars				
considered gases / technologies:		**R-134a**	**HFO-1234yf**	**R-744**
GWP AR4 of refrigerant	[1]	1 430	4	1
refrigerating capacity	kW	4	4	4
electric/mechanic capacity	kW	4	4	3.6
installation lifetime	years	12	12	12
invest cost hardware (first fill ex-cluded)	€	300	303	450
annual operating hours	h/a	300	300	300
final energy cost	€/kWh	0.446	0.446	0.446
discount rate (societal view / emission reduction cost)	%	4%	4%	4%
HFC operators' cost for containment & recovery (FGR Art 3-8)	€/a	-	-	-
additional maintenance cost for non-HFCs	€/a	-	-	55
refrigerant charge	kg	0.5	0.5	0.34
refrigerant cost first fill, average 2024-2036	€/kg	47.6	70	2.5
refrigerant cost first fill, average 2050	€/kg	76.5	70	2.5
refrigerant cost first fill, counterfactual scenario, 2014 pre-phase-down prices	€/kg	5	70	2.5
installation type is refilled?		yes	yes	yes
refrigerant cost refill, average 2024-2036	€/kg	95.1	140	5
refrigerant cost refill, 2050	€/kg	152.9	140	5
refrigerant cost refill, counterfactual scenario, 2014 pre-phase-down prices	€/kg	10	140	5
leakage rate first fill / refill	kg/kg	0.5%	0.5%	0.5%
leakage rate operation	1/a	10.0%	10.0%	10.0%
technologically tolerable refrigerant loss	kg/kg	40%	40%	40%
recovery rate end of life	kg/kg	50%	50%	50%
Penetration rate in new installations, 2024-2036 average	%	-	90.8%	9.2%
Penetration rate in new installations, 2050	%	-	80.0%	20.0%

Table 84: AnaFgas sector sheet for the MP alignment scenario: Mobile AC – Buses

Mobile AC - Buses				
considered gases / technologies:		**R-134a**	**R-744**	**R-513A**
GWP AR4 of refrigerant	[1]	1 430	1	631.4
refrigerating capacity	kW	25	25	25
electric/mechanic capacity	kW	16.7	15.87	16.7
installation lifetime	years	10	10	10
invest cost hardware (first fill excluded)	€	13 000	23 400	13 650
annual operating hours	h/a	2 000	2 000	2 000
final energy cost	€/kWh	0.259	0.259	0.259
discount rate (societal view / emission reduction cost)	%	4%	4%	4%
HFC operators' cost for containment & recovery (FGR Art 3-8)	€/a	-	-	-
additional maintenance cost for non-HFCs	€/a	-	55	-
refrigerant charge	kg	10.4	6.97	10.4
refrigerant cost first fill, average 2024-2036	€/kg	47.6	2.5	48.8
refrigerant cost first fill, average 2050	€/kg	76.5	2.5	61.6
refrigerant cost first fill, counterfactual scenario, 2014 pre-phase-down prices	€/kg	5	2.5	30
installation type is refilled?		yes	yes	yes
refrigerant cost refill, average 2024-2036	€/kg	95.1	5	97.6
refrigerant cost refill, 2050	€/kg	152.9	5	123.2
refrigerant cost refill, counterfactual scenario, 2014 pre-phase-down prices	€/kg	10	5	60
leakage rate first fill / refill	kg/kg	0.0%	0.0%	0.0%
leakage rate operation	1/a	15.0%	15.0%	15.0%
technologically tolerable refrigerant loss	kg/kg	40%	40%	40%
recovery rate end of life	kg/kg	63%	63%	63%
Penetration rate in new installations, 2024-2036 average	%	23.3%	20.3%	56.4%
Penetration rate in new installations, 2050	%	10.0%	25.0%	65.0%

Table 85: AnaFgas sector sheet for the MP alignment scenario: Mobile AC - Trucks N1

Mobile AC - Trucks N1				
considered gases / technologies:		**R-134a**	**R-744**	**HFO-1234yf**
GWP AR4 of refrigerant	[1]	1 430	1	4
refrigerating capacity	kW	8	8	8
electric/mechanic capacity	kW	8	7.6	8
installation lifetime	years	10	10	10
invest cost hardware (first fill excluded)	€	300	450	304
annual operating hours	h/a	300	300	300
final energy cost	€/kWh	0.259	0.259	0.259
discount rate (societal view / emission reduction cost)	%	4%	4%	4%
HFC operators' cost for containment & recovery (FGR Art 3-8)	€/a	-	-	-
additional maintenance cost for non-HFCs	€/a	-	55	-
refrigerant charge	kg	1	0.67	1
refrigerant cost first fill, average 2024-2036	€/kg	47.6	2.5	70
refrigerant cost first fill, average 2050	€/kg	76.5	2.5	70
refrigerant cost first fill, counterfactual scenario, 2014 pre-phase-down prices	€/kg	5	2.5	70
installation type is refilled?		yes	yes	yes
refrigerant cost refill, average 2024-2036	€/kg	95.1	5	140
refrigerant cost refill, 2050	€/kg	152.9	5	140
refrigerant cost refill, counterfactual scenario, 2014 pre-phase-down prices	€/kg	10	5	140
leakage rate first fill / refill	kg/kg	0.0%	0.0%	0.0%
leakage rate operation	1/a	10.0%	10.0%	10.0%
technologically tolerable refrigerant loss	kg/kg	40%	40%	40%
recovery rate end of life	kg/kg	13%	13%	13%
Penetration rate in new installations, 2024-2036 average	%	72.3%	0.8%	26.9%
Penetration rate in new installations, 2050	%	60.0%	10.0%	30.0%

Table 86: AnaFgas sector sheet for the MP alignment scenario: Mobile AC - Trucks N2

Mobile AC - Trucks N2				
considered gases / technologies:		**R-134a**	**R-744**	**HFO-1234yf**
GWP AR4 of refrigerant	[1]	1 430	1	4
refrigerating capacity	kW	8	8	8
electric/mechanic capacity	kW	8	7.6	8
installation lifetime	years	10	10	10
invest cost hardware (first fill excluded)	€	300	450	304
annual operating hours	h/a	300	300	300
final energy cost	€/kWh	0.259	0.259	0.259
discount rate (societal view / emission reduction cost)	%	4%	4%	4%
HFC operators' cost for containment & recovery (FGR Art 3-8)	€/a	-	-	-
additional maintenance cost for non-HFCs	€/a	-	55	-
refrigerant charge	kg	1	0.67	1
refrigerant cost first fill, average 2024-2036	€/kg	47.6	2.5	70
refrigerant cost first fill, average 2050	€/kg	76.5	2.5	70
refrigerant cost first fill, counterfactual scenario, 2014 pre-phase-down prices	€/kg	5	2.5	70
installation type is refilled?		yes	yes	yes
refrigerant cost refill, average 2024-2036	€/kg	95.1	5	140
refrigerant cost refill, 2050	€/kg	152.9	5	140
refrigerant cost refill, counterfactual scenario, 2014 pre-phase-down prices	€/kg	10	5	140
leakage rate first fill / refill	kg/kg	0.0%	0.0%	0.0%
leakage rate operation	1/a	15.0%	15.0%	15.0%
technologically tolerable refrigerant loss	kg/kg	40%	40%	40%
recovery rate end of life	kg/kg	13%	13%	13%
Penetration rate in new installations, 2024-2036 average	%	92.7%	3.9%	3.5%
Penetration rate in new installations, 2050	%	85.0%	10.0%	5.0%

Table 87: AnaFgas sector sheet for the MP alignment scenario: Mobile AC - Trucks N3

Mobile AC - Trucks N3			
considered gases / technologies:		**R-134a**	**R-744**
GWP AR4 of refrigerant	[1]	1 430	1
refrigerating capacity	kW	8	8
electric/mechanic capacity	kW	8	7.6
installation lifetime	years	10	10
invest cost hardware (first fill excluded)	€	300	450
annual operating hours	h/a	300	300
final energy cost	€/kWh	0.259	0.259
discount rate (societal view / emission reduction cost)	%	4%	4%
HFC operators' cost for containment & recovery (FGR Art 3-8)	€/a	-	-
additional maintenance cost for non-HFCs	€/a	-	55
refrigerant charge	kg	1	0.67
refrigerant cost first fill, average 2024-2036	€/kg	47.6	2.5
refrigerant cost first fill, average 2050	€/kg	76.5	2.5
refrigerant cost first fill, counterfactual scenario, 2014 pre-phase-down prices	€/kg	5	2.5
installation type is refilled?		yes	yes
refrigerant cost refill, average 2024-2036	€/kg	95.1	5
refrigerant cost refill, 2050	€/kg	152.9	5
refrigerant cost refill, counterfactual scenario, 2014 pre-phase-down prices	€/kg	10	5
leakage rate first fill / refill	kg/kg	0.0%	0.0%
leakage rate operation	1/a	15.0%	15.0%
technologically tolerable refrigerant loss	kg/kg	40%	40%
recovery rate end of life	kg/kg	13%	13%
Penetration rate in new installations, 2024-2036 average	%	96.1%	3.9%
Penetration rate in new installations, 2050	%	90.0%	10.0%

Table 88: AnaFgas sector sheet for the MP alignment scenario: Mobile AC - Passenger ships

Mobile AC - Passenger ships				
considered gases / technologies:		**R-134a**	**R-513A**	**Naturals**
GWP AR4 of refrigerant	[1]	1 430	631.4	0.5
refrigerating capacity	kW	975	975	975
electric/mechanic capacity	kW	180	180	162
installation lifetime	years	30	30	30
invest cost hardware (first fill excluded)	€	123 500	129 675	172 900
annual operating hours	h/a	3 000	3 000	3 000
final energy cost	€/kWh	0.073	0.073	0.073
discount rate (societal view / emission reduction cost)	%	4%	4%	4%
HFC operators' cost for containment & recovery (FGR Art 3-8)	€/a	2 039	2 039	-
additional maintenance cost for non-HFCs	€/a	-	-	-
refrigerant charge	kg	520	520	468
refrigerant cost first fill, average 2024-2036	€/kg	95.1	97.6	4.5
refrigerant cost first fill, average 2050	€/kg	152.9	123.2	4.5
refrigerant cost first fill, counterfactual scenario, 2014 pre-phase-down prices	€/kg	10	60	4.5
installation type is refilled?		yes	yes	yes
refrigerant cost refill, average 2024-2036	€/kg	95.1	97.6	4.5
refrigerant cost refill, 2050	€/kg	152.9	123.2	4.5
refrigerant cost refill, counterfactual scenario, 2014 pre-phase-down prices	€/kg	10	60	4.5
leakage rate first fill / refill	kg/kg	0.0%	0.0%	0.0%
leakage rate operation	1/a	40.0%	40.0%	40.0%
technologically tolerable refrigerant loss	kg/kg	40%	40%	40%
recovery rate end of life	kg/kg	63%	63%	63%
Penetration rate in new installations, 2024-2036 average	%	9.6%	81.3%	9.1%
Penetration rate in new installations, 2050	%	-	-	100.0%

Table 89: AnaFgas sector sheet for the MP alignment scenario: Mobile AC - Cargo ships

Mobile AC - Cargo ships				
considered gases / technologies:		**R-134a**	**NH3/brine**	**R-513A**
GWP AR4 of refrigerant	[1]	1 430	0	631.4
refrigerating capacity	kW	300	300	300
electric/mechanic capacity	kW	55.3	47.01	55.3
installation lifetime	years	30	30	30
invest cost hardware (first fill excluded)	€	38 000	59 660	39 900
annual operating hours	h/a	3 000	3 000	3 000
final energy cost	€/kWh	0.073	0.073	0.073
discount rate (societal view / emission reduction cost)	%	4%	4%	4%
HFC operators' cost for containment & recovery (FGR Art 3-8)	€/a	778	-	778
additional maintenance cost for non-HFCs	€/a	-	1 000	-
refrigerant charge	kg	160	52.8	160
refrigerant cost first fill, average 2024-2036	€/kg	95.1	4	97.6
refrigerant cost first fill, average 2050	€/kg	152.9	4	123.2
refrigerant cost first fill, counterfactual scenario, 2014 pre-phase-down prices	€/kg	10	4	60
installation type is refilled?		yes	yes	yes
refrigerant cost refill, average 2024-2036	€/kg	95.1	4	97.6
refrigerant cost refill, 2050	€/kg	152.9	4	123.2
refrigerant cost refill, counterfactual scenario, 2014 pre-phase-down prices	€/kg	10	4	60
leakage rate first fill / refill	kg/kg	1.0%	1.0%	1.0%
leakage rate operation	1/a	40.0%	40.0%	40.0%
technologically tolerable refrigerant loss	kg/kg	40%	40%	40%
recovery rate end of life	kg/kg	63%	63%	63%
Penetration rate in new installations, 2024-2036 average	%	15.7%	15.0%	69.3%
Penetration rate in new installations, 2050	%	-	100.0%	-

Table 90: AnaFgas sector sheet for the MP alignment scenario: Mobile AC – Tram

Mobile AC - Tram					
considered gases / technologies:		**R-134a**	**R-744/CO2**	**R-513A**	**HCs**
GWP AR4 of refrigerant	[1]	1 430	1	631.4	4
refrigerating capacity	kW	35	35	35	35
electric/mechanic capacity	kW	15	13.5	15	14.55
installation lifetime	years	25	25	25	25
invest cost hardware (first fill excluded)	€	25 000	30 000	25 250	27 500
annual operating hours	h/a	2 000	2 000	2 000	2 000
final energy cost	€/kWh	0.08	0.08	0.08	0.08
discount rate (societal view / emission reduction cost)	%	4%	4%	4%	4%
HFC operators' cost for containment & recovery (FGR Art 3-8)	€/a	2	-	2	-
additional maintenance cost for non-HFCs	€/a	-	90	-	-
refrigerant charge	kg	8	6.4	8	8
refrigerant cost first fill, average 2024-2036	€/kg	47.6	2.5	48.8	10
refrigerant cost first fill, average 2050	€/kg	76.5	2.5	61.6	10
refrigerant cost first fill, counterfactual scenario, 2014 pre-phase-down prices	€/kg	5	2.5	30	10
installation type is refilled?		yes	yes	yes	yes
refrigerant cost refill, average 2024-2036	€/kg	95.1	5	97.6	20
refrigerant cost refill, 2050	€/kg	152.9	5	123.2	20
refrigerant cost refill, counterfactual scenario, 2014 pre-phase-down prices	€/kg	10	5	60	20
leakage rate first fill / refill	kg/kg	0.2%	0.2%	0.2%	0.2%
leakage rate operation	1/a	7.0%	7.0%	7.0%	7.0%
technologically tolerable refrigerant loss	kg/kg	25%	25%	25%	25%
recovery rate end of life	kg/kg	66%	66%	66%	66%
Penetration rate in new installations, 2024-2036 average	%	8.9%	40.5%	45.2%	5.4%
Penetration rate in new installations, 2050	%	-	50.0%	40.0%	10.0%

Table 91: AnaFgas sector sheet for the MP alignment scenario: Mobile AC – Metro

Mobile AC - Metro				
considered gases / technologies:		**R-134a**	**R-744/CO2**	**R-513A**
GWP AR4 of refrigerant	[1]	1 430	1	631.4
refrigerating capacity	kW	35	35	35
electric/mechanic capacity	kW	15	13.5	15
installation lifetime	years	25	25	25
invest cost hardware (first fill excluded)	€	25 000	30 000	25 250
annual operating hours	h/a	2 000	2 000	2 000
final energy cost	€/kWh	0.08	0.08	0.08
discount rate (societal view / emission reduction cost)	%	4%	4%	4%
HFC operators' cost for containment & recovery (FGR Art 3-8)	€/a	2	-	2
additional maintenance cost for non-HFCs	€/a	-	90	-
refrigerant charge	kg	8	6.4	8
refrigerant cost first fill, average 2024-2036	€/kg	47.6	2.5	48.8
refrigerant cost first fill, average 2050	€/kg	76.5	2.5	61.6
refrigerant cost first fill, counterfactual scenario, 2014 pre-phase-down prices	€/kg	5	2.5	30
installation type is refilled?		yes	yes	yes
refrigerant cost refill, average 2024-2036	€/kg	95.1	5	97.6
refrigerant cost refill, 2050	€/kg	152.9	5	123.2
refrigerant cost refill, counterfactual scenario, 2014 pre-phase-down prices	€/kg	10	5	60
leakage rate first fill / refill	kg/kg	0.2%	0.2%	0.2%
leakage rate operation	1/a	7.0%	7.0%	7.0%
technologically tolerable refrigerant loss	kg/kg	25%	25%	25%
recovery rate end of life	kg/kg	66%	66%	66%
Penetration rate in new installations, 2024-2036 average	%	7.4%	47.4%	45.2%
Penetration rate in new installations, 2050	%	-	60.0%	40.0%

Table 92: AnaFgas sector sheet for the MP alignment scenario: Mobile AC – Train

Mobile AC - Train						
considered gases / technologies:		**R-134a**	**R-407C**	**R-744 / HCs**	**R-513A**	**R-729**
GWP AR4 of refrigerant	[1]	1 430	1 773.9	2.5	631.4	0
refrigerating capacity	kW	35	35	35	35	35
electric/mechanic capacity	kW	15	15	13.5	15	13.5
installation lifetime	years	25	25	25	25	25
invest cost hardware (first fill excluded)	€	25 000	25 000	30 000	25 250	50 000
annual operating hours	h/a	2 000	2 000	2 000	2 000	2 000
final energy cost	€/kWh	0.08	0.08	0.08	0.08	0.08
discount rate (societal view / emission reduction cost)	%	4%	4%	4%	4%	4%
HFC operators' cost for containment & recovery (FGR Art 3-8)	€/a	2	2	-	2	-
additional maintenance cost for non-HFCs	€/a	-	-	-	-	-
refrigerant charge	kg	8	8	8	8	8
refrigerant cost first fill, average 2024-2036	€/kg	47.6	57.8	6.3	48.8	2
refrigerant cost first fill, average 2050	€/kg	76.5	93.7	6.3	61.6	2
refrigerant cost first fill, counterfactual scenario, 2014 pre-phase-down prices	€/kg	5	5	6.3	30	2
installation type is refilled?		yes	yes	yes	yes	yes
refrigerant cost refill, average 2024-2036	€/kg	95.1	113.3	12.5	97.6	4
refrigerant cost refill, 2050	€/kg	152.9	183.4	12.5	123.2	4
refrigerant cost refill, counterfactual scenario, 2014 pre-phase-down prices	€/kg	10	10	12.5	60	4
leakage rate first fill / refill	kg/kg	0.2%	0.2%	0.2%	0.2%	0.2%
leakage rate operation	1/a	7.0%	7.0%	7.0%	7.0%	7.0%
technologically tolerable refrigerant loss	kg/kg	25%	25%	25%	25%	25%
recovery rate end of life	kg/kg	66%	66%	66%	66%	66%
Penetration rate in new installations, 2024-2036 average	%	4.4%	-	33.6%	38.3%	23.7%
Penetration rate in new installations, 2050	%	-	-	40.0%	30.0%	30.0%

Table 93: AnaFgas sector sheet for the MP alignment scenario: Aerosols – technical

Aerosols - technical				
considered gases / technologies:		**HFC-134a**	**HFC-152a**	**HFC-1234ze**
GWP AR4 of propellant	[1]	1 430	124	7
preparation / canning cost (propellant excluded) per kg propellant	€/kg	20	20	20
propellant charge	kg	0.15	0.15	0.15
propellant cost first fill, average 2024-2036	€/kg	47.6	8.7	15.0
propellant cost first fill, 2050	€/kg	76.5	11.2	15.0
propellant cost first fill, counterfactual scenario, 2014 pre-phase-down prices	€/kg	5.0	5.0	15.0
emission rate on application	kg/kg	100%	100%	100%
Penetration rate (defined on HFC-based niche of sector), 2024-2036 average	%	-	18.9%	81.1%
Penetration rate (defined on HFC-based niche of sector), 2050	%	-	18.9%	81.1%

Table 94: AnaFgas sector sheet for the MP alignment scenario: Aerosols – MDIs

Aerosols - MDIs				
considered gases / technologies:		**HFC-134a**	**HFC-227ea**	**HFC-152a**
GWP AR4 of propellant	[1]	1 430	3 220	124
preparation / canning cost (propellant excluded) per kg propellant	€/kg	705.88	705.88	705.88
propellant charge	kg	0.005	0.005	0.005
propellant cost first fill, average 2024-2036	€/kg	50.6	103.9	11.7
propellant cost first fill, 2050	€/kg	79.5	169.0	14.2
propellant cost first fill, counterfactual scenario, 2014 pre-phase-down prices	€/kg	8.0	8.0	8.0
emission rate on application	kg/kg	100%	100%	100%
Penetration rate (defined on HFC-based niche of sector), 2024-2036 average	%	84.4%	4.0%	11.6%
Penetration rate (defined on HFC-based niche of sector), 2050	%	48.0%	2.0%	50.0%

Table 95: AnaFgas sector sheet for the MP alignment scenario: Fire extinguishers

Fire extinguishers							
considered gases / technologies:		**HFC-227ea**	**HFC-23**	**HFC-125**	**HFC-236fa**	**HFC-134a**	**low-GWP alternatives (FK-5-1-12, inert gases)**
GWP AR4 of suppression agent	[1]	3 220	14 800	3 500	9 810	1 430	0.5
room size	m³	200	200	200	200	200	200
required gas concentration (for suppression of class C hazards (energized electrical equipment)	m³ / m³	5.8%	17.4%	9.0%	8.6%	15.3%	21.3%
molar mass of suppression agent	g/mol	170	70	120	152	102	175
molar volume at room temperature	l/mol	24.47	24.47	24.47	24.47	24.47	24.47
installed gas quantity	kg	80.6	99.6	88.3	106.8	127.6	303.9
installation lifetime	years	20	20	20	20	20	20
invest cost hardware (first fill excluded)	€	14 000	11 500	14 000	14 000	14 000	14 000
discount rate (societal view / emission reduction cost)	%	4%	4%	4%	4%	4%	4%
HFC operators' cost for containment & recovery (FGR Art 3-8)	€/a	117	117	117	117	117	-
additional maintenance cost for non-HFCs	€/a	-	-	-	-	-	-
suppression agent cost first fill, average 2024-2036	€/kg	109.9	454.9	118.3	306.2	56.6	11
suppression agent cost first fill, 2050	€/kg	175	754.2	189	504.6	85.5	11
suppression agent cost first fill, counterfactual scenario, 2014 pre-phase-down prices	€/kg	14	14	14	14	14	11
installation type is refilled?		yes	yes	yes	yes	yes	yes
suppression agent cost refill, average 2024-2036	€/kg	109.9	454.9	117.6	306.2	56.6	11
suppression agent cost refill, 2050	€/kg	175	754.2	187.9	504.6	85.5	11
suppression agent cost refill, counterfactual scenario, 2014 pre-phase-down prices	€/kg	14	14	14	14	14	11
leakage rate first fill / refill	kg/kg	0.1%	0.1%	0.1%	0.1%	0.1%	0.1%
leakage rate operation	1/a	2.0%	2.0%	2.0%	5.0%	4.0%	2.0%
recovery rate end of life	kg/kg	91%	91%	91%	91%	91%	91%
Penetration rate in new installations (in HFC-based niche of sector), 2024-2036 average	%	-	-	-	-	-	100.0%
Penetration rate in new installations (in HFC-based niche of sector), 2050	%	-	-	-	-	-	100.0%

Table 96: AnaFgas sector sheet for the MP alignment scenario: Solvents

Solvents					
considered gases / technologies:		**HFC-43-10mee**	**HFC-365mfc**	**HFO-1233zd**	**Novec 7100**
GWP AR4 of propellant	[1]	1 640	794	4.5	297
preparation / canning cost (propellant excluded) per kg propellant	€/kg	20	20	20	20
propellant charge	kg	0.15	0.15	0.15	0.15
propellant cost first fill, average 2024-2036	€/kg	53.9	29.7	25.0	25.0
propellant cost first fill, 2050	€/kg	87.0	45.7	25.0	25.0
propellant cost first fill, counterfactual scenario, 2014 pre-phase-down prices	€/kg	5.0	6.0	25.0	25.0
emission rate on application	kg/kg	100%	100%	100%	100%
Penetration rate (defined on HFC-based niche of sector), 2024-2036 average	%	62.0%	1.8%	27.0%	9.2%
Penetration rate (defined on HFC-based niche of sector), 2050	%	57.9%	1.8%	29.7%	10.6%

Table 97: AnaFgas sector sheet for the MP alignment scenario: Foam OCF

considered gases / technologies:		**HFC-134a**	**HFO-1234ze**
GWP AR4 of blowing agent	[1]	1 430	7
product		OCF cans, 660g, hereof 110g pro-pellant	OCF cans, 660g, hereof 110g pro-pellant
production facility annual output	m³/a	10 000	10 000
thermal conductivity	mW/ (m * K)	30	30
production facility insulation capacity an-nual output	m³/ a * ((m * K) / mW))	333	333
product density	kg/m³	42	42
blowing agent in formulation	pbw	110	110
total weight of formulation	pbw	660	660
foam product lifetime	years	50	50
invest cost for conversion of production line including development	€	-	22 500
economic lifetime of conversion investment	years	15	15
discount rate (societal view / emission re-duction cost)	%	4%	4%
blowing agent cost, average 2024-2036	€/kg	22.3	18.0
blowing agent cost, average 2050	€/kg	24.3	20.0
blowing agent cost, counterfactual sce-nario, 2014 pre-phase-down prices	€/kg	5.0	15.0
manufacturing emission factor of blowing agent	kg/kg	15%	15%
leakage rate in foam product lifetime, baseline scenario	1/a	1.0%	1.0%
Penetration rate (defined on HFC-based niche of sector), 2024-2036 average	%	-	100.0%
Penetration rate (defined on HFC-based niche of sector), 2050	%	-	100.0%

Table 98: AnaFgas sector sheet for the MP alignment scenario: Foam XPS

Foam XPS (extruded polystyrene)					
considered gases / technologies:		**XPS / HFC-134a**	**XPS / HFC-152a**	**XPS / HFO-1234ze**	**XPS / CO2**
GWP AR4 of blowing agent	[1]	1 430	124	7	1
product		XPS-134a Panel 1200 x 600 x 1400 mm, density 35	XPS Panel 1200 x 600 x 50 mm, density 35	XPS Panel 1200 x 600 x 1400 mm, density 40	XPS Panel 1200 x 600 x 50 mm, density 35
production facility annual output	m³/a	75 000	87 931	75 000	87 931
thermal conductivity	mW/ (m * K)	29	34	29	34
production facility insulation capacity annual output	m³/ a * ((m * K) / mW))	2 586	2 586	2 586	2 586
product density	kg/m³	35	35	40	35
blowing agent in formulation	pbw	7	10	8	10
total weight of formulation	pbw	100	90	100	90
foam product lifetime	years	50	50	50	50
invest cost for conversion of production line including development	€	-	-	1 000 000	1 500 000
economic lifetime of conversion investment	years	15	15	15	15
discount rate (societal view / emission reduction cost)	%	4%	4%	4%	4%
blowing agent cost, average 2024-2036	€/kg	22.3	9.2	18.0	5.5
blowing agent cost, average 2050	€/kg	24.3	11.2	20.0	7.5
blowing agent cost, counterfactual scenario, 2014 pre-phase-down prices	€/kg	5.0	5.0	15.0	2.5
manufacturing emission factor of blowing agent	kg/kg	30%	100%	30%	30%
leakage rate in foam product lifetime, baseline scenario	1/a	0.8%	0.8%	0.8%	0.8%
Penetration rate (defined on HFC-based niche of sector), 2024-2036 average	%	-	8.4%	91.6%	-
Penetration rate (defined on HFC-based niche of sector), 2050	%	-	-	100.0%	-

Table 99: AnaFgas sector sheet for the MP alignment scenario: Foam PU spray

Foam PU (polyurethane) spray				
considered gases / technologies:		**HFC-365mfc / HFC-245fa**	**HFO-1233zd / HFO-1336mzz**	**H2O**
GWP AR4 of blowing agent	[1]	864.8	4.5	0
product		spray foam, density 60	spray foam, density 60	spray foam, density 60
production facility annual output	m³/a	1 667	1 583	1 944
thermal conductivity	mW/ (m * K)	30	29	35
production facility insulation capacity annual output	m³/ a * ((m * K) / mW))	56	56	56
product density	kg/m³	60	60	60
blowing agent in formulation	pbw	15	15	15
total weight of formulation	pbw	245	245	245
foam product lifetime	years	50	50	50
invest cost for conversion of production line including development	€	-	22 500	22 500
economic lifetime of conversion investment	years	15	15	15
discount rate (societal view / emission reduction cost)	%	4%	4%	4%
blowing agent cost, average 2024-2036	€/kg	17.3	18.0	3.0
blowing agent cost, average 2050	€/kg	19.3	20.0	5.0
blowing agent cost, counterfactual scenario, 2014 pre-phase-down prices	€/kg	5.7	15.0	0.0
manufacturing emission factor of blowing agent	kg/kg	15%	15%	15%
leakage rate in foam product lifetime, baseline scenario	1/a	1.0%	1.0%	1.0%
Penetration rate (defined on HFC-based niche of sector), 2024-2036 average	%	-	90.0%	10.0%
Penetration rate (defined on HFC-based niche of sector), 2050	%	-	90.0%	10.0%

Table 100: AnaFgas sector sheet for the MP alignment scenario: Foam PU non-spray

Foam PU (polyurethane) non-spray			
considered gases / technologies:		**HFC-365mfc / HFC-245fa**	**HFO-1233zd / HFO-1336mzz**
GWP AR4 of blowing agent	[1]	864.8	4.5
product		Blockfoam 1 m^3, density 60	Blockfoam 1 m^3, density 60
production facility annual output	m^3/a	10 000	9 500
thermal conductivity	mW/ (m * K)	22	21
production facility insulation capacity annual output	m^3/ a * ((m * K) / mW))	455	455
product density	kg/m^3	60	60
blowing agent in formulation	pbw	12	14
total weight of formulation	pbw	242	244
foam product lifetime	years	50	50
invest cost for conversion of production line including development	€	-	480 000
economic lifetime of conversion investment	years	15	15
discount rate (societal view / emission reduction cost)	%	4%	4%
blowing agent cost, average 2024-2036	€/kg	17.3	18.0
blowing agent cost, average 2050	€/kg	19.3	20.0
blowing agent cost, counterfactual scenario, 2014 pre-phase-down prices	€/kg	5.7	15.0
manufacturing emission factor of blowing agent	kg/kg	15%	15%
leakage rate in foam product lifetime, baseline scenario	1/a	1.0%	1.0%
Penetration rate (defined on HFC-based niche of sector), 2024-2036 average	%	-	100.0%
Penetration rate (defined on HFC-based niche of sector), 2050	%	-	100.0%

Table 101: AnaFgas sector sheet for the MP alignment scenario: Electrical switchgear, medium voltage

Electrical switchgear, medium voltage		
considered gases / technologies:		**SF6**
GWP AR4 of insulation gas	[1]	22 800
rated voltage	kW	24
installation lifetime	years	40
invest cost hardware (first fill excluded)	€	15 000
discount rate (societal view / emission reduction cost)	%	4%
maintenance cost	€/a	-
insulation gas charge	kg	5
insulation gas cost first fill, average 2024-2036	€/kg	10
insulation gas cost first fill, average 2050	€/kg	10
insulation gas cost first fill, counterfactual scenario, 2014 pre-phase-down prices	€/kg	10
installation type is refilled?		no
insulation gas cost refill, average 2024-2036	€/kg	-
insulation gas cost refill, 2050	€/kg	-
insulation gas cost refill, counterfactual scenario, 2014 pre-phase-down prices	€/kg	-
leakage rate first fill / refill	kg/kg	0.9%
leakage rate operation	1/a	0.1%
technologically tolerable insulation gas loss	kg/kg	5%
recovery rate end of life	kg/kg	90%
Penetration rate in new installations, 2024-2036 average	%	100.0%
Penetration rate in new installations, 2050	%	100.0%

Table 102: AnaFgas sector sheet for the MP alignment scenario: Electrical switchgear, high voltage

Electrical switchgear, high voltage		
considered gases / technologies:		**SF6**
GWP AR4 of insulation gas	[1]	22 800
rated voltage	kW	110
installation lifetime	years	40
invest cost hardware (first fill excluded)	€	225 000
discount rate (societal view / emission reduction cost)	%	4%
maintenance cost	€/a	110
insulation gas charge	kg	90
insulation gas cost first fill, average 2024-2036	€/kg	10
insulation gas cost first fill, average 2050	€/kg	10
insulation gas cost first fill, counterfactual scenario, 2014 pre-phase-down prices	€/kg	10
installation type is refilled?		yes
insulation gas cost refill, average 2024-2036	€/kg	10
insulation gas cost refill, 2050	€/kg	10
insulation gas cost refill, counterfactual scenario, 2014 pre-phase-down prices	€/kg	10
leakage rate first fill / refill	kg/kg	0.9%
leakage rate operation	1/a	1.0%
technologically tolerable insulation gas loss	kg/kg	20%
recovery rate end of life	kg/kg	90%
Penetration rate in new installations, 2024-2036 average	%	100.0%
Penetration rate in new installations, 2050	%	100.0%

Annex 2.6: AnaFgas model installation parameters: sector sheets (proportionate action scenario)

Table 103: AnaFgas sector sheet for the proportionate action scenario: Domestic Refrigeration

Domestic Refrigeration			
considered gases / technologies:		**HFC 134a**	**R-600a**
GWP AR4 of refrigerant	[1]	1 430	4
refrigerating capacity	kW	0.2	0.2
electric/mechanic capacity	kW	0.13	0.12
installation lifetime	years	15	15
invest cost hardware (first fill excluded)	€	400	392
annual operating hours	h/a	7 200	7 200
final energy cost	€/kWh	0.215	0.215
discount rate (societal view / emission reduction cost)	%	4%	4%
HFC operators' cost for containment & recovery (FGR Art 3-8)	€/a	-	-
additional maintenance cost for non-HFCs	€/a	-	-
refrigerant charge	kg	0.12	0.06
refrigerant cost first fill, average 2024-2036	€/kg	98.2	10
refrigerant cost first fill, average 2050	€/kg	235.5	10
refrigerant cost first fill, counterfactual scenario, 2014 pre-phase-down prices	€/kg	5	10
installation type is refilled?		no	no
refrigerant cost refill, average 2024-2036	€/kg	-	-
refrigerant cost refill, 2050	€/kg	-	-
refrigerant cost refill, counterfactual scenario, 2014 pre-phase-down prices	€/kg	-	-
leakage rate first fill / refill	kg/kg	0.5%	0.5%
leakage rate operation	1/a	0.3%	0.3%
technologically tolerable refrigerant loss	kg/kg	20%	20%
recovery rate end of life	kg/kg	70%	70%
Penetration rate in new installations, 2024-2036 average	%	-	100.0%
Penetration rate in new installations, 2050	%	-	100.0%

Table 104: AnaFgas sector sheet for the proportionate action scenario: Commercial refrigeration – Hermetics

Commercial refrigeration - Hermetics				
considered gases / technologies:		**HFC 134a**	**R-600a/290-direct**	**R-454C/R-455A**
GWP AR4 of refrigerant	[1]	1 430	4	148.2
refrigerating capacity	kW	0.6	0.6	0.6
electric/mechanic capacity	kW	0.38	0.36	0.38
installation lifetime	years	10	10	10
invest cost hardware (first fill excluded)	€	1 000	980	1 020
annual operating hours	h/a	6 000	6 000	6 000
final energy cost	€/kWh	0.145	0.145	0.145
discount rate (societal view / emission reduction cost)	%	4%	4%	4%
HFC operators' cost for containment & recovery (FGR Art 3-8)	€/a	3	-	3
additional maintenance cost for non-HFCs	€/a	-	-	-
refrigerant charge	kg	0.4	0.2	0.4
refrigerant cost first fill, average 2024-2036	€/kg	98.2	10	39.7
refrigerant cost first fill, average 2050	€/kg	235.5	10	53.9
refrigerant cost first fill, counterfactual scenario, 2014 pre-phase-down prices	€/kg	5	10	30
installation type is refilled?		no	no	no
refrigerant cost refill, average 2024-2036	€/kg	-	-	-
refrigerant cost refill, 2050	€/kg	-	-	-
refrigerant cost refill, counterfactual scenario, 2014 pre-phase-down prices	€/kg	-	-	-
leakage rate first fill / refill	kg/kg	0.5%	0.5%	0.5%
leakage rate operation	1/a	1.0%	1.0%	1.0%
technologically tolerable refrigerant loss	kg/kg	20%	20%	20%
recovery rate end of life	kg/kg	61%	61%	61%
Penetration rate in new installations, 2024-2036 average	%	-	100.0%	-
Penetration rate in new installations, 2050	%	-	100.0%	-

Table 105: AnaFgas sector sheet for the proportionate action scenario: Commercial refrigeration - Condensing units

Commercial refrigeration - Condensing units									
considered gases / technologies:		**R-404A**	**R-134a DX**	**HC (R-290 DX)**	**R-744 (CO2)**	**HC (R-290 + secondary liquid)**	**R-448A/R-449A**	**R-513A**	**R-454C/ R-455A**
GWP AR4 of refrigerant	[1]	3 921.6	1430	3	1	3	1 392.1	631.4	148.2
refrigerating capacity	kW	4	4	4	4	4	4	4	4
electric/mechanic capacity	kW	2.5	2.5	2.43	2.38	2.38	2.45	2.45	2.53
installation lifetime	years	12	12	12	12	12	12	12	12
invest cost hardware (first fill excluded)	€	3 800	3 800	3 990	4 560	4 560	3 800	3 800	3 876
annual operating hours	h/a	5 840	5 840	5 840	5 840	5 840	5 840	5 840	5 840
final energy cost	€/kWh	0.145	0.145	0.145	0.145	0.145	0.145	0.145	0.145
discount rate (societal view / emission reduction cost)	%	4%	4%	4%	4%	4%	4%	4%	4%
HFC operators' cost for containment & recovery (FGR Art 3-8)	€/a	77	77	-	-	-	77	77	77
additional maintenance cost for non-HFCs	€/a	-	-	55	90	55	-	-	-
refrigerant charge	kg	4	4	2	2.67	0.8	4	4	4
refrigerant cost first fill, average 2024-2036	€/kg	501.6	196.1	20	5	20	241.4	142.3	79.3
refrigerant cost first fill, average 2050	€/kg	1226	470.4	20	5	20	508.8	263.6	107.8
refrigerant cost first fill, counterfactual scenario, 2014 pre-phase-down prices	€/kg	10	10	20	5	20	60	60	60
installation type is refilled?		yes	yes	yes	yes	yes	yes	yes	yes
refrigerant cost refill, average 2024-2036	€/kg	501.6	196.1	20	5	20	241.4	142.3	79.3
refrigerant cost refill, 2050	€/kg	1226	470.4	20	5	20	508.8	263.6	107.8
refrigerant cost refill, counterfactual scenario, 2014 pre-phase-down prices	€/kg	10	10	20	5	20	60	60	60
leakage rate first fill / refill	kg/kg	1.0%	1.0%	1.0%	1.0%	1.0%	1.0%	1.0%	1.0%
leakage rate operation	1/a	6.0%	6.0%	6.0%	6.0%	6.0%	6.0%	6.0%	6.0%
technologically tolerable refrigerant loss	kg/kg	25%	25%	25%	25%	25%	25%	25%	25%
recovery rate end of life	kg/kg	71%	71%	71%	71%	71%	71%	71%	71%
Penetration rate in new installations, 2024-2036 average	%	0.5%	2.6%	51.3%	24.3%	13.2%	0.4%	1.7%	6.0%
Penetration rate in new installations, 2050	%	-	-	60.0%	25.0%	15.0%	-	-	-

Table 106: AnaFgas sector sheet for the proportionate action scenario: Commercial refrigeration - Central systems

Commercial refrigeration - Central systems									
considered gases / technologies:		**R-404A DX**	**R-134a DX**	**HC+CO2+ CO2 cas-cade**	**R-744 transcriti-cal**	**HC+sec. liq-uid+CO2**	**R-448A/R-449A**	**HFC 1234ze + CO2+CO2 cascade**	**R-513A (also in cascade)**
GWP AR4 of refrigerant	[1]	3 921.6	1430	4	1	4	1 392.1	7	631.4
refrigerating capacity	kW	100	100	100	100	100	100	100	100
electric/mechanic capacity	kW	40	40	37	37	40	39.2	38.8	39.6
installation lifetime	years	12	12	12	12	12	12	12	12
invest cost hardware (first fill excluded)	€	320 000	320 000	368 000	342 400	336 000	320 000	352 000	320 000
annual operating hours	h/a	4 380	4 380	4 380	4 380	4 380	4 380	4 380	4 380
final energy cost	€/kWh	0.145	0.145	0.145	0.145	0.145	0.145	0.145	0.145
discount rate (societal view / emission reduction cost)	%	4%	4%	4%	4%	4%	4%	4%	4%
HFC operators' cost for containment & recovery (FGR Art 3-8)	€/a	655	655	-	-	-	655	-	655
additional maintenance cost for non-HFCs	€/a	-	-	55	255	55	-	-	-
refrigerant charge	kg	230	230	57.5	230	23	230	76.67	230
refrigerant cost first fill, average 2024-2036	€/kg	501.6	196.1	20	5	20	241.4	60	142.3
refrigerant cost first fill, average 2050	€/kg	1226	470.4	20	5	20	508.8	60	263.6
refrigerant cost first fill, counterfactual scenario, 2014 pre-phase-down prices	€/kg	10	10	20	5	20	60	60	60
installation type is refilled?		yes	yes	yes	yes	yes	yes	yes	yes
refrigerant cost refill, average 2024-2036	€/kg	501.6	196.1	20	5	20	241.4	60	142.3
refrigerant cost refill, 2050	€/kg	1226	470.4	20	5	20	508.8	60	263.6
refrigerant cost refill, counterfactual scenario, 2014 pre-phase-down prices	€/kg	10	10	20	5	20	60	60	60
leakage rate first fill / refill	kg/kg	1.0%	1.0%	1.0%	1.0%	1.0%	1.0%	1.0%	1.0%
leakage rate operation	1/a	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%
technologically tolerable refrigerant loss	kg/kg	25%	25%	25%	25%	25%	25%	25%	25%
recovery rate end of life	kg/kg	71%	71%	71%	71%	71%	71%	71%	71%
Penetration rate in new installations, 2024-2036 average	%	-	0.3%	16.5%	53.7%	16.5%	0.7%	4.9%	7.4%
Penetration rate in new installations, 2050	%	-	-	17.5%	60.0%	17.5%	-	5.0%	-

Table 107: AnaFgas sector sheet for the proportionate action scenario: Industrial refrigeration – small

Industrial refrigeration - small						
considered gases / technologies:		**R-404A**	**R-134a**	**R-717**	**CO2 / HC**	**R-513A**
GWP AR4 of refrigerant	[1]	3 921.6	1 430	0	2.5	631.4
refrigerating capacity	kW	270	270	270	270	270
electric/mechanic capacity	kW	168.75	168.75	151.88	160.31	165.38
installation lifetime	years	30	30	30	30	30
invest cost hardware (first fill excluded)	€	425 000	425 000	531 250	552 500	425 000
annual operating hours	h/a	4 500	4 500	4 500	4 500	4 500
final energy cost	€/kWh	0.095	0.095	0.095	0.095	0.095
discount rate (societal view / emission reduction cost)	%	4%	4%	4%	4%	4%
HFC operators' cost for containment & recovery (FGR Art 3-8)	€/a	1 142	1 142	-	-	1 142
additional maintenance cost for non-HFCs	€/a	-	-	1 000	55	-
refrigerant charge	kg	650	650	650	650	650
refrigerant cost first fill, average 2024-2036	€/kg	501.6	196.1	4	12.5	142.3
refrigerant cost first fill, average 2050	€/kg	1226	470.4	4	12.5	263.6
refrigerant cost first fill, counterfactual scenario, 2014 pre-phase-down prices	€/kg	10	10	4	12.5	60
installation type is refilled?		yes	yes	yes	yes	yes
refrigerant cost refill, average 2024-2036	€/kg	501.6	196.1	4	12.5	142.3
refrigerant cost refill, 2050	€/kg	1226	470.4	4	12.5	263.6
refrigerant cost refill, counterfactual scenario, 2014 pre-phase-down prices	€/kg	10	10	4	12.5	60
leakage rate first fill / refill	kg/kg	1.0%	1.0%	1.0%	1.0%	1.0%
leakage rate operation	1/a	5.4%	5.4%	5.4%	5.4%	5.4%
technologically tolerable refrigerant loss	kg/kg	30%	30%	30%	30%	30%
recovery rate end of life	kg/kg	65%	65%	65%	65%	65%
Penetration rate in new installations, 2024-2036 average	%	0.3%	0.3%	48.3%	49.3%	1.8%
Penetration rate in new installations, 2050	%	-	-	50.0%	50.0%	-

Table 108: AnaFgas sector sheet for the proportionate action scenario: Industrial refrigeration – large

Industrial refrigeration - large					
considered gases / technologies:		**R-404A**	**R-717**	**HFC-1234ze**	**R-513A (also as cascade + CO2)**
GWP AR4 of refrigerant	[1]	3 921.6	0	7	631.4
refrigerating capacity	kW	5 000	5 000	5 000	5 000
electric/mechanic capacity	kW	2 000	1 780	1 960	1 960
installation lifetime	years	30	30	30	30
invest cost hardware (first fill excluded)	€	6 000 000	7 800 000	6 120 000	6 000 000
annual operating hours	h/a	4 500	4 500	4 500	4 500
final energy cost	€/kWh	0.095	0.095	0.095	0.095
discount rate (societal view / emission reduction cost)	%	4%	4%	4%	4%
HFC operators' cost for con-tainment & recovery (FGR Art 3-8)	€/a	1 285	-	-	1 285
additional maintenance cost for non-HFCs	€/a	-	2 000	-	-
refrigerant charge	kg	4 000	4 000	4 000	4 000
refrigerant cost first fill, average 2024-2036	€/kg	501.6	4	60	142.3
refrigerant cost first fill, average 2050	€/kg	1226	4	60	263.6
refrigerant cost first fill, counter-factual scenario, 2014 pre-phase-down prices	€/kg	10	4	60	60
installation type is refilled?		yes	yes	yes	yes
refrigerant cost refill, average 2024-2036	€/kg	501.6	4	60	142.3
refrigerant cost refill, 2050	€/kg	1226	4	60	263.6
refrigerant cost refill, counter-factual scenario, 2014 pre-phase-down prices	€/kg	10	4	60	60
leakage rate first fill / refill	kg/kg	1.0%	1.0%	1.0%	1.0%
leakage rate operation	1/a	4.0%	4.0%	4.0%	4.0%
technologically tolerable refrig-erant loss	kg/kg	0%	0%	0%	0%
recovery rate end of life	kg/kg	70%	70%	70%	70%
Penetration rate in new installa-tions, 2024-2036 average	%	0.1%	91.5%	8.0%	0.5%
Penetration rate in new installa-tions, 2050	%	-	92.6%	7.4%	-

Table 109: AnaFgas sector sheet for the proportionate action scenario: Transport refrigeration – Vans

Transport refrigeration - Vans							
considered gases / technologies:		**HFC 134a**	**R-404A**	**R-744**	**R-452A**	**R-513A**	**R-454C/R-455A**
GWP AR4 of refrigerant	[1]	1 430	3 921.6	1	2 140.5	631.4	148.2
refrigerating capacity	kW	3	3	3	3	3	3
electric/mechanic capacity	kW	1.5	1.5	1.39	1.5	1.5	1.5
installation lifetime	years	10	10	10	10	10	10
invest cost hardware (first fill excluded)	€	3 000	3 000	3 369	3 000	3 000	3 150
annual operating hours	h/a	1 500	1 500	1 500	1 500	1 500	1 500
final energy cost	€/kWh	0.259	0.259	0.259	0.259	0.259	0.259
discount rate (societal view / emission reduction cost)	%	4%	4%	4%	4%	4%	4%
HFC operators' cost for containment & recovery (FGR Art 3-8)	€/a	77	77	-	77	77	77
additional maintenance cost for non-HFCs	€/a	-	-	55	-	-	-
refrigerant charge	kg	1.5	1.5	1.5	1.5	1.5	1.5
refrigerant cost first fill, average 2024-2036	€/kg	98.2	260.6	2.5	164.5	71.1	39.7
refrigerant cost first fill, average 2050	€/kg	235.5	637.1	2.5	370	131.8	53.9
refrigerant cost first fill, counterfactual scenario, 2014 pre-phase-down prices	€/kg	5	5	2.5	25	30	30
installation type is refilled?		yes	yes	yes	yes	yes	yes
refrigerant cost refill, average 2024-2036	€/kg	196.1	501.6	5	329	142.3	79.3
refrigerant cost refill, 2050	€/kg	470.4	1226	5	740	263.6	107.8
refrigerant cost refill, counterfactual scenario, 2014 pre-phase-down prices	€/kg	10	10	5	50	60	60
leakage rate first fill / refill	kg/kg	1.0%	1.0%	1.0%	1.0%	1.0%	1.0%
leakage rate operation	1/a	28.0%	28.0%	28.0%	28.0%	28.0%	28.0%
technologically tolerable refrigerant loss	kg/kg	25%	25%	25%	25%	25%	25%
recovery rate end of life	kg/kg	66%	66%	66%	66%	66%	66%
Penetration rate in new installations, 2024-2036 average	%	1.1%	0.3%	87.1%	0.4%	5.0%	6.2%
Penetration rate in new installations, 2050	%	-	-	95.0%	-	-	5.0%

Table 110: AnaFgas sector sheet for the proportionate action scenario: Transport refrigeration - Trucks & Trailers

Transport refrigeration - Trucks & Trailers							
considered gases / technologies:		**R-404A**	**R-290 direct**	**R-744**	**R-513A**	**R-452A**	**R-454C/R-455A**
GWP AR4 of refrigerant	[1]	3 921.6	3	1	631.4	2 140.5	148.2
refrigerating capacity	kW	9	9	9	9	9	9
electric/mechanic capacity	kW	8	7.68	7.2	8	8	8
installation lifetime	years	10	10	10	10	10	10
invest cost hardware (first fill excluded)	€	15 000	16 500	17 250	15 000	15 000	15 300
annual operating hours	h/a	4 000	4 000	4 000	4 000	4 000	4 000
final energy cost	€/kWh	0.259	0.259	0.259	0.259	0.259	0.259
discount rate (societal view / emission reduction cost)	%	4%	4%	4%	4%	4%	4%
HFC operators' cost for containment & recovery (FGR Art 3-8)	€/a	74	-	-	74	74	74
additional maintenance cost for non-HFCs	€/a	-	55	90	-	-	-
refrigerant charge	kg	6.5	3.25	6.5	6.5	6.5	6.5
refrigerant cost first fill, average 2024-2036	€/kg	260.6	10	2.5	71.1	164.5	39.7
refrigerant cost first fill, average 2050	€/kg	637.1	10	2.5	131.8	370	53.9
refrigerant cost first fill, counterfactual scenario, 2014 pre-phase-down prices	€/kg	5	10	2.5	30	25	30
installation type is refilled?		yes	yes	yes	yes	yes	yes
refrigerant cost refill, average 2024-2036	€/kg	501.6	20	5	142.3	329	79.3
refrigerant cost refill, 2050	€/kg	1226	20	5	263.6	740	107.8
refrigerant cost refill, counterfactual scenario, 2014 pre-phase-down prices	€/kg	10	20	5	60	50	60
leakage rate first fill / refill	kg/kg	1.0%	1.0%	1.0%	1.0%	1.0%	1.0%
leakage rate operation	1/a	18.0%	18.0%	18.0%	18.0%	18.0%	18.0%
technologically tolerable refrigerant loss	kg/kg	25%	25%	25%	25%	25%	25%
recovery rate end of life	kg/kg	66%	66%	66%	66%	66%	66%
Penetration rate in new installations, 2024-2036 average	%	0.3%	8.3%	73.8%	10.0%	1.5%	6.2%
Penetration rate in new installations, 2050	%	-	10.0%	80.0%	5.0%	-	5.0%

Table 111: AnaFgas sector sheet for the proportionate action scenario: Transport refrigeration – Ships

Transport refrigeration - Ships				
considered gases / technologies:		**R-404A**	**NH3/CO2**	**R-452A**
GWP AR4 of refrigerant	[1]	3 921.6	0	2 140.5
refrigerating capacity	kW	990	990	990
electric/mechanic capacity	kW	468	439.92	439.92
installation lifetime	years	30	30	30
invest cost hardware (first fill excluded)	€	2 000 000	2 300 000	2 000 000
annual operating hours	h/a	5 000	5 000	5 000
final energy cost	€/kWh	0.073	0.073	0.073
discount rate (societal view / emission reduction cost)	%	4%	4%	4%
HFC operators' cost for containment & recovery (FGR Art 3-8)	€/a	108	-	108
additional maintenance cost for non-HFCs	€/a	-	1 000	-
refrigerant charge	kg	1 000	750	1 000
refrigerant cost first fill, average 2024-2036	€/kg	501.6	4	329
refrigerant cost first fill, average 2050	€/kg	1226	4	740
refrigerant cost first fill, counterfactual scenario, 2014 pre-phase-down prices	€/kg	10	4	50
installation type is refilled?		yes	yes	yes
refrigerant cost refill, average 2024-2036	€/kg	501.6	4	329
refrigerant cost refill, 2050	€/kg	1226	4	740
refrigerant cost refill, counterfactual scenario, 2014 pre-phase-down prices	€/kg	10	4	50
leakage rate first fill / refill	kg/kg	1.0%	1.0%	1.0%
leakage rate operation	1/a	40.0%	40.0%	40.0%
technologically tolerable refrigerant loss	kg/kg	25%	25%	25%
recovery rate end of life	kg/kg	54%	54%	54%
Penetration rate in new installations, 2024-2036 average	%	0.3%	95.8%	3.8%
Penetration rate in new installations, 2050	%	-	100.0%	-

Table 112: AnaFgas sector sheet for the proportionate action scenario: Room AC – Moveables

Room AC - Moveables			
considered gases / technologies:		**R-410A direct**	**R-290**
GWP AR4 of refrigerant	[1]	2 087.5	3
refrigerating capacity	kW	3	3
electric/mechanic capacity	kW	0.67	0.67
installation lifetime	years	10	10
invest cost hardware (first fill excluded)	€	300	294
annual operating hours	h/a	500	500
final energy cost	€/kWh	0.215	0.215
discount rate (societal view / emission reduction cost)	%	4%	4%
HFC operators' cost for containment & recovery (FGR Art 3-8)	€/a	3	-
additional maintenance cost for non-HFCs	€/a	-	-
refrigerant charge	kg	0.75	0.38
refrigerant cost first fill, average 2024-2036	€/kg	141	10
refrigerant cost first fill, average 2050	€/kg	341.5	10
refrigerant cost first fill, counterfactual scenario, 2014 pre-phase-down prices	€/kg	5	10
installation type is refilled?		no	no
refrigerant cost refill, average 2024-2036	€/kg	-	-
refrigerant cost refill, 2050	€/kg	-	-
refrigerant cost refill, counterfactual scenario, 2014 pre-phase-down prices	€/kg	-	-
leakage rate first fill / refill	kg/kg	0.0%	0.0%
leakage rate operation	1/a	3.0%	3.0%
technologically tolerable refrigerant loss	kg/kg	25%	25%
recovery rate end of life	kg/kg	53%	53%
Penetration rate in new installations, 2024-2036 average	%	-	100.0%
Penetration rate in new installations, 2050	%	-	100.0%

Table 113: AnaFgas sector sheet for the proportionate action scenario: Room AC - Single split

Room AC - Single split (includes small multi-split <12 kW & reversible air-to-air heat pumps)				
considered gases / technologies:		**R-410A direct**	**R-290**	**HFC-32**
GWP AR4 of refrigerant	[1]	2 087.5	3	675
refrigerating capacity	kW	4.5	4.5	4.5
electric/mechanic capacity	kW	1	1	1
installation lifetime	years	10	10	10
invest cost hardware (first fill excluded)	€	750	803	750
annual operating hours	h/a	1 500	1 500	1 500
final energy cost	€/kWh	0.215	0.215	0.215
discount rate (societal view / emission reduction cost)	%	4%	4%	4%
HFC operators' cost for containment & recovery (FGR Art 3-8)	€/a	9	-	9
additional maintenance cost for non-HFCs	€/a	-	-	-
refrigerant charge	kg	1.5	0.75	1.2
refrigerant cost first fill, average 2024-2036	€/kg	141	10	54
refrigerant cost first fill, average 2050	€/kg	341.5	10	118.8
refrigerant cost first fill, counterfactual scenario, 2014 pre-phase-down prices	€/kg	5	10	10
installation type is refilled?		yes	yes	yes
refrigerant cost refill, average 2024-2036	€/kg	280.5	20	108
refrigerant cost refill, 2050	€/kg	679.2	20	237.6
refrigerant cost refill, counterfactual scenario, 2014 pre-phase-down prices	€/kg	10	20	20
leakage rate first fill / refill	kg/kg	3.5%	3.5%	3.5%
leakage rate operation	1/a	5.0%	5.0%	5.0%
technologically tolerable refrigerant loss	kg/kg	25%	25%	25%
recovery rate end of life	kg/kg	60%	60%	60%
Penetration rate in new installations, 2024-2036 average	%	0.5%	96.3%	3.3%
Penetration rate in new installations, 2050	%	-	100.0%	-

Table 114: AnaFgas sector sheet for the proportionate action scenario: Room AC – Rooftop

Room AC - Packaged systems (rooftop units), cooling only					
considered gases / technologies:		**R-410A direct**	**HFC-32**	**R-454C/R-455A**	**R-290**
GWP AR4 of refrigerant	[1]	2 087.5	675	148.2	3
refrigerating capacity	kW	30	30	30	30
electric/mechanic capacity	kW	15	14.85	15	14.7
installation lifetime	years	10	10	10	10
invest cost hardware (first fill excluded)	€	10 000	10 200	10 300	10 500
annual operating hours	h/a	3 000	3 000	3 000	3 000
final energy cost	€/kWh	0.145	0.145	0.145	0.145
discount rate (societal view / emission reduction cost)	%	4%	4%	4%	4%
HFC operators' cost for containment & recovery (FGR Art 3-8)	€/a	215	215	215	-
additional maintenance cost for non-HFCs	€/a	-	-	-	55
refrigerant charge	kg	10.5	8.4	10.5	5.25
refrigerant cost first fill, average 2024-2036	€/kg	280.5	108	79.3	20
refrigerant cost first fill, average 2050	€/kg	679.2	237.6	107.8	20
refrigerant cost first fill, counterfactual scenario, 2014 pre-phase-down prices	€/kg	10	20	60	20
installation type is refilled?		yes	yes	yes	yes
refrigerant cost refill, average 2024-2036	€/kg	280.5	108	79.3	20
refrigerant cost refill, 2050	€/kg	679.2	237.6	107.8	20
refrigerant cost refill, counterfactual scenario, 2014 pre-phase-down prices	€/kg	10	20	60	20
leakage rate first fill / refill	kg/kg	0.0%	0.0%	0.0%	0.0%
leakage rate operation	1/a	3.0%	3.0%	3.0%	3.0%
technologically tolerable refrigerant loss	kg/kg	25%	25%	25%	25%
recovery rate end of life	kg/kg	77%	77%	77%	77%
Penetration rate in new installations, 2024-2036 average	%	1.6%	47.3%	32.8%	18.2%
Penetration rate in new installations, 2050	%	-	5.0%	25.0%	70.0%

Table 115: AnaFgas sector sheet for the proportionate action scenario: Room AC – VRF

Room AC - VRF cooling only (includes Single-split >3kg VRF Multi-Split)						
considered gases / technologies:		**R-410A direct**	**HFC-32**	**R-454C/R-455A**	**R-290**	**R-290 + evap. Secondary**
GWP AR4 of refrigerant	[1]	2 087.5	675	148.2	3	3
refrigerating capacity	kW	27	27	27	27	27
electric/mechanic capacity	kW	8	8	7.84	7.76	7.6
installation lifetime	years	13	13	13	13	13
invest cost hardware (first fill excluded)	€	9 500	9 738	9 738	12 350	12 920
annual operating hours	h/a	3 000	3 000	3 000	3 000	3 000
final energy cost	€/kWh	0.145	0.145	0.145	0.145	0.145
discount rate (societal view / emission reduction cost)	%	4%	4%	4%	4%	4%
HFC operators' cost for containment & recovery (FGR Art 3-8)	€/a	226	226	226	-	-
additional maintenance cost for non-HFCs	€/a	-	-	-	55	55
refrigerant charge	kg	13.5	10.8	13.5	6.75	6.75
refrigerant cost first fill, average 2024-2036	€/kg	280.5	108	79.3	20	20
refrigerant cost first fill, average 2050	€/kg	679.2	237.6	107.8	20	20
refrigerant cost first fill, counterfactual scenario, 2014 pre-phase-down prices	€/kg	10	20	60	20	20
installation type is refilled?		yes	yes	yes	yes	yes
refrigerant cost refill, average 2024-2036	€/kg	280.5	108	79.3	20	20
refrigerant cost refill, 2050	€/kg	679.2	237.6	107.8	20	20
refrigerant cost refill, counterfactual scenario, 2014 pre-phase-down prices	€/kg	10	20	60	20	20
leakage rate first fill / refill	kg/kg	0.3%	0.3%	0.3%	0.3%	0.3%
leakage rate operation	1/a	5.6%	5.6%	5.6%	5.6%	5.6%
technologically tolerable refrigerant loss	kg/kg	25%	25%	25%	25%	25%
recovery rate end of life	kg/kg	77%	77%	77%	77%	77%
Penetration rate in new installations, 2024-2036 average	%	2.1%	39.0%	49.0%	4.9%	4.9%
Penetration rate in new installations, 2050	%	-	5.0%	65.0%	15.0%	15.0%

Table 116: AnaFgas sector sheet for the proportionate action scenario: Minichillers

Minichillers						
considered gases / technologies:		**R-410A**	**R-32**	**HFO-1234ze**	**R-290 direct**	**R-454C/R-455A**
GWP AR4 of refrigerant	[1]	2 087.5	675	7	3	148.2
refrigerating capacity	kW	2	2	2	2	2
electric/mechanic capacity	kW	2	1.98	2	1.94	1.98
installation lifetime	years	12	12	12	12	12
invest cost hardware (first fill excluded)	€	450	459	450	495	473
annual operating hours	h/a	1 860	1 860	1 860	1 860	1 860
final energy cost	€/kWh	0.145	0.145	0.145	0.145	0.145
discount rate (societal view / emission reduction cost)	%	4%	4%	4%	4%	4%
HFC operators' cost for containment & recovery (FGR Art 3-8)	€/a	141	141	-	-	141
additional maintenance cost for non-HFCs	€/a	-	-	-	-	-
refrigerant charge	kg	0.65	0.43	0.72	0.33	0.65
refrigerant cost first fill, average 2024-2036	€/kg	141	54	30	10	39.7
refrigerant cost first fill, average 2050	€/kg	341.5	118.8	30	10	53.9
refrigerant cost first fill, counterfactual scenario, 2014 pre-phase-down prices	€/kg	5	10	30	10	30
installation type is refilled?		yes	yes	yes	yes	yes
refrigerant cost refill, average 2024-2036	€/kg	280.5	108	60	20	79.3
refrigerant cost refill, 2050	€/kg	679.2	237.6	60	20	107.8
refrigerant cost refill, counterfactual scenario, 2014 pre-phase-down prices	€/kg	10	20	60	20	60
leakage rate first fill / refill	kg/kg	0.5%	0.5%	0.5%	0.5%	0.5%
leakage rate operation	1/a	2.4%	2.4%	2.4%	2.4%	2.4%
technologically tolerable refrigerant loss	kg/kg	20%	20%	20%	20%	20%
recovery rate end of life	kg/kg	78%	78%	78%	78%	78%
Penetration rate in new installations, 2024-2036 average	%	1.6%	26.9%	38.4%	16.2%	16.8%
Penetration rate in new installations, 2050	%	-	-	66.7%	33.3%	-

Table 117: AnaFgas sector sheet for the proportionate action scenario: Displacement chillers – small

Displacement chillers - small							
considered gases / technologies:		**R-410A**	**H2O (R-718)**	**R-32**	**HFO-1234ze**	**R-290 direct**	**R-454C/R-455A**
GWP AR4 of refrigerant	[1]	2 087.5	0	675	7	3	148.2
refrigerating capacity	kW	80	80	80	80	80	80
electric/mechanic capacity	kW	28	26.32	27.72	27.72	27.16	27.72
installation lifetime	years	15	15	15	15	15	15
invest cost hardware (first fill excluded)	€	18 000	25 200	18 900	18 360	20 700	18 900
annual operating hours	h/a	1 860	1 860	1 860	1 860	1 860	1 860
final energy cost	€/kWh	0.145	0.145	0.145	0.145	0.145	0.145
discount rate (societal view / emission reduction cost)	%	4%	4%	4%	4%	4%	4%
HFC operators' cost for containment & recovery (FGR Art 3-8)	€/a	143	-	143	-	-	143
additional maintenance cost for non-HFCs	€/a	-	-	-	-	-	-
refrigerant charge	kg	26	18	17.33	28.6	13	26
refrigerant cost first fill, average 2024-2036	€/kg	280.5	0.1	108	60	20	79.3
refrigerant cost first fill, average 2050	€/kg	679.2	0.3	237.6	60	20	107.8
refrigerant cost first fill, counterfactual scenario, 2014 pre-phase-down prices	€/kg	10	0	20	60	20	60
installation type is refilled?		yes	yes	yes	yes	yes	yes
refrigerant cost refill, average 2024-2036	€/kg	280.5	0.1	108	60	20	79.3
refrigerant cost refill, 2050	€/kg	679.2	0.3	237.6	60	20	107.8
refrigerant cost refill, counterfactual scenario, 2014 pre-phase-down prices	€/kg	10	0	20	60	20	60
leakage rate first fill / refill	kg/kg	0.5%	0.5%	0.5%	0.5%	0.5%	0.5%
leakage rate operation	1/a	2.4%	2.4%	2.4%	2.4%	2.4%	2.4%
technologically tolerable refrigerant loss	kg/kg	20%	20%	20%	20%	20%	20%
recovery rate end of life	kg/kg	78%	78%	78%	78%	78%	78%
Penetration rate in new installations, 2024-2036 average	%	1.1%	52.5%	12.7%	8.0%	22.3%	3.5%
Penetration rate in new installations, 2050	%	-	61.4%	-	7.2%	31.3%	-

Table 118: AnaFgas sector sheet for the proportionate action scenario: Displacement chillers – large

Displacement chillers - large								
considered gases / technologies:		**R-134a**	**R-407C**	**R-410A**	**R-717 / R-718**	**R-32**	**HFO-1234ze**	**R-454C/R-455A**
GWP AR4 of refrigerant	[1]	1 430	1 773.9	2 087.5	0	675	7	148.2
refrigerating capacity	kW	400	400	400	400	400	400	400
electric/mechanic capacity	kW	129	129	129	122.55	127.07	127.71	127.71
installation lifetime	years	15	15	15	15	15	15	15
invest cost hardware (first fill excluded)	€	70 000	70 000	70 000	87 500	73 500	73 500	73 500
annual operating hours	h/a	1 860	1 860	1 860	1 860	1 860	1 860	1 860
final energy cost	€/kWh	0.095	0.095	0.095	0.095	0.095	0.095	0.095
discount rate (societal view / emission reduction cost)	%	4%	4%	4%	4%	4%	4%	4%
HFC operators' cost for containment & recovery (FGR Art 3-8)	€/a	278	278	278	-	278	-	278
additional maintenance cost for non-HFCs	€/a	-	-	-	73	-	-	-
refrigerant charge	kg	150	150	150	75	120	150	150
refrigerant cost first fill, average 2024-2036	€/kg	196.1	235.9	280.5	4	108	60	79.3
refrigerant cost first fill, average 2050	€/kg	470.4	568.8	679.2	4	237.6	60	107.8
refrigerant cost first fill, counterfactual scenario, 2014 pre-phase-down prices	€/kg	10	10	10	4	20	60	60
installation type is refilled?		yes	yes	yes	yes	yes	yes	yes
refrigerant cost refill, average 2024-2036	€/kg	196.1	235.9	280.5	4	108	60	79.3
refrigerant cost refill, 2050	€/kg	470.4	568.8	679.2	4	237.6	60	107.8
refrigerant cost refill, counterfactual scenario, 2014 pre-phase-down prices	€/kg	10	10	10	4	20	60	60
leakage rate first fill / refill	kg/kg	0.5%	0.5%	0.5%	0.5%	0.5%	0.5%	0.5%
leakage rate operation	1/a	2.4%	2.4%	2.4%	2.4%	2.4%	2.4%	2.4%
technologically tolerable refrigerant loss	kg/kg	20%	20%	20%	20%	20%	20%	20%
recovery rate end of life	kg/kg	78%	78%	78%	78%	78%	78%	78%
Penetration rate in new installations, 2024-2036 average	%	0.3%	0.2%	0.5%	70.5%	13.6%	10.2%	4.5%
Penetration rate in new installations, 2050	%	-	-	-	89.5%	-	10.5%	-

Table 119: AnaFgas sector sheet for the proportionate action scenario: Centrifugal chillers

Centrifugal chillers					
considered gases / technologies:		**HFC 134a**	**HFO-1234ze**	**HFO-1233zd**	**CO2 / NH3**
GWP AR4 of refrigerant	[1]	1 430	7	4.5	0.5
refrigerating capacity	kW	1 500	1 500	1 500	1 500
electric/mechanic capacity	kW	300	297	297	270
installation lifetime	years	25	25	25	25
invest cost hardware (first fill excluded)	€	140 000	141 400	141 400	154 000
annual operating hours	h/a	3 350	3 350	3 350	3 350
final energy cost	€/kWh	0.095	0.095	0.095	0.095
discount rate (societal view / emission reduction cost)	%	4%	4%	4%	4%
HFC operators' cost for containment & recovery (FGR Art 3-8)	€/a	278	-	-	-
additional maintenance cost for non-HFCs	€/a	-	-	-	-
refrigerant charge	kg	630	630	630	630
refrigerant cost first fill, average 2024-2036	€/kg	196.1	60	50	4.5
refrigerant cost first fill, average 2050	€/kg	470.4	60	50	4.5
refrigerant cost first fill, counterfactual scenario, 2014 pre-phase-down prices	€/kg	10	60	50	4.5
installation type is refilled?		yes	yes	yes	yes
refrigerant cost refill, average 2024-2036	€/kg	196.1	60	50	4.5
refrigerant cost refill, 2050	€/kg	470.4	60	50	4.5
refrigerant cost refill, counterfactual scenario, 2014 pre-phase-down prices	€/kg	10	60	50	4.5
leakage rate first fill / refill	kg/kg	0.5%	0.5%	0.5%	0.5%
leakage rate operation	1/a	2.4%	2.4%	2.4%	2.4%
technologically tolerable refrigerant loss	kg/kg	20%	20%	20%	20%
recovery rate end of life	kg/kg	78%	78%	78%	78%
Penetration rate in new installations, 2024-2036 average	%	0.7%	10.0%	10.0%	79.3%
Penetration rate in new installations, 2050	%	-	10.0%	10.0%	80.0%

Table 120: AnaFgas sector sheet for the proportionate action scenario: Heat pumps – small

Heat pumps - small (<12 kW, excluding small reversable air/air heat pumps covered in the single split subsector)							
considered gases / technologies:		**R-134a**	**R-410A**	**R-407C**	**HCs**	**R-32**	**R-513A**
GWP AR4 of refrigerant	[1]	1 430	2 087.5	1 773.9	4	675	631.4
refrigerating capacity	kW	11	11	11	11	11	11
electric/mechanic capacity	kW	6.88	6.88	6.88	6.67	6.81	6.81
installation lifetime	years	15	15	15	15	15	15
invest cost hardware (first fill excluded)	€	8 380	8 380	8 380	8 799	8 548	8 380
annual operating hours	h/a	2 000	2 000	2 000	2 000	2 000	2 000
final energy cost	€/kWh	0.215	0.215	0.215	0.215	0.215	0.215
discount rate (societal view / emission reduction cost)	%	4%	4%	4%	4%	4%	4%
HFC operators' cost for containment & recovery (FGR Art 3-8)	€/a	6	6	6	-	6	6
additional maintenance cost for non-HFCs	€/a	-	-	-	-	-	-
refrigerant charge	kg	2.6	2.6	2.6	1.3	2.08	2.6
refrigerant cost first fill, average 2024-2036	€/kg	98.2	141	120.6	10	54	71.1
refrigerant cost first fill, average 2050	€/kg	235.5	341.5	290.9	10	118.8	131.8
refrigerant cost first fill, counterfactual scenario, 2014 pre-phase-down prices	€/kg	5	5	5	10	10	30
installation type is refilled?		yes	yes	yes	yes	yes	yes
refrigerant cost refill, average 2024-2036	€/kg	196.1	280.5	235.9	20	108	142.3
refrigerant cost refill, 2050	€/kg	470.4	679.2	568.8	20	237.6	263.6
refrigerant cost refill, counterfactual scenario, 2014 pre-phase-down prices	€/kg	10	10	10	20	20	60
leakage rate first fill / refill	kg/kg	0.5%	0.5%	0.5%	0.5%	0.5%	0.5%
leakage rate operation	1/a	3.5%	3.5%	3.5%	3.5%	3.5%	3.5%
technologically tolerable refrigerant loss	kg/kg	30%	30%	30%	30%	30%	30%
recovery rate end of life	kg/kg	59%	59%	59%	59%	59%	59%
Penetration rate in new installations, 2024-2036 average	%	0.1%	0.7%	-	97.0%	2.0%	0.2%
Penetration rate in new installations, 2050	%	-	-	-	100.0%	-	-

Table 121: AnaFgas sector sheet for the proportionate action scenario: Heat pumps – medium

Heat pumps - medium (12-200kW)									
considered gases / technologies:		**R-134a**	**R-410A**	**R-407C**	**HCs**	**R-32**	**R-513A**	**HFO-1234ze**	**R-454B**
GWP AR4 of refrigerant	[1]	1 430	2 087.5	1 773.9	4	675	631.4	7	466.3
refrigerating capacity	kW	110	110	110	110	110	110	110	110
electric/mechanic capacity	kW	68.75	68.75	68.75	66.69	68.06	68.75	68.06	68.75
installation lifetime	years	15	15	15	15	15	15	15	15
invest cost hardware (first fill excluded)	€	30 000	30 000	30 000	33 000	31 500	30 000	31 500	30 000
annual operating hours	h/a	2 000	2 000	2 000	2 000	2 000	2 000	2 000	2 000
final energy cost	€/kWh	0.145	0.145	0.145	0.145	0.145	0.145	0.145	0.145
discount rate (societal view / emission reduction cost)	%	4%	4%	4%	4%	4%	4%	4%	4%
HFC operators' cost for containment & recovery (FGR Art 3-8)	€/a	283	283	283	-	283	283	-	283
additional maintenance cost for non-HFCs	€/a	-	-	-	55	-	-	-	-
refrigerant charge	kg	26	26	26	13	18	20.8	26	20.8
refrigerant cost first fill, average 2024-2036	€/kg	147.1	210.8	178.2	15	81	106.7	45	88.6
refrigerant cost first fill, average 2050	€/kg	353	510.3	429.9	15	178.2	197.7	45	155.9
refrigerant cost first fill, counterfactual scenario, 2014 pre-phase-down prices	€/kg	7.5	7.5	7.5	15	15	45	45	43
installation type is refilled?		yes	yes	yes	yes	yes	yes	yes	yes
refrigerant cost refill, average 2024-2036	€/kg	196.1	280.5	235.9	20	108	142.3	60	118.2
refrigerant cost refill, 2050	€/kg	470.4	679.2	568.8	20	237.6	263.6	60	208
refrigerant cost refill, counterfactual scenario, 2014 pre-phase-down prices	€/kg	10	10	10	20	20	60	60	57.3
leakage rate first fill / refill	kg/kg	0.5%	0.5%	0.5%	0.5%	0.5%	0.5%	0.5%	0.5%
leakage rate operation	1/a	4.5%	4.5%	4.5%	4.5%	4.5%	4.5%	4.5%	4.5%
technologically tolerable refrigerant loss	kg/kg	30%	30%	30%	30%	30%	30%	30%	30%
recovery rate end of life	kg/kg	59%	59%	59%	59%	59%	59%	59%	59%
Penetration rate in new installations, 2024-2036 average	%	0.1%	1.2%	-	42.3%	13.4%	0.1%	30.9%	12.0%
Penetration rate in new installations, 2050	%	-	-	-	55.0%	-	-	45.0%	-

Table 122: AnaFgas sector sheet for the proportionate action scenario: Heat pumps – large

Heat pumps - large (>200kW, district heating & industrial)					
considered gases / technologies:		**R-134a**	**HFO-1234ze**	**CO2 (R-744)**	**NH3 / R-723**
GWP AR4 of refrigerant	[1]	1 430	7	1	0
refrigerating capacity	kW	3 173.08	3 173.08	3 173.08	3 173.08
electric/mechanic capacity	kW	1 983.17	1 963.34	1 913.76	1 884.01
installation lifetime	years	20	20	20	20
invest cost hardware (first fill excluded)	€	2 800 000	2 856 000	3 360 000	3 220 000
annual operating hours	h/a	6 000	6 000	6 000	6 000
final energy cost	€/kWh	0.095	0.095	0.095	0.095
discount rate (societal view / emission reduction cost)	%	4%	4%	4%	4%
HFC operators' cost for containment & recovery (FGR Art 3-8)	€/a	283	-	-	-
additional maintenance cost for non-HFCs	€/a	-	-	255	145
refrigerant charge	kg	750	600	500	500
refrigerant cost first fill, average 2024-2036	€/kg	196.1	60	5	4
refrigerant cost first fill, average 2050	€/kg	470.4	60	5	4
refrigerant cost first fill, counterfactual scenario, 2014 pre-phase-down prices	€/kg	10	60	5	4
installation type is refilled?		yes	yes	yes	yes
refrigerant cost refill, average 2024-2036	€/kg	196.1	60	5	4
refrigerant cost refill, 2050	€/kg	470.4	60	5	4
refrigerant cost refill, counterfactual scenario, 2014 pre-phase-down prices	€/kg	10	60	5	4
leakage rate first fill / refill	kg/kg	0.5%	0.5%	0.5%	0.5%
leakage rate operation	1/a	6.0%	6.0%	6.0%	6.0%
technologically tolerable refrigerant loss	kg/kg	30%	30%	30%	30%
recovery rate end of life	kg/kg	76%	76%	76%	76%
Penetration rate in new installations, 2024-2036 average	%	2.2%	27.8%	25.1%	44.9%
Penetration rate in new installations, 2050	%	-	30.0%	25.0%	45.0%

Table 123: AnaFgas sector sheet for the proportionate action scenario: Mobile AC - Passenger cars

Mobile AC - Passenger cars				
considered gases / technologies:		**R-134a**	**HFO-1234yf**	**R-744**
GWP AR4 of refrigerant	[1]	1 430	4	1
refrigerating capacity	kW	4	4	4
electric/mechanic capacity	kW	4	4	3.6
installation lifetime	years	12	12	12
invest cost hardware (first fill excluded)	€	300	303	450
annual operating hours	h/a	300	300	300
final energy cost	€/kWh	0.446	0.446	0.446
discount rate (societal view / emission reduction cost)	%	4%	4%	4%
HFC operators' cost for containment & recovery (FGR Art 3-8)	€/a	-	-	-
additional maintenance cost for non-HFCs	€/a	-	-	55
refrigerant charge	kg	0.5	0.5	0.34
refrigerant cost first fill, average 2024-2036	€/kg	98.2	70	2.5
refrigerant cost first fill, average 2050	€/kg	235.5	70	2.5
refrigerant cost first fill, counterfactual scenario, 2014 pre-phase-down prices	€/kg	5	70	2.5
installation type is refilled?		yes	yes	yes
refrigerant cost refill, average 2024-2036	€/kg	196.1	140	5
refrigerant cost refill, 2050	€/kg	470.4	140	5
refrigerant cost refill, counterfactual scenario, 2014 pre-phase-down prices	€/kg	10	140	5
leakage rate first fill / refill	kg/kg	0.5%	0.5%	0.5%
leakage rate operation	1/a	10.0%	10.0%	10.0%
technologically tolerable refrigerant loss	kg/kg	40%	40%	40%
recovery rate end of life	kg/kg	50%	50%	50%
Penetration rate in new installations, 2024-2036 average	%	-	90.8%	9.2%
Penetration rate in new installations, 2050	%	-	80.0%	20.0%

Table 124: AnaFgas sector sheet for the proportionate action scenario: Mobile AC – Buses

Mobile AC - Buses				
considered gases / technologies:		**R-134a**	**R-744**	**R-513A**
GWP AR4 of refrigerant	[1]	1 430	1	631.4
refrigerating capacity	kW	25	25	25
electric/mechanic capacity	kW	16.7	15.87	16.7
installation lifetime	years	10	10	10
invest cost hardware (first fill excluded)	€	13 000	23 400	13 650
annual operating hours	h/a	2 000	2 000	2 000
final energy cost	€/kWh	0.259	0.259	0.259
discount rate (societal view / emission reduction cost)	%	4%	4%	4%
HFC operators' cost for containment & recovery (FGR Art 3-8)	€/a	-	-	-
additional maintenance cost for non-HFCs	€/a	-	55	-
refrigerant charge	kg	10.4	6.97	10.4
refrigerant cost first fill, average 2024-2036	€/kg	98.2	2.5	71.1
refrigerant cost first fill, average 2050	€/kg	235.5	2.5	131.8
refrigerant cost first fill, counterfactual scenario, 2014 pre-phase-down prices	€/kg	5	2.5	30
installation type is refilled?		yes	yes	yes
refrigerant cost refill, average 2024-2036	€/kg	196.1	5	142.3
refrigerant cost refill, 2050	€/kg	470.4	5	263.6
refrigerant cost refill, counterfactual scenario, 2014 pre-phase-down prices	€/kg	10	5	60
leakage rate first fill / refill	kg/kg	0.0%	0.0%	0.0%
leakage rate operation	1/a	15.0%	15.0%	15.0%
technologically tolerable refrigerant loss	kg/kg	40%	40%	40%
recovery rate end of life	kg/kg	63%	63%	63%
Penetration rate in new installations, 2024-2036 average	%	4.9%	38.7%	56.4%
Penetration rate in new installations, 2050	%	-	35.0%	65.0%

Table 125: AnaFgas sector sheet for the proportionate action scenario: Mobile AC - Trucks N1

Mobile AC - Trucks N1				
considered gases / technologies:		**R-134a**	**R-744**	**HFO-1234yf**
GWP AR4 of refrigerant	[1]	1 430	1	4
refrigerating capacity	kW	8	8	8
electric/mechanic capacity	kW	8	7.6	8
installation lifetime	years	10	10	10
invest cost hardware (first fill excluded)	€	300	450	304
annual operating hours	h/a	300	300	300
final energy cost	€/kWh	0.259	0.259	0.259
discount rate (societal view / emission reduction cost)	%	4%	4%	4%
HFC operators' cost for containment & recovery (FGR Art 3-8)	€/a	-	-	-
additional maintenance cost for non-HFCs	€/a	-	55	-
refrigerant charge	kg	1	0.67	1
refrigerant cost first fill, average 2024-2036	€/kg	98.2	2.5	70
refrigerant cost first fill, average 2050	€/kg	235.5	2.5	70
refrigerant cost first fill, counterfactual scenario, 2014 pre-phase-down prices	€/kg	5	2.5	70
installation type is refilled?		yes	yes	yes
refrigerant cost refill, average 2024-2036	€/kg	196.1	5	140
refrigerant cost refill, 2050	€/kg	470.4	5	140
refrigerant cost refill, counterfactual scenario, 2014 pre-phase-down prices	€/kg	10	5	140
leakage rate first fill / refill	kg/kg	0.0%	0.0%	0.0%
leakage rate operation	1/a	10.0%	10.0%	10.0%
technologically tolerable refrigerant loss	kg/kg	40%	40%	40%
recovery rate end of life	kg/kg	13%	13%	13%
Penetration rate in new installations, 2024-2036 average	%	31.5%	6.9%	61.6%
Penetration rate in new installations, 2050	%	-	10.0%	90.0%

Table 126: AnaFgas sector sheet for the proportionate action scenario: Mobile AC - Trucks N2

Mobile AC - Trucks N2				
considered gases / technologies:		**R-134a**	**R-744**	**HFO-1234yf**
GWP AR4 of refrigerant	[1]	1 430	1	4
refrigerating capacity	kW	8	8	8
electric/mechanic capacity	kW	8	7.6	8
installation lifetime	years	10	10	10
invest cost hardware (first fill excluded)	€	300	450	304
annual operating hours	h/a	300	300	300
final energy cost	€/kWh	0.259	0.259	0.259
discount rate (societal view / emission reduction cost)	%	4%	4%	4%
HFC operators' cost for containment & recovery (FGR Art 3-8)	€/a	-	-	-
additional maintenance cost for non-HFCs	€/a	-	55	-
refrigerant charge	kg	1	0.67	1
refrigerant cost first fill, average 2024-2036	€/kg	98.2	2.5	70
refrigerant cost first fill, average 2050	€/kg	235.5	2.5	70
refrigerant cost first fill, counterfactual scenario, 2014 pre-phase-down prices	€/kg	5	2.5	70
installation type is refilled?		yes	yes	yes
refrigerant cost refill, average 2024-2036	€/kg	196.1	5	140
refrigerant cost refill, 2050	€/kg	470.4	5	140
refrigerant cost refill, counterfactual scenario, 2014 pre-phase-down prices	€/kg	10	5	140
leakage rate first fill / refill	kg/kg	0.0%	0.0%	0.0%
leakage rate operation	1/a	15.0%	15.0%	15.0%
technologically tolerable refrigerant loss	kg/kg	40%	40%	40%
recovery rate end of life	kg/kg	13%	13%	13%
Penetration rate in new installations, 2024-2036 average	%	44.5%	7.7%	47.8%
Penetration rate in new installations, 2050	%	-	20.0%	80.0%

Table 127: AnaFgas sector sheet for the proportionate action scenario: Mobile AC - Trucks N3

Mobile AC - Trucks N3				
considered gases / technologies:		**R-134a**	**R-744**	**HFO-1234yf**
GWP AR4 of refrigerant	[1]	1 430	1	4
refrigerating capacity	kW	8	8	8
electric/mechanic capacity	kW	8	7.6	8
installation lifetime	years	10	10	10
invest cost hardware (first fill excluded)	€	300	450	304
annual operating hours	h/a	300	300	300
final energy cost	€/kWh	0.259	0.259	0.259
discount rate (societal view / emission reduction cost)	%	4%	4%	4%
HFC operators' cost for containment & recovery (FGR Art 3-8)	€/a	-	-	-
additional maintenance cost for non-HFCs	€/a	-	55	-
refrigerant charge	kg	1	0.67	1
refrigerant cost first fill, average 2024-2036	€/kg	98.2	2.5	70
refrigerant cost first fill, average 2050	€/kg	235.5	2.5	70
refrigerant cost first fill, counterfactual scenario, 2014 pre-phase-down prices	€/kg	5	2.5	70
installation type is refilled?		yes	yes	yes
refrigerant cost refill, average 2024-2036	€/kg	196.1	5	140
refrigerant cost refill, 2050	€/kg	470.4	5	140
refrigerant cost refill, counterfactual scenario, 2014 pre-phase-down prices	€/kg	10	5	140
leakage rate first fill / refill	kg/kg	0.0%	0.0%	0.0%
leakage rate operation	1/a	15.0%	15.0%	15.0%
technologically tolerable refrigerant loss	kg/kg	40%	40%	40%
recovery rate end of life	kg/kg	13%	13%	13%
Penetration rate in new installations, 2024-2036 average	%	62.5%	11.2%	26.3%
Penetration rate in new installations, 2050	%	5.0%	25.0%	70.0%

Table 128: AnaFgas sector sheet for the proportionate action scenario: Mobile AC - Passenger ships

Mobile AC - Passenger ships				
considered gases / technologies:		**R-134a**	**R-513A**	**Naturals**
GWP AR4 of refrigerant	[1]	1 430	631.4	0.5
refrigerating capacity	kW	975	975	975
electric/mechanic capacity	kW	180	180	162
installation lifetime	years	30	30	30
invest cost hardware (first fill excluded)	€	123 500	129 675	172 900
annual operating hours	h/a	3 000	3 000	3 000
final energy cost	€/kWh	0.073	0.073	0.073
discount rate (societal view / emission reduction cost)	%	4%	4%	4%
HFC operators' cost for containment & recovery (FGR Art 3-8)	€/a	2 039	2 039	-
additional maintenance cost for non-HFCs	€/a	-	-	-
refrigerant charge	kg	520	520	468
refrigerant cost first fill, average 2024-2036	€/kg	196.1	142.3	4.5
refrigerant cost first fill, average 2050	€/kg	470.4	263.6	4.5
refrigerant cost first fill, counterfactual scenario, 2014 pre-phase-down prices	€/kg	10	60	4.5
installation type is refilled?		yes	yes	yes
refrigerant cost refill, average 2024-2036	€/kg	196.1	142.3	4.5
refrigerant cost refill, 2050	€/kg	470.4	263.6	4.5
refrigerant cost refill, counterfactual scenario, 2014 pre-phase-down prices	€/kg	10	60	4.5
leakage rate first fill / refill	kg/kg	0.0%	0.0%	0.0%
leakage rate operation	1/a	40.0%	40.0%	40.0%
technologically tolerable refrigerant loss	kg/kg	40%	40%	40%
recovery rate end of life	kg/kg	63%	63%	63%
Penetration rate in new installations, 2024-2036 average	%	1.5%	29.2%	69.3%
Penetration rate in new installations, 2050	%	-	-	100.0%

Table 129: AnaFgas sector sheet for the proportionate action scenario: Mobile AC - Cargo ships

Mobile AC - Cargo ships				
considered gases / technologies:		**R-134a**	**NH3/brine**	**R-513A**
GWP AR4 of refrigerant	[1]	1 430	0	631.4
refrigerating capacity	kW	300	300	300
electric/mechanic capacity	kW	55.3	47.01	55.3
installation lifetime	years	30	30	30
invest cost hardware (first fill excluded)	€	38 000	59 660	39 900
annual operating hours	h/a	3 000	3 000	3 000
final energy cost	€/kWh	0.073	0.073	0.073
discount rate (societal view / emission reduction cost)	%	4%	4%	4%
HFC operators' cost for containment & recovery (FGR Art 3-8)	€/a	778	-	778
additional maintenance cost for non-HFCs	€/a	-	1 000	-
refrigerant charge	kg	160	52.8	160
refrigerant cost first fill, average 2024-2036	€/kg	196.1	4	142.3
refrigerant cost first fill, average 2050	€/kg	470.4	4	263.6
refrigerant cost first fill, counterfactual scenario, 2014 pre-phase-down prices	€/kg	10	4	60
installation type is refilled?		yes	yes	yes
refrigerant cost refill, average 2024-2036	€/kg	196.1	4	142.3
refrigerant cost refill, 2050	€/kg	470.4	4	263.6
refrigerant cost refill, counterfactual scenario, 2014 pre-phase-down prices	€/kg	10	4	60
leakage rate first fill / refill	kg/kg	1.0%	1.0%	1.0%
leakage rate operation	1/a	40.0%	40.0%	40.0%
technologically tolerable refrigerant loss	kg/kg	40%	40%	40%
recovery rate end of life	kg/kg	63%	63%	63%
Penetration rate in new installations, 2024-2036 average	%	3.6%	77.4%	19.0%
Penetration rate in new installations, 2050	%	-	100.0%	-

Table 130: AnaFgas sector sheet for the proportionate action scenario: Mobile AC – Tram

Mobile AC - Tram					
considered gases / technologies:		**R-134a**	**R-744/CO2**	**R-513A**	**HCs**
GWP AR4 of refrigerant	[1]	1 430	1	631.4	4
refrigerating capacity	kW	35	35	35	35
electric/mechanic capacity	kW	15	13.5	15	14.55
installation lifetime	years	25	25	25	25
invest cost hardware (first fill excluded)	€	25 000	30 000	25 250	27 500
annual operating hours	h/a	2 000	2 000	2 000	2 000
final energy cost	€/kWh	0.08	0.08	0.08	0.08
discount rate (societal view / emission reduction cost)	%	4%	4%	4%	4%
HFC operators' cost for containment & recovery (FGR Art 3-8)	€/a	2	-	2	-
additional maintenance cost for non-HFCs	€/a	-	90	-	-
refrigerant charge	kg	8	6.4	8	8
refrigerant cost first fill, average 2024-2036	€/kg	98.2	2.5	71.1	10
refrigerant cost first fill, average 2050	€/kg	235.5	2.5	131.8	10
refrigerant cost first fill, counterfactual scenario, 2014 pre-phase-down prices	€/kg	5	2.5	30	10
installation type is refilled?		yes	yes	yes	yes
refrigerant cost refill, average 2024-2036	€/kg	196.1	5	142.3	20
refrigerant cost refill, 2050	€/kg	470.4	5	263.6	20
refrigerant cost refill, counterfactual scenario, 2014 pre-phase-down prices	€/kg	10	5	60	20
leakage rate first fill / refill	kg/kg	0.2%	0.2%	0.2%	0.2%
leakage rate operation	1/a	7.0%	7.0%	7.0%	7.0%
technologically tolerable refrigerant loss	kg/kg	25%	25%	25%	25%
recovery rate end of life	kg/kg	66%	66%	66%	66%
Penetration rate in new installations, 2024-2036 average	%	3.3%	76.7%	9.8%	10.2%
Penetration rate in new installations, 2050	%	-	50.0%	-	50.0%

Table 131: AnaFgas sector sheet for the proportionate action scenario: Mobile AC – Metro

Mobile AC - Metro				
considered gases / technologies:		**R-134a**	**R-744/CO2**	**R-513A**
GWP AR4 of refrigerant	[1]	1 430	1	631.4
refrigerating capacity	kW	35	35	35
electric/mechanic capacity	kW	15	13.5	15
installation lifetime	years	25	25	25
invest cost hardware (first fill ex-cluded)	€	25 000	30 000	25 250
annual operating hours	h/a	2 000	2 000	2 000
final energy cost	€/kWh	0.08	0.08	0.08
discount rate (societal view / emission reduction cost)	%	4%	4%	4%
HFC operators' cost for containment & recovery (FGR Art 3-8)	€/a	2	-	2
additional maintenance cost for non-HFCs	€/a	-	90	-
refrigerant charge	kg	8	6.4	8
refrigerant cost first fill, average 2024-2036	€/kg	98.2	2.5	71.1
refrigerant cost first fill, average 2050	€/kg	235.5	2.5	131.8
refrigerant cost first fill, counterfactual scenario, 2014 pre-phase-down prices	€/kg	5	2.5	30
installation type is refilled?		yes	yes	yes
refrigerant cost refill, average 2024-2036	€/kg	196.1	5	142.3
refrigerant cost refill, 2050	€/kg	470.4	5	263.6
refrigerant cost refill, counterfactual scenario, 2014 pre-phase-down prices	€/kg	10	5	60
leakage rate first fill / refill	kg/kg	0.2%	0.2%	0.2%
leakage rate operation	1/a	7.0%	7.0%	7.0%
technologically tolerable refrigerant loss	kg/kg	25%	25%	25%
recovery rate end of life	kg/kg	66%	66%	66%
Penetration rate in new installations, 2024-2036 average	%	2.0%	88.2%	9.8%
Penetration rate in new installations, 2050	%	-	100.0%	-

Table 132: AnaFgas sector sheet for the proportionate action scenario: Mobile AC – Train

Mobile AC - Train						
considered gases / technologies:		**R-134a**	**R-407C**	**R-744 / HCs**	**R-513A**	**R-729**
GWP AR4 of refrigerant	[1]	1 430	1773.9	2.5	631.4	0
refrigerating capacity	kW	35	35	35	35	35
electric/mechanic capacity	kW	15	15	13.5	15	13.5
installation lifetime	years	25	25	25	25	25
invest cost hardware (first fill excluded)	€	25 000	25 000	30 000	25 250	50 000
annual operating hours	h/a	2 000	2 000	2 000	2 000	2 000
final energy cost	€/kWh	0.08	0.08	0.08	0.08	0.08
discount rate (societal view / emission reduction cost)	%	4%	4%	4%	4%	4%
HFC operators' cost for containment & recovery (FGR Art 3-8)	€/a	2	2	-	2	-
additional maintenance cost for non-HFCs	€/a	-	-	-	-	-
refrigerant charge	kg	8	8	8	8	8
refrigerant cost first fill, average 2024-2036	€/kg	98.2	120.6	6.3	71.1	2
refrigerant cost first fill, average 2050	€/kg	235.5	290.9	6.3	131.8	2
refrigerant cost first fill, counterfactual scenario, 2014 pre-phase-down prices	€/kg	5	5	6.3	30	2
installation type is refilled?		yes	yes	yes	yes	yes
refrigerant cost refill, average 2024-2036	€/kg	196.1	235.9	12.5	142.3	4
refrigerant cost refill, 2050	€/kg	470.4	568.8	12.5	263.6	4
refrigerant cost refill, counterfactual scenario, 2014 pre-phase-down prices	€/kg	10	10	12.5	60	4
leakage rate first fill / refill	kg/kg	0.2%	0.2%	0.2%	0.2%	0.2%
leakage rate operation	1/a	7.0%	7.0%	7.0%	7.0%	7.0%
technologically tolerable refrigerant loss	kg/kg	25%	25%	25%	25%	25%
recovery rate end of life	kg/kg	66%	66%	66%	66%	66%
Penetration rate in new installations, 2024-2036 average	%	1.7%	-	89.6%	8.5%	0.2%
Penetration rate in new installations, 2050	%	-	-	100.0%	-	-

Table 133: AnaFgas sector sheet for the proportionate action scenario: Aerosols – technical

Aerosols - technical				
considered gases / technologies:		**HFC-134a**	**HFC-152a**	**HFC-1234ze**
GWP AR4 of propellant	[1]	1 430	124	7
preparation / canning cost (propellant excluded) per kg propellant	€/kg	20	20	20
propellant charge	kg	0.15	0.15	0.15
propellant cost first fill, average 2024-2036	€/kg	98.2	13.1	15.0
propellant cost first fill, 2050	€/kg	235.5	25.0	15.0
propellant cost first fill, counterfactual scenario, 2014 pre-phase-down prices	€/kg	5.0	5.0	15.0
emission rate on application	kg/kg	100%	100%	100%
Penetration rate (defined on HFC-based niche of sector), 2024-2036 average	%	-	8.7%	91.3%
Penetration rate (defined on HFC-based niche of sector), 2050	%	-	-	100.0%

Table 134: AnaFgas sector sheet for the proportionate action scenario: Aerosols – MDIs

Aerosols - MDIs					
considered gases / technologies:		**HFC-134a**	**HFC-227ea**	**HFC-1234ze**	**HFC-152a**
GWP AR4 of propellant	[1]	1 430	3 220	7	124
preparation / canning cost (propellant excluded) per kg propellant	€/kg	706	706	706	706
propellant charge	kg	0.005	0.005	0.005	0.005
propellant cost first fill, average 2024-2036	€/kg	101.2	217.8	24.0	16.1
propellant cost first fill, 2050	€/kg	238.5	527.0	24.0	28.0
propellant cost first fill, counterfactual scenario, 2014 pre-phase-down prices	€/kg	8.0	8.0	24.0	8.0
emission rate on application	kg/kg	100%	100%	100%	100%
Penetration rate (defined on HFC-based niche of sector), 2024-2036 average	%	46.5%	4.0%	2.7%	46.8%
Penetration rate (defined on HFC-based niche of sector), 2050	%	5.0%	2.0%	43.0%	50.0%

Table 135: AnaFgas sector sheet for the proportionate action scenario: Fire extinguishers

Fire extinguishers							
considered gases / technologies:		**HFC-227ea**	**HFC-23**	**HFC-125**	**HFC-236fa**	**HFC-134a**	**low-GWP alternatives (FK-5-1-12, inert gases)**
GWP AR4 of suppression agent	[1]	3 220	14 800	3 500	9 810	1 430	0.5
room size	m³	200	200	200	200	200	200
required gas concentration (for suppression of class C hazards (energized electrical equipment)	m³ / m³	5.8%	17.4%	9.0%	8.6%	15.3%	21.3%
molar mass of suppression agent	g/mol	170	70	120	152	102	175
molar volume at room temperature	l/mol	24.47	24.47	24.47	24.47	24.47	24.47
installed gas quantity	kg	80.6	99.6	88.3	106.8	127.6	303.9
installation lifetime	years	20	20	20	20	20	20
invest cost hardware (first fill excluded)	€	14 000	11 500	14 000	14 000	14 000	14 000
discount rate (societal view / emission reduction cost)	%	4%	4%	4%	4%	4%	4%
HFC operators' cost for containment & recovery (FGR Art 3-8)	€/a	117	117	117	117	117	-
additional maintenance cost for non-HFCs	€/a	-	-	-	-	-	-
suppression agent cost first fill, average 2024-2036	€/kg	223.8	978.5	242.1	653.3	107.2	11
suppression agent cost first fill, 2050	€/kg	533	2399.6	578.2	1595.3	244.5	11
suppression agent cost first fill, counterfactual scenario, 2014 pre-phase-down prices	€/kg	14	14	14	14	14	11
installation type is refilled?		yes	yes	yes	yes	yes	yes
suppression agent cost refill, average 2024-2036	€/kg	223.8	978.5	240.6	653.3	107.2	11
suppression agent cost refill, 2050	€/kg	533	2399.6	574.6	1595.3	244.5	11
suppression agent cost refill, counterfactual scenario, 2014 pre-phase-down prices	€/kg	14	14	14	14	14	11
leakage rate first fill / refill	kg/kg	0.1%	0.1%	0.1%	0.1%	0.1%	0.1%
leakage rate operation	1/a	2.0%	2.0%	2.0%	5.0%	4.0%	2.0%
recovery rate end of life	kg/kg	91%	91%	91%	91%	91%	91%
Penetration rate in new installations (in HFC-based niche of sector), 2024-2036 average	%	-	-	-	-	-	100.0%
Penetration rate in new installations (in HFC-based niche of sector), 2050	%	-	-	-	-	-	100.0%

Table 136: AnaFgas sector sheet for the proportionate action scenario: Solvents

Solvents					
considered gases / technologies:		**HFC-43-10mee**	**HFC-365mfc**	**HFO-1233zd**	**Novec 7100**
GWP AR4 of solvent	[1]	1 640	794	4.5	297
preparation / canning cost (solvent excluded) per kg solvent	€/kg	20	20	20	20
solvent charge	kg	0.15	0.15	0.15	0.15
propellant cost first fill, average 2024-2036	€/kg	111.9	57.7	25.0	25.0
propellant cost first fill, 2050	€/kg	269.4	134.0	25.0	25.0
propellant cost first fill, counterfactual scenario, 2014 pre-phase-down prices	€/kg	5.0	6.0	25.0	25.0
emission rate on application	kg/kg	100%	100%	100%	100%
Penetration rate (defined on HFC-based niche of sector), 2024-2036 average	%	2.8%	0.1%	72.8%	24.3%
Penetration rate (defined on HFC-based niche of sector), 2050	%	-	-	73.7%	26.3%

Table 137: AnaFgas sector sheet for the proportionate action scenario: Foam OCF

Foam OCF (one component foam)			
considered gases / technologies:		**HFC-134a**	**HFO-1234ze**
GWP AR4 of blowing agent	[1]	1 430	7
product		OCF cans, 660g, hereof 110g propellant	OCF cans, 660g, hereof 110g propellant
production facility annual output	m³/a	10 000	10 000
thermal conductivity	mW/ (m * K)	30	30
production facility insulation capacity annual output	m³/ a * ((m * K) / mW))	333	333
product density	kg/m³	42	42
blowing agent in formulation	pbw	110	110
total weight of formulation	pbw	660	660
foam product lifetime	years	50	50
invest cost for conversion of production line including development	€	-	22 500
economic lifetime of conversion investment	years	15	15
discount rate (societal view / emission reduction cost)	%	4%	4%
blowing agent cost, average 2024-2036	€/kg	25.8	21.5
blowing agent cost, average 2050	€/kg	35.4	31.1
blowing agent cost, counterfactual scenario, 2014 pre-phase-down prices	€/kg	5.0	15.0
manufacturing emission factor of blowing agent	kg/kg	15%	15%
leakage rate in foam product lifetime, baseline scenario	1/a	1.0%	1.0%
Penetration rate (defined on HFC-based niche of sector), 2024-2036 average	%	-	100.0%
Penetration rate (defined on HFC-based niche of sector), 2050	%	-	100.0%

Table 138: AnaFgas sector sheet for the proportionate action scenario: Foam XPS

Foam XPS (extruded polystyrene)					
considered gases / technologies:		**XPS / HFC-134a**	**XPS / HFC-152a**	**XPS / HFO-1234ze**	**XPS / CO2**
GWP AR4 of blowing agent	[1]	1 430	124	7	1
product		XPS-134a Panel 1200 x 600 x 1400 mm, density 35	XPS Panel 1200 x 600 x 50 mm, density 35	XPS Panel 1200 x 600 x 1400 mm, density 40	XPS Panel 1200 x 600 x 50 mm, density 35
production facility annual output	m³/a	75 000	87 931	75 000	87 931
thermal conductivity	mW/ (m * K)	29	34	29	34
production facility insulation capacity annual output	m³/ a * ((m * K) / mW))	2 586	2 586	2 586	2 586
product density	kg/m³	35	35	40	35
blowing agent in formulation	pbw	7	10	8	10
total weight of formulation	pbw	100	90	100	90
foam product lifetime	years	50	50	50	50
invest cost for conversion of production line including development	€	-	-	1 000 000	1 500 000
economic lifetime of conversion investment	years	15	15	15	15
discount rate (societal view / emission reduction cost)	%	4%	4%	4%	4%
blowing agent cost, average 2024-2036	€/kg	25.8	12.8	21.5	9.0
blowing agent cost, average 2050	€/kg	35.4	22.4	31.1	18.6
blowing agent cost, counterfactual scenario, 2014 pre-phase-down prices	€/kg	5.0	5.0	15.0	2.5
manufacturing emission factor of blowing agent	kg/kg	30%	100%	30%	30%
leakage rate in foam product lifetime, baseline scenario	1/a	0.8%	0.8%	0.8%	0.8%
Penetration rate (defined on HFC-based niche of sector), 2024-2036 average	%	-	8.4%	91.6%	-
Penetration rate (defined on HFC-based niche of sector), 2050	%	-	-	100.0%	-

Table 139: AnaFgas sector sheet for the proportionate action scenario: Foam PU spray

Foam PU (polyurethane) spray				
considered gases / technologies:		**HFC-365mfc / HFC-245fa**	**HFO-1233zd / HFO-1336mzz**	**H2O**
GWP AR4 of blowing agent	[1]	864.8	4.5	0
product		spray foam, density 60	spray foam, density 60	spray foam, density 60
production facility annual output	m³/a	1 667	1 583	1 944
thermal conductivity	mW/ (m * K)	30	29	35
production facility insulation capacity annual output	m³/ a * ((m * K) / mW))	56	56	56
product density	kg/m³	60	60	60
blowing agent in formulation	pbw	15	15	15
total weight of formulation	pbw	245	245	245
foam product lifetime	years	50	50	50
invest cost for conversion of production line including development	€	-	22 500	22 500
economic lifetime of conversion investment	years	15	15	15
discount rate (societal view / emission reduction cost)	%	4%	4%	4%
blowing agent cost, average 2024-2036	€/kg	20.9	21.5	6.5
blowing agent cost, average 2050	€/kg	30.5	31.1	16.1
blowing agent cost, counterfactual scenario, 2014 pre-phase-down prices	€/kg	5.7	15.0	0.0
manufacturing emission factor of blowing agent	kg/kg	15%	15%	15%
leakage rate in foam product lifetime, baseline scenario	1/a	1.0%	1.0%	1.0%
Penetration rate (defined on HFC-based niche of sector), 2024-2036 average	%	-	90.0%	10.0%
Penetration rate (defined on HFC-based niche of sector), 2050	%	-	90.0%	10.0%

Table 140: AnaFgas sector sheet for the proportionate action scenario: Foam PU non-spray

Foam PU (polyurethane) non-spray			
considered gases / technologies:		**HFC-365mfc / HFC-245fa**	**HFO-1233zd / HFO-1336mzz**
GWP AR4 of blowing agent	[1]	864.8	4.5
product		Blockfoam 1 m^3, density 60	Blockfoam 1 m^3, density 60
production facility annual output	m^3/a	10 000	9 500
thermal conductivity	mW/ (m * K)	22	21
production facility insulation capacity annual output	m^3/ a * ((m * K) / mW))	455	455
product density	kg/m^3	60	60
blowing agent in formulation	pbw	12	14
total weight of formulation	pbw	242	244
foam product lifetime	years	50	50
invest cost for conversion of production line including development	€	-	480 000
economic lifetime of conversion investment	years	15	15
discount rate (societal view / emission reduction cost)	%	4%	4%
blowing agent cost, average 2024-2036	€/kg	20.9	21.5
blowing agent cost, average 2050	€/kg	30.5	31.1
blowing agent cost, counterfactual scenario, 2014 pre-phase-down prices	€/kg	5.7	15.0
manufacturing emission factor of blowing agent	kg/kg	15%	15%
leakage rate in foam product lifetime, baseline scenario	1/a	1.0%	1.0%
Penetration rate (defined on HFC-based niche of sector), 2024-2036 average	%	-	100.0%
Penetration rate (defined on HFC-based niche of sector), 2050	%	-	100.0%

Table 141: AnaFgas sector sheet for the proportionate action scenario: Electrical switchgear, medium voltage

Electrical switchgear, medium voltage				
considered gases / technologies:		**SF6**	**Air**	**Novec 5110**
GWP AR4 of insulation gas	[1]	22 800	0	1
rated voltage	kW	24	24	24
installation lifetime	years	40	40	40
invest cost hardware (first fill excluded)	€	15 000	18 000	17 250
discount rate (societal view / emission reduction cost)	%	4%	4%	4%
maintenance cost	€/a	-	-	-
insulation gas charge	kg	5	2	1
insulation gas cost first fill, average 2024-2036	€/kg	10	2	200
insulation gas cost first fill, average 2050	€/kg	10	2	200
insulation gas cost first fill, counterfactual scenario, 2014 pre-phase-down prices	€/kg	10	2	200
installation type is refilled?		no	no	no
insulation gas cost refill, average 2024-2036	€/kg	-	-	-
insulation gas cost refill, 2050	€/kg	-	-	-
insulation gas cost refill, counterfactual scenario, 2014 pre-phase-down prices	€/kg	-	-	-
leakage rate first fill / refill	kg/kg	0.9%	0.9%	0.9%
leakage rate operation	1/a	0.1%	0.1%	0.1%
technologically tolerable insulation gas loss	kg/kg	5%	5%	5%
recovery rate end of life	kg/kg	90%	90%	90%
Penetration rate in new installations, 2024-2036 average	%	61.4%	25.8%	12.9%
Penetration rate in new installations, 2050	%	5.0%	63.3%	31.7%

Table 142: AnaFgas sector sheet for the proportionate action scenario: Electrical switchgear, high voltage

Electrical switchgear, high voltage				
considered gases / technologies:		**SF6**	**Air**	**Novec 4710**
GWP AR4 of insulation gas	[1]	22 800	0	2 100
rated voltage	kW	110	110	110
installation lifetime	years	40	40	40
invest cost hardware (first fill excluded)	€	225 000	270 000	258 750
discount rate (societal view / emission reduction cost)	%	4%	4%	4%
maintenance cost	€/a	110	-	110
insulation gas charge	kg	90	36	21.6
insulation gas cost first fill, average 2024-2036	€/kg	10	2	500
insulation gas cost first fill, average 2050	€/kg	10	2	500
insulation gas cost first fill, counterfactual scenario, 2014 pre-phase-down prices	€/kg	10	2	500
installation type is refilled?		yes	yes	yes
insulation gas cost refill, average 2024-2036	€/kg	10	2	500
insulation gas cost refill, 2050	€/kg	10	2	500
insulation gas cost refill, counterfactual scenario, 2014 pre-phase-down prices	€/kg	10	2	500
leakage rate first fill / refill	kg/kg	0.9%	0.9%	0.9%
leakage rate operation	1/a	1.0%	1.0%	1.0%
technologically tolerable insulation gas loss	kg/kg	20%	20%	20%
recovery rate end of life	kg/kg	90%	90%	90%
Penetration rate in new installations, 2024-2036 average	%	61.4%	12.9%	25.8%
Penetration rate in new installations, 2050	%	5.0%	31.7%	63.3%

Annex 2.7: AnaFgas model installation parameters: sector sheets (maximum feasibility scenario)

Table 143: AnaFgas sector sheet for the maximum feasibility scenario: Domestic Refrigeration

Domestic Refrigeration			
considered gases / technologies:		**HFC 134a**	**R-600a**
GWP AR4 of refrigerant	[1]	1 430	4
refrigerating capacity	kW	0.2	0.2
electric/mechanic capacity	kW	0.13	0.12
installation lifetime	years	15	15
invest cost hardware (first fill excluded)	€	400	392
annual operating hours	h/a	7 200	7 200
final energy cost	€/kWh	0.215	0.215
discount rate (societal view / emission reduction cost)	%	4%	4%
HFC operators' cost for containment & recovery (FGR Art 3-8)	€/a	-	-
additional maintenance cost for non-HFCs	€/a	-	-
refrigerant charge	kg	0.12	0.06
refrigerant cost first fill, average 2024-2036	€/kg	109.3	10
refrigerant cost first fill, average 2050	€/kg	262.5	10
refrigerant cost first fill, counterfactual scenario, 2014 pre-phase-down prices	€/kg	5	10
installation type is refilled?		no	no
refrigerant cost refill, average 2024-2036	€/kg	-	-
refrigerant cost refill, 2050	€/kg	-	-
refrigerant cost refill, counterfactual scenario, 2014 pre-phase-down prices	€/kg	-	-
leakage rate first fill / refill	kg/kg	0.5%	0.5%
leakage rate operation	1/a	0.3%	0.3%
technologically tolerable refrigerant loss	kg/kg	20%	20%
recovery rate end of life	kg/kg	70%	70%
Penetration rate in new installations, 2024-2036 average	%	-	100.0%
Penetration rate in new installations, 2050	%	-	100.0%

Table 144: AnaFgas sector sheet for the maximum feasibility scenario: Commercial refrigeration – Hermetics

Commercial refrigeration - Hermetics				
considered gases / technologies:		**HFC 134a**	**R-600a/290-direct**	**R-454C/R-455A**
GWP AR4 of refrigerant	[1]	1 430	4	148.2
refrigerating capacity	kW	0.6	0.6	0.6
electric/mechanic capacity	kW	0.38	0.36	0.38
installation lifetime	years	10	10	10
invest cost hardware (first fill excluded)	€	1 000	980	1 020
annual operating hours	h/a	6 000	6 000	6 000
final energy cost	€/kWh	0.145	0.145	0.145
discount rate (societal view / emission reduction cost)	%	4%	4%	4%
HFC operators' cost for containment & recovery (FGR Art 3-8)	€/a	3	-	3
additional maintenance cost for non-HFCs	€/a	-	-	-
refrigerant charge	kg	0.4	0.2	0.4
refrigerant cost first fill, average 2024-2036	€/kg	109.3	10	40.8
refrigerant cost first fill, average 2050	€/kg	262.5	10	56.7
refrigerant cost first fill, counterfactual scenario, 2014 pre-phase-down prices	€/kg	5	10	30
installation type is refilled?		no	no	no
refrigerant cost refill, average 2024-2036	€/kg	-	-	-
refrigerant cost refill, 2050	€/kg	-	-	-
refrigerant cost refill, counterfactual scenario, 2014 pre-phase-down prices	€/kg	-	-	-
leakage rate first fill / refill	kg/kg	0.5%	0.5%	0.5%
leakage rate operation	1/a	1.0%	1.0%	1.0%
technologically tolerable refrigerant loss	kg/kg	20%	20%	20%
recovery rate end of life	kg/kg	61%	61%	61%
Penetration rate in new installations, 2024-2036 average	%	-	100.0%	-
Penetration rate in new installations, 2050	%	-	100.0%	-

Table 145: AnaFgas sector sheet for the maximum feasibility scenario: Commercial refrigeration - Condensing units

Commercial refrigeration - Condensing units									
considered gases / technologies:		**R-404A**	**R-134a DX**	**HC (R-290 DX)**	**R-744 (CO2)**	**HC (R-290 + secondary liquid)**	**R-448A/R-449A**	**R-513A**	**R-454C/ R-455A**
GWP AR4 of refrigerant	[1]	3 921.6	1 430	3	1	3	1 392.1	631.4	148.2
refrigerating capacity	kW	4	4	4	4	4	4	4	4
electric/mechanic capacity	kW	2.5	2.5	2.43	2.38	2.38	2.45	2.45	2.53
installation lifetime	years	12	12	12	12	12	12	12	12
invest cost hardware (first fill excluded)	€	3 800	3 800	3 990	4 560	4 560	3 800	3 800	3 876
annual operating hours	h/a	5 840	5 840	5 840	5 840	5 840	5 840	5 840	5 840
final energy cost	€/kWh	0.145	0.145	0.145	0.145	0.145	0.145	0.145	0.145
discount rate (societal view / emission reduction cost)	%	4%	4%	4%	4%	4%	4%	4%	4%
HFC operators' cost for containment & recovery (FGR Art 3-8)	€/a	77	77	-	-	-	77	77	77
additional maintenance cost for non-HFCs	€/a	-	-	55	90	55	-	-	-
refrigerant charge	kg	4	4	2	2.67	0.8	4	4	4
refrigerant cost first fill, average 2024-2036	€/kg	560	218.3	20	5	20	263	152.1	81.6
refrigerant cost first fill, average 2050	€/kg	1368.5	524.4	20	5	20	561.4	287.4	113.4
refrigerant cost first fill, counterfactual scenario, 2014 pre-phase-down prices	€/kg	10	10	20	5	20	60	60	60
installation type is refilled?		yes	yes	yes	yes	yes	yes	yes	yes
refrigerant cost refill, average 2024-2036	€/kg	560	218.3	20	5	20	263	152.1	81.6
refrigerant cost refill, 2050	€/kg	1368.5	524.4	20	5	20	561.4	287.4	113.4
refrigerant cost refill, counterfactual scenario, 2014 pre-phase-down prices	€/kg	10	10	20	5	20	60	60	60
leakage rate first fill / refill	kg/kg	1.0%	1.0%	1.0%	1.0%	1.0%	1.0%	1.0%	1.0%
leakage rate operation	1/a	6.0%	6.0%	6.0%	6.0%	6.0%	6.0%	6.0%	6.0%
technologically tolerable refrigerant loss	kg/kg	25%	25%	25%	25%	25%	25%	25%	25%
recovery rate end of life	kg/kg	71%	71%	71%	71%	71%	71%	71%	71%
Penetration rate in new installations, 2024-2036 average	%	0.5%	1.2%	55.7%	24.3%	14.5%	0.4%	0.4%	2.9%
Penetration rate in new installations, 2050	%	-	-	60.0%	25.0%	15.0%	-	-	-

Table 146: AnaFgas sector sheet for the maximum feasibility scenario: Commercial refrigeration - Central systems

Commercial refrigeration - Central systems									
considered gases / technologies:		**R-404A DX**	**R-134a DX**	**HC+CO2+ CO2 cascade**	**R-744 transcritical**	**HC+sec. liquid+CO2**	**R-448A/R-449A**	**HFC 1234ze + CO2+CO2 cascade**	**R-513A (also in cascade)**
GWP AR4 of refrigerant	[1]	3 921.6	1 430	4	1	4	1 392.1	7	631.4
refrigerating capacity	kW	100	100	100	100	100	100	100	100
electric/mechanic capacity	kW	40	40	37	37	40	39.2	38.8	39.6
installation lifetime	years	12	12	12	12	12	12	12	12
invest cost hardware (first fill excluded)	€	320 000	320 000	368 000	342 400	336 000	320 000	352 000	320 000
annual operating hours	h/a	4 380	4 380	4 380	4 380	4 380	4 380	4 380	4 380
final energy cost	€/kWh	0.145	0.145	0.145	0.145	0.145	0.145	0.145	0.145
discount rate (societal view / emission reduction cost)	%	4%	4%	4%	4%	4%	4%	4%	4%
HFC operators' cost for containment & recovery (FGR Art 3-8)	€/a	655	655	-	-	-	655	-	655
additional maintenance cost for non-HFCs	€/a	-	-	55	255	55	-	-	-
refrigerant charge	kg	230	230	57.5	230	23	230	76.67	230
refrigerant cost first fill, average 2024-2036	€/kg	560	218.3	20	5	20	263	60	152.1
refrigerant cost first fill, average 2050	€/kg	1368.5	524.4	20	5	20	561.4	60	287.4
refrigerant cost first fill, counterfactual scenario, 2014 pre-phase-down prices	€/kg	10	10	20	5	20	60	60	60
installation type is refilled?		yes	yes	yes	yes	yes	yes	yes	yes
refrigerant cost refill, average 2024-2036	€/kg	560	218.3	20	5	20	263	60	152.1
refrigerant cost refill, 2050	€/kg	1368.5	524.4	20	5	20	561.4	60	287.4
refrigerant cost refill, counterfactual scenario, 2014 pre-phase-down prices	€/kg	10	10	20	5	20	60	60	60
leakage rate first fill / refill	kg/kg	1.0%	1.0%	1.0%	1.0%	1.0%	1.0%	1.0%	1.0%
leakage rate operation	1/a	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%
technologically tolerable refrigerant loss	kg/kg	25%	25%	25%	25%	25%	25%	25%	25%
recovery rate end of life	kg/kg	71%	71%	71%	71%	71%	71%	71%	71%
Penetration rate in new installations, 2024-2036 average	%	-	0.3%	17.1%	59.1%	17.1%	0.7%	4.9%	0.7%
Penetration rate in new installations, 2050	%	-	-	17.5%	60.0%	17.5%	-	5.0%	-

Table 147: AnaFgas sector sheet for the maximum feasibility scenario: Industrial refrigeration – small

Industrial refrigeration - small						
considered gases / technologies:		**R-404A**	**R-134a**	**R-717**	**CO2 / HC**	**R-513A**
GWP AR4 of refrigerant	[1]	3 921.6	1430	0	2.5	631.4
refrigerating capacity	kW	270	270	270	270	270
electric/mechanic capacity	kW	168.75	168.75	151.88	160.31	165.38
installation lifetime	years	30	30	30	30	30
invest cost hardware (first fill excluded)	€	425 000	425 000	531 250	552 500	425 000
annual operating hours	h/a	4 500	4 500	4 500	4 500	4 500
final energy cost	€/kWh	0.095	0.095	0.095	0.095	0.095
discount rate (societal view / emission reduction cost)	%	4%	4%	4%	4%	4%
HFC operators' cost for containment & recovery (FGR Art 3-8)	€/a	1 142	1 142	-	-	1 142
additional maintenance cost for non-HFCs	€/a	-	-	1 000	55	-
refrigerant charge	kg	650	650	650	650	650
refrigerant cost first fill, average 2024-2036	€/kg	560	218.3	4	12.5	152.1
refrigerant cost first fill, average 2050	€/kg	1368.5	524.4	4	12.5	287.4
refrigerant cost first fill, counterfactual scenario, 2014 pre-phase-down prices	€/kg	10	10	4	12.5	60
installation type is refilled?		yes	yes	yes	yes	yes
refrigerant cost refill, average 2024-2036	€/kg	560	218.3	4	12.5	152.1
refrigerant cost refill, 2050	€/kg	1368.5	524.4	4	12.5	287.4
refrigerant cost refill, counterfactual scenario, 2014 pre-phase-down prices	€/kg	10	10	4	12.5	60
leakage rate first fill / refill	kg/kg	1.0%	1.0%	1.0%	1.0%	1.0%
leakage rate operation	1/a	5.4%	5.4%	5.4%	5.4%	5.4%
technologically tolerable refrigerant loss	kg/kg	30%	30%	30%	30%	30%
recovery rate end of life	kg/kg	65%	65%	65%	65%	65%
Penetration rate in new installations, 2024-2036 average	%	0.3%	0.3%	48.3%	49.3%	1.8%
Penetration rate in new installations, 2050	%	-	-	50.0%	50.0%	-

Table 148: AnaFgas sector sheet for the maximum feasibility scenario: Industrial refrigeration – large

Industrial refrigeration - large					
considered gases / technologies:		**R-404A**	**R-717**	**HFC-1234ze**	**R-513A (also as cascade + CO2)**
GWP AR4 of refrigerant	[1]	3 921.6	0	7	631.4
refrigerating capacity	kW	5 000	5 000	5 000	5 000
electric/mechanic capacity	kW	2 000	1 780	1 960	1 960
installation lifetime	years	30	30	30	30
invest cost hardware (first fill excluded)	€	6 000 000	7 800 000	6 120 000	6 000 000
annual operating hours	h/a	4 500	4 500	4 500	4 500
final energy cost	€/kWh	0.095	0.095	0.095	0.095
discount rate (societal view / emission reduction cost)	%	4%	4%	4%	4%
HFC operators' cost for containment & recovery (FGR Art 3-8)	€/a	1 285	-	-	1 285
additional maintenance cost for non-HFCs	€/a	-	2 000	-	-
refrigerant charge	kg	4 000	4 000	4 000	4 000
refrigerant cost first fill, average 2024-2036	€/kg	560	4	60	152.1
refrigerant cost first fill, average 2050	€/kg	1368.5	4	60	287.4
refrigerant cost first fill, counter-factual scenario, 2014 pre-phase-down prices	€/kg	10	4	60	60
installation type is refilled?		yes	yes	yes	yes
refrigerant cost refill, average 2024-2036	€/kg	560	4	60	152.1
refrigerant cost refill, 2050	€/kg	1368.5	4	60	287.4
refrigerant cost refill, counter-factual scenario, 2014 pre-phase-down prices	€/kg	10	4	60	60
leakage rate first fill / refill	kg/kg	1.0%	1.0%	1.0%	1.0%
leakage rate operation	1/a	4.0%	4.0%	4.0%	4.0%
technologically tolerable refrigerant loss	kg/kg	0%	0%	0%	0%
recovery rate end of life	kg/kg	70%	70%	70%	70%
Penetration rate in new installations, 2024-2036 average	%	0.1%	91.5%	8.0%	0.5%
Penetration rate in new installations, 2050	%	-	92.6%	7.4%	-

Table 149: AnaFgas sector sheet for the maximum feasibility scenario: Transport refrigeration – Vans

Transport refrigeration - Vans							
considered gases / technologies:		**HFC 134a**	**R-404A**	**R-744**	**R-452A**	**R-513A**	**R-454C/R-455A**
GWP AR4 of refrigerant	[1]	1 430	3 921.6	1	2 140.5	631.4	148.2
refrigerating capacity	kW	3	3	3	3	3	3
electric/mechanic capacity	kW	1.5	1.5	1.39	1.5	1.5	1.5
installation lifetime	years	10	10	10	10	10	10
invest cost hardware (first fill excluded)	€	3 000	3 000	3 369	3 000	3 000	3 150
annual operating hours	h/a	1 500	1 500	1 500	1 500	1 500	1 500
final energy cost	€/kWh	0.259	0.259	0.259	0.259	0.259	0.259
discount rate (societal view / emission reduction cost)	%	4%	4%	4%	4%	4%	4%
HFC operators' cost for containment & recovery (FGR Art 3-8)	€/a	77	77	-	77	77	77
additional maintenance cost for non-HFCs	€/a	-	-	55	-	-	-
refrigerant charge	kg	1.5	1.5	1.5	1.5	1.5	1.5
refrigerant cost first fill, average 2024-2036	€/kg	109.3	290.9	2.5	181.1	76	40.8
refrigerant cost first fill, average 2050	€/kg	262.5	711.2	2.5	410.5	143.7	56.7
refrigerant cost first fill, counterfactual scenario, 2014 pre-phase-down prices	€/kg	5	5	2.5	25	30	30
installation type is refilled?		yes	yes	yes	yes	yes	yes
refrigerant cost refill, average 2024-2036	€/kg	218.3	560	5	362.1	152.1	81.6
refrigerant cost refill, 2050	€/kg	524.4	1368.5	5	820.9	287.4	113.4
refrigerant cost refill, counterfactual scenario, 2014 pre-phase-down prices	€/kg	10	10	5	50	60	60
leakage rate first fill / refill	kg/kg	1.0%	1.0%	1.0%	1.0%	1.0%	1.0%
leakage rate operation	1/a	28.0%	28.0%	28.0%	28.0%	28.0%	28.0%
technologically tolerable refrigerant loss	kg/kg	25%	25%	25%	25%	25%	25%
recovery rate end of life	kg/kg	66%	66%	66%	66%	66%	66%
Penetration rate in new installations, 2024-2036 average	%	1.1%	0.3%	94.6%	0.4%	2.3%	1.3%
Penetration rate in new installations, 2050	%	-	-	100.0%	-	-	-

Table 150: AnaFgas sector sheet for the maximum feasibility scenario: Transport refrigeration - Trucks & Trailers

Transport refrigeration - Trucks & Trailers							
considered gases / technologies:		**R-404A**	**R-290 direct**	**R-744**	**R-513A**	**R-452A**	**R-454C/R-455A**
GWP AR4 of refrigerant	[1]	3 921.6	3	1	631.4	2 140.5	148.2
refrigerating capacity	kW	9	9	9	9	9	9
electric/mechanic capacity	kW	8	7.68	7.2	8	8	8
installation lifetime	years	10	10	10	10	10	10
invest cost hardware (first fill excluded)	€	15 000	16 500	17 250	15 000	15 000	15 300
annual operating hours	h/a	4 000	4 000	4 000	4 000	4 000	4 000
final energy cost	€/kWh	0.259	0.259	0.259	0.259	0.259	0.259
discount rate (societal view / emission reduction cost)	%	4%	4%	4%	4%	4%	4%
HFC operators' cost for containment & recovery (FGR Art 3-8)	€/a	74	-	-	74	74	74
additional maintenance cost for non-HFCs	€/a	-	55	90	-	-	-
refrigerant charge	kg	6.5	3.25	6.5	6.5	6.5	6.5
refrigerant cost first fill, average 2024-2036	€/kg	290.9	10	2.5	76	181.1	40.8
refrigerant cost first fill, average 2050	€/kg	711.2	10	2.5	143.7	410.5	56.7
refrigerant cost first fill, counterfactual scenario, 2014 pre-phase-down prices	€/kg	5	10	2.5	30	25	30
installation type is refilled?		yes	yes	yes	yes	yes	yes
refrigerant cost refill, average 2024-2036	€/kg	560	20	5	152.1	362.1	81.6
refrigerant cost refill, 2050	€/kg	1368.5	20	5	287.4	820.9	113.4
refrigerant cost refill, counterfactual scenario, 2014 pre-phase-down prices	€/kg	10	20	5	60	50	60
leakage rate first fill / refill	kg/kg	1.0%	1.0%	1.0%	1.0%	1.0%	1.0%
leakage rate operation	1/a	18.0%	18.0%	18.0%	18.0%	18.0%	18.0%
technologically tolerable refrigerant loss	kg/kg	25%	25%	25%	25%	25%	25%
recovery rate end of life	kg/kg	66%	66%	66%	66%	66%	66%
Penetration rate in new installations, 2024-2036 average	%	0.3%	15.2%	77.8%	3.8%	1.5%	1.3%
Penetration rate in new installations, 2050	%	-	20.0%	80.0%	-	-	-

Table 151: AnaFgas sector sheet for the maximum feasibility scenario: Transport refrigeration – Ships

Transport refrigeration - Ships				
considered gases / technologies:		**R-404A**	**NH3/CO2**	**R-452A**
GWP AR4 of refrigerant	[1]	3 921.6	0	2 140.5
refrigerating capacity	kW	990	990	990
electric/mechanic capacity	kW	468	439.92	439.92
installation lifetime	years	30	30	30
invest cost hardware (first fill excluded)	€	2 000 000	2 300 000	2 000 000
annual operating hours	h/a	5 000	5 000	5 000
final energy cost	€/kWh	0.073	0.073	0.073
discount rate (societal view / emission reduction cost)	%	4%	4%	4%
HFC operators' cost for containment & recovery (FGR Art 3-8)	€/a	108	-	108
additional maintenance cost for non-HFCs	€/a	-	1 000	-
refrigerant charge	kg	1 000	750	1 000
refrigerant cost first fill, average 2024-2036	€/kg	560	4	362.1
refrigerant cost first fill, average 2050	€/kg	1368.5	4	820.9
refrigerant cost first fill, counterfactual scenario, 2014 pre-phase-down prices	€/kg	10	4	50
installation type is refilled?		yes	yes	yes
refrigerant cost refill, average 2024-2036	€/kg	560	4	362.1
refrigerant cost refill, 2050	€/kg	1368.5	4	820.9
refrigerant cost refill, counterfactual scenario, 2014 pre-phase-down prices	€/kg	10	4	50
leakage rate first fill / refill	kg/kg	1.0%	1.0%	1.0%
leakage rate operation	1/a	40.0%	40.0%	40.0%
technologically tolerable refrigerant loss	kg/kg	25%	25%	25%
recovery rate end of life	kg/kg	54%	54%	54%
Penetration rate in new installations, 2024-2036 average	%	0.3%	98.5%	1.2%
Penetration rate in new installations, 2050	%	-	100.0%	-

Table 152: AnaFgas sector sheet for the maximum feasibility scenario: Room AC – Moveables

Room AC - Moveables			
considered gases / technologies:		**R-410A direct**	**R-290**
GWP AR4 of refrigerant	[1]	2 087.5	3
refrigerating capacity	kW	3	3
electric/mechanic capacity	kW	0.67	0.67
installation lifetime	years	10	10
invest cost hardware (first fill excluded)	€	300	294
annual operating hours	h/a	500	500
final energy cost	€/kWh	0.215	0.215
discount rate (societal view / emission reduction cost)	%	4%	4%
HFC operators' cost for containment & recovery (FGR Art 3-8)	€/a	3	-
additional maintenance cost for non-HFCs	€/a	-	-
refrigerant charge	kg	0.75	0.38
refrigerant cost first fill, average 2024-2036	€/kg	157.2	10
refrigerant cost first fill, average 2050	€/kg	380.9	10
refrigerant cost first fill, counterfactual scenario, 2014 pre-phase-down prices	€/kg	5	10
installation type is refilled?		no	no
refrigerant cost refill, average 2024-2036	€/kg	-	-
refrigerant cost refill, 2050	€/kg	-	-
refrigerant cost refill, counterfactual scenario, 2014 pre-phase-down prices	€/kg	-	-
leakage rate first fill / refill	kg/kg	0.0%	0.0%
leakage rate operation	1/a	3.0%	3.0%
technologically tolerable refrigerant loss	kg/kg	25%	25%
recovery rate end of life	kg/kg	53%	53%
Penetration rate in new installations, 2024-2036 average	%	-	100.0%
Penetration rate in new installations, 2050	%	-	100.0%

Table 153: AnaFgas sector sheet for the maximum feasibility scenario: Room AC - Single split

Room AC - Single split (includes small multi-split <12 kW & reversible air-to-air heat pumps)				
considered gases / technologies:		**R-410A direct**	**R-290**	**HFC-32**
GWP AR4 of refrigerant	[1]	2 087.5	3	675
refrigerating capacity	kW	4.5	4.5	4.5
electric/mechanic capacity	kW	1	1	1
installation lifetime	years	10	10	10
invest cost hardware (first fill ex-cluded)	€	750	803	750
annual operating hours	h/a	1 500	1 500	1 500
final energy cost	€/kWh	0.215	0.215	0.215
discount rate (societal view / emission reduction cost)	%	4%	4%	4%
HFC operators' cost for containment & recovery (FGR Art 3-8)	€/a	9	-	9
additional maintenance cost for non-HFCs	€/a	-	-	-
refrigerant charge	kg	1.5	0.75	1.2
refrigerant cost first fill, average 2024-2036	€/kg	157.2	10	59.2
refrigerant cost first fill, average 2050	€/kg	380.9	10	131.6
refrigerant cost first fill, counterfactual scenario, 2014 pre-phase-down prices	€/kg	5	10	10
installation type is refilled?		yes	yes	yes
refrigerant cost refill, average 2024-2036	€/kg	312.7	20	118.4
refrigerant cost refill, 2050	€/kg	757.6	20	263.1
refrigerant cost refill, counterfactual scenario, 2014 pre-phase-down prices	€/kg	10	20	20
leakage rate first fill / refill	kg/kg	3.5%	3.5%	3.5%
leakage rate operation	1/a	5.0%	5.0%	5.0%
technologically tolerable refrigerant loss	kg/kg	25%	25%	25%
recovery rate end of life	kg/kg	60%	60%	60%
Penetration rate in new installations, 2024-2036 average	%	0.5%	96.3%	3.3%
Penetration rate in new installations, 2050	%	-	100.0%	-

Table 154: AnaFgas sector sheet for the maximum feasibility scenario: Room AC – Rooftop

Room AC - Packaged systems (rooftop units), cooling only					
considered gases / technologies:		**R-410A direct**	**HFC-32**	**R-454C/R-455A**	**R-290**
GWP AR4 of refrigerant	[1]	2 087.5	675	148.2	3
refrigerating capacity	kW	30	30	30	30
electric/mechanic capacity	kW	15	14.85	15	14.7
installation lifetime	years	10	10	10	10
invest cost hardware (first fill excluded)	€	10 000	10 200	10 300	10 500
annual operating hours	h/a	3 000	3 000	3 000	3 000
final energy cost	€/kWh	0.145	0.145	0.145	0.145
discount rate (societal view / emission reduction cost)	%	4%	4%	4%	4%
HFC operators' cost for containment & recovery (FGR Art 3-8)	€/a	215	215	215	-
additional maintenance cost for non-HFCs	€/a	-	-	-	55
refrigerant charge	kg	10.5	8.4	10.5	5.25
refrigerant cost first fill, average 2024-2036	€/kg	312.7	118.4	81.6	20
refrigerant cost first fill, average 2050	€/kg	757.6	263.1	113.4	20
refrigerant cost first fill, counterfactual scenario, 2014 pre-phase-down prices	€/kg	10	20	60	20
installation type is refilled?		yes	yes	yes	yes
refrigerant cost refill, average 2024-2036	€/kg	312.7	118.4	81.6	20
refrigerant cost refill, 2050	€/kg	757.6	263.1	113.4	20
refrigerant cost refill, counterfactual scenario, 2014 pre-phase-down prices	€/kg	10	20	60	20
leakage rate first fill / refill	kg/kg	0.0%	0.0%	0.0%	0.0%
leakage rate operation	1/a	3.0%	3.0%	3.0%	3.0%
technologically tolerable refrigerant loss	kg/kg	25%	25%	25%	25%
recovery rate end of life	kg/kg	77%	77%	77%	77%
Penetration rate in new installations, 2024-2036 average	%	1.6%	47.3%	32.8%	18.2%
Penetration rate in new installations, 2050	%	-	5.0%	25.0%	70.0%

Table 155: AnaFgas sector sheet for the maximum feasibility scenario: Room AC – VRF

Room AC - VRF cooling only (includes Single-split >3kg VRF Multi-Split)						
considered gases / technologies:		**R-410A direct**	**HFC-32**	**R-454C/R-455A**	**R-290**	**R-290 + evap. Secondary**
GWP AR4 of refrigerant	[1]	2 087.5	675	148.2	3	3
refrigerating capacity	kW	27	27	27	27	27
electric/mechanic capacity	kW	8	8	7.84	7.76	7.6
installation lifetime	years	13	13	13	13	13
invest cost hardware (first fill excluded)	€	9 500	9 738	9 738	12 350	12 920
annual operating hours	h/a	3 000	3 000	3 000	3 000	3 000
final energy cost	€/kWh	0.145	0.145	0.145	0.145	0.145
discount rate (societal view / emission reduction cost)	%	4%	4%	4%	4%	4%
HFC operators' cost for containment & recovery (FGR Art 3-8)	€/a	226	226	226	-	-
additional maintenance cost for non-HFCs	€/a	-	-	-	55	55
refrigerant charge	kg	13.5	10.8	13.5	6.75	6.75
refrigerant cost first fill, average 2024-2036	€/kg	312.7	118.4	81.6	20	20
refrigerant cost first fill, average 2050	€/kg	757.6	263.1	113.4	20	20
refrigerant cost first fill, counterfactual scenario, 2014 pre-phase-down prices	€/kg	10	20	60	20	20
installation type is refilled?		yes	yes	yes	yes	yes
refrigerant cost refill, average 2024-2036	€/kg	312.7	118.4	81.6	20	20
refrigerant cost refill, 2050	€/kg	757.6	263.1	113.4	20	20
refrigerant cost refill, counterfactual scenario, 2014 pre-phase-down prices	€/kg	10	20	60	20	20
leakage rate first fill / refill	kg/kg	0.3%	0.3%	0.3%	0.3%	0.3%
leakage rate operation	1/a	5.6%	5.6%	5.6%	5.6%	5.6%
technologically tolerable refrigerant loss	kg/kg	25%	25%	25%	25%	25%
recovery rate end of life	kg/kg	77%	77%	77%	77%	77%
Penetration rate in new installations, 2024-2036 average	%	2.1%	39.0%	49.0%	4.9%	4.9%
Penetration rate in new installations, 2050	%	-	5.0%	65.0%	15.0%	15.0%

Table 156: AnaFgas sector sheet for the maximum feasibility scenario: Minichillers

Minichillers						
considered gases / technologies:		**R-410A**	**R-32**	**HFO-1234ze**	**R-290 direct**	**R-454C/R-455A**
GWP AR4 of refrigerant	[1]	2 087.5	675	7	3	148.2
refrigerating capacity	kW	2	2	2	2	2
electric/mechanic capacity	kW	2	1.98	2	1.94	1.98
installation lifetime	years	12	12	12	12	12
invest cost hardware (first fill excluded)	€	450	459	450	495	473
annual operating hours	h/a	1 860	1 860	1 860	1 860	1 860
final energy cost	€/kWh	0.145	0.145	0.145	0.145	0.145
discount rate (societal view / emission reduction cost)	%	4%	4%	4%	4%	4%
HFC operators' cost for containment & recovery (FGR Art 3-8)	€/a	141	141	-	-	141
additional maintenance cost for non-HFCs	€/a	-	-	-	-	-
refrigerant charge	kg	0.65	0.43	0.72	0.33	0.65
refrigerant cost first fill, average 2024-2036	€/kg	157.2	59.2	30	10	40.8
refrigerant cost first fill, average 2050	€/kg	380.9	131.6	30	10	56.7
refrigerant cost first fill, counterfactual scenario, 2014 pre-phase-down prices	€/kg	5	10	30	10	30
installation type is refilled?		yes	yes	yes	yes	yes
refrigerant cost refill, average 2024-2036	€/kg	312.7	118.4	60	20	81.6
refrigerant cost refill, 2050	€/kg	757.6	263.1	60	20	113.4
refrigerant cost refill, counterfactual scenario, 2014 pre-phase-down prices	€/kg	10	20	60	20	60
leakage rate first fill / refill	kg/kg	0.5%	0.5%	0.5%	0.5%	0.5%
leakage rate operation	1/a	2.4%	2.4%	2.4%	2.4%	2.4%
technologically tolerable refrigerant loss	kg/kg	20%	20%	20%	20%	20%
recovery rate end of life	kg/kg	78%	78%	78%	78%	78%
Penetration rate in new installations, 2024-2036 average	%	1.6%	26.9%	38.4%	16.2%	16.8%
Penetration rate in new installations, 2050	%	-	-	66.7%	33.3%	-

Table 157: AnaFgas sector sheet for the maximum feasibility scenario: Displacement chillers – small

Displacement chillers - small							
considered gases / technologies:		**R-410A**	**H2O (R-718)**	**R-32**	**HFO-1234ze**	**R-290 direct**	**R-454C/R-455A**
GWP AR4 of refrigerant	[1]	2 087.5	0	675	7	3	148.2
refrigerating capacity	kW	80	80	80	80	80	80
electric/mechanic capacity	kW	28	26.32	27.72	27.72	27.16	27.72
installation lifetime	years	15	15	15	15	15	15
invest cost hardware (first fill excluded)	€	18 000	25 200	18 900	18 360	20 700	18 900
annual operating hours	h/a	1 860	1 860	1 860	1 860	1 860	1 860
final energy cost	€/kWh	0.145	0.145	0.145	0.145	0.145	0.145
discount rate (societal view / emission reduction cost)	%	4%	4%	4%	4%	4%	4%
HFC operators' cost for containment & recovery (FGR Art 3-8)	€/a	143	-	143	-	-	143
additional maintenance cost for non-HFCs	€/a	-	-	-	-	-	-
refrigerant charge	kg	26	18	17.33	28.6	13	26
refrigerant cost first fill, average 2024-2036	€/kg	312.7	0.1	118.4	60	20	81.6
refrigerant cost first fill, average 2050	€/kg	757.6	0.4	263.1	60	20	113.4
refrigerant cost first fill, counterfactual scenario, 2014 pre-phase-down prices	€/kg	10	0	20	60	20	60
installation type is refilled?		yes	yes	yes	yes	yes	yes
refrigerant cost refill, average 2024-2036	€/kg	312.7	0.1	118.4	60	20	81.6
refrigerant cost refill, 2050	€/kg	757.6	0.4	263.1	60	20	113.4
refrigerant cost refill, counterfactual scenario, 2014 pre-phase-down prices	€/kg	10	0	20	60	20	60
leakage rate first fill / refill	kg/kg	0.5%	0.5%	0.5%	0.5%	0.5%	0.5%
leakage rate operation	1/a	2.4%	2.4%	2.4%	2.4%	2.4%	2.4%
technologically tolerable refrigerant loss	kg/kg	20%	20%	20%	20%	20%	20%
recovery rate end of life	kg/kg	78%	78%	78%	78%	78%	78%
Penetration rate in new installations, 2024-2036 average	%	1.1%	52.5%	12.7%	8.0%	22.3%	3.5%
Penetration rate in new installations, 2050	%	-	61.4%	-	7.2%	31.3%	-

Table 158: AnaFgas sector sheet for the maximum feasibility scenario: Displacement chillers – large

Displacement chillers - large								
considered gases / technologies:		**R-134a**	**R-407C**	**R-410A**	**R-717 / R-718**	**R-32**	**HFO-1234ze**	**R-454C/R-455A**
GWP AR4 of refrigerant	[1]	1 430	1 773.9	2 087.5	0	675	7	148.2
refrigerating capacity	kW	400	400	400	400	400	400	400
electric/mechanic capacity	kW	129	129	129	122.55	127.07	127.71	127.71
installation lifetime	years	15	15	15	15	15	15	15
invest cost hardware (first fill excluded)	€	70 000	70 000	70 000	87 500	73 500	73 500	73 500
annual operating hours	h/a	1 860	1 860	1 860	1 860	1 860	1 860	1 860
final energy cost	€/kWh	0.095	0.095	0.095	0.095	0.095	0.095	0.095
discount rate (societal view / emission reduction cost)	%	4%	4%	4%	4%	4%	4%	4%
HFC operators' cost for containment & recovery (FGR Art 3-8)	€/a	278	278	278	-	278	-	278
additional maintenance cost for non-HFCs	€/a	-	-	-	73	-	-	-
refrigerant charge	kg	150	150	150	75	120	150	150
refrigerant cost first fill, average 2024-2036	€/kg	218.3	262.8	312.7	4	118.4	60	81.6
refrigerant cost first fill, average 2050	€/kg	524.4	634.3	757.6	4	263.1	60	113.4
refrigerant cost first fill, counterfactual scenario, 2014 pre-phase-down prices	€/kg	10	10	10	4	20	60	60
installation type is refilled?		yes	yes	yes	yes	yes	yes	yes
refrigerant cost refill, average 2024-2036	€/kg	218.3	262.8	312.7	4	118.4	60	81.6
refrigerant cost refill, 2050	€/kg	524.4	634.3	757.6	4	263.1	60	113.4
refrigerant cost refill, counterfactual scenario, 2014 pre-phase-down prices	€/kg	10	10	10	4	20	60	60
leakage rate first fill / refill	kg/kg	0.5%	0.5%	0.5%	0.5%	0.5%	0.5%	0.5%
leakage rate operation	1/a	2.4%	2.4%	2.4%	2.4%	2.4%	2.4%	2.4%
technologically tolerable refrigerant loss	kg/kg	20%	20%	20%	20%	20%	20%	20%
recovery rate end of life	kg/kg	78%	78%	78%	78%	78%	78%	78%
Penetration rate in new installations, 2024-2036 average	%	0.3%	0.2%	0.5%	70.5%	13.6%	10.2%	4.5%
Penetration rate in new installations, 2050	%	-	-	-	89.5%	-	10.5%	-

Table 159: AnaFgas sector sheet for the maximum feasibility scenario: Centrifugal chillers

Centrifugal chillers					
considered gases / technologies:		**HFC 134a**	**HFO-1234ze**	**HFO-1233zd**	**CO2 / NH3**
GWP AR4 of refrigerant	[1]	1 430	7	4.5	0.5
refrigerating capacity	kW	1 500	1 500	1 500	1 500
electric/mechanic capacity	kW	300	297	297	270
installation lifetime	years	25	25	25	25
invest cost hardware (first fill excluded)	€	140 000	141 400	141 400	154 000
annual operating hours	h/a	3 350	3 350	3 350	3 350
final energy cost	€/kWh	0.095	0.095	0.095	0.095
discount rate (societal view / emission reduction cost)	%	4%	4%	4%	4%
HFC operators' cost for contain-ment & recovery (FGR Art 3-8)	€/a	278	-	-	-
additional maintenance cost for non-HFCs	€/a	-	-	-	-
refrigerant charge	kg	630	630	630	630
refrigerant cost first fill, average 2024-2036	€/kg	218.3	60	50	4.5
refrigerant cost first fill, average 2050	€/kg	524.4	60	50	4.5
refrigerant cost first fill, counter-factual scenario, 2014 pre-phase-down prices	€/kg	10	60	50	4.5
installation type is refilled?		yes	yes	yes	yes
refrigerant cost refill, average 2024-2036	€/kg	218.3	60	50	4.5
refrigerant cost refill, 2050	€/kg	524.4	60	50	4.5
refrigerant cost refill, counter-factual scenario, 2014 pre-phase-down prices	€/kg	10	60	50	4.5
leakage rate first fill / refill	kg/kg	0.5%	0.5%	0.5%	0.5%
leakage rate operation	1/a	2.4%	2.4%	2.4%	2.4%
technologically tolerable refrig-erant loss	kg/kg	20%	20%	20%	20%
recovery rate end of life	kg/kg	78%	78%	78%	78%
Penetration rate in new installa-tions, 2024-2036 average	%	0.7%	10.0%	10.0%	79.3%
Penetration rate in new installa-tions, 2050	%	-	10.0%	10.0%	80.0%

Table 160: AnaFgas sector sheet for the maximum feasibility scenario: Heat pumps – small

Heat pumps - small (<12 kW, excluding small reversable air/air heat pumps covered in the single split subsector)							
considered gases / technologies:		**R-134a**	**R-410A**	**R-407C**	**HCs**	**R-32**	**R-513A**
GWP AR4 of refrigerant	[1]	1 430	2 087.5	1 773.9	4	675	631.4
refrigerating capacity	kW	11	11	11	11	11	11
electric/mechanic capacity	kW	6.88	6.88	6.88	6.67	6.81	6.81
installation lifetime	years	15	15	15	15	15	15
invest cost hardware (first fill excluded)	€	8 380	8 380	8 380	8 799	8 548	8 380
annual operating hours	h/a	2 000	2 000	2 000	2 000	2 000	2 000
final energy cost	€/kWh	0.215	0.215	0.215	0.215	0.215	0.215
discount rate (societal view / emission reduction cost)	%	4%	4%	4%	4%	4%	4%
HFC operators' cost for containment & recovery (FGR Art 3-8)	€/a	6	6	6	-	6	6
additional maintenance cost for non-HFCs	€/a	-	-	-	-	-	-
refrigerant charge	kg	2.6	2.6	2.6	1.3	2.08	2.6
refrigerant cost first fill, average 2024-2036	€/kg	109.3	157.2	134.3	10	59.2	76
refrigerant cost first fill, average 2050	€/kg	262.5	380.9	324.4	10	131.6	143.7
refrigerant cost first fill, counterfactual scenario, 2014 pre-phase-down prices	€/kg	5	5	5	10	10	30
installation type is refilled?		yes	yes	yes	yes	yes	yes
refrigerant cost refill, average 2024-2036	€/kg	218.3	312.7	262.8	20	118.4	152.1
refrigerant cost refill, 2050	€/kg	524.4	757.6	634.3	20	263.1	287.4
refrigerant cost refill, counterfactual scenario, 2014 pre-phase-down prices	€/kg	10	10	10	20	20	60
leakage rate first fill / refill	kg/kg	0.5%	0.5%	0.5%	0.5%	0.5%	0.5%
leakage rate operation	1/a	3.5%	3.5%	3.5%	3.5%	3.5%	3.5%
technologically tolerable refrigerant loss	kg/kg	30%	30%	30%	30%	30%	30%
recovery rate end of life	kg/kg	59%	59%	59%	59%	59%	59%
Penetration rate in new installations, 2024-2036 average	%	0.1%	0.7%	-	97.0%	2.0%	0.2%
Penetration rate in new installations, 2050	%	-	-	-	100.0%	-	-

Table 161: AnaFgas sector sheet for the maximum feasibility scenario: Heat pumps – medium

Heat pumps - medium (12-200kW)									
considered gases / technologies:		**R-134a**	**R-410A**	**R-407C**	**HCs**	**R-32**	**R-513A**	**HFO-1234ze**	**R-454B**
GWP AR4 of refrigerant	[1]	1 430	2 087.5	1 773.9	4	675	631.4	7	466.3
refrigerating capacity	kW	110	110	110	110	110	110	110	110
electric/mechanic capacity	kW	68.75	68.75	68.75	66.69	68.06	68.75	68.06	68.75
installation lifetime	years	15	15	15	15	15	15	15	15
invest cost hardware (first fill excluded)	€	30 000	30 000	30 000	33 000	31 500	30 000	31 500	30 000
annual operating hours	h/a	2 000	2 000	2 000	2 000	2 000	2 000	2 000	2 000
final energy cost	€/kWh	0.145	0.145	0.145	0.145	0.145	0.145	0.145	0.145
discount rate (societal view / emission reduction cost)	%	4%	4%	4%	4%	4%	4%	4%	4%
HFC operators' cost for containment & recovery (FGR Art 3-8)	€/a	283	283	283	-	283	283	-	283
additional maintenance cost for non-HFCs	€/a	-	-	-	55	-	-	-	-
refrigerant charge	kg	26	26	26	13	18	20.8	26	20.8
refrigerant cost first fill, average 2024-2036	€/kg	163.8	234.9	198.6	15	88.8	114.1	45	94
refrigerant cost first fill, average 2050	€/kg	393.5	569.3	479.4	15	197.3	215.6	45	169.1
refrigerant cost first fill, counterfactual scenario, 2014 pre-phase-down prices	€/kg	7.5	7.5	7.5	15	15	45	45	43
installation type is refilled?		yes	yes	yes	yes	yes	yes	yes	yes
refrigerant cost refill, average 2024-2036	€/kg	218.3	312.7	262.8	20	118.4	152.1	60	125.4
refrigerant cost refill, 2050	€/kg	524.4	757.6	634.3	20	263.1	287.4	60	225.6
refrigerant cost refill, counterfactual scenario, 2014 pre-phase-down prices	€/kg	10	10	10	20	20	60	60	57.3
leakage rate first fill / refill	kg/kg	0.5%	0.5%	0.5%	0.5%	0.5%	0.5%	0.5%	0.5%
leakage rate operation	1/a	4.5%	4.5%	4.5%	4.5%	4.5%	4.5%	4.5%	4.5%
technologically tolerable refrigerant loss	kg/kg	30%	30%	30%	30%	30%	30%	30%	30%
recovery rate end of life	kg/kg	59%	59%	59%	59%	59%	59%	59%	59%
Penetration rate in new installations, 2024-2036 average	%	0.1%	1.2%	-	42.3%	13.4%	0.1%	30.9%	12.0%
Penetration rate in new installations, 2050	%	-	-	-	55.0%	-	-	45.0%	-

Table 162: AnaFgas sector sheet for the maximum feasibility scenario: Heat pumps – large

Heat pumps - large (>200kW, district heating & industrial)					
considered gases / technologies:		**R-134a**	**HFO-1234ze**	**CO2 (R-744)**	**NH3 / R-723**
GWP AR4 of refrigerant	[1]	1 430	7	1	0
refrigerating capacity	kW	3 173.08	3 173.08	3 173.08	3 173.08
electric/mechanic capacity	kW	1 983.17	1 963.34	1 913.76	1 884.01
installation lifetime	years	20	20	20	20
invest cost hardware (first fill excluded)	€	2 800 000	2 856 000	3 360 000	3 220 000
annual operating hours	h/a	6 000	6 000	6 000	6 000
final energy cost	€/kWh	0.095	0.095	0.095	0.095
discount rate (societal view / emission reduction cost)	%	4%	4%	4%	4%
HFC operators' cost for containment & recovery (FGR Art 3-8)	€/a	283	-	-	-
additional maintenance cost for non-HFCs	€/a	-	-	255	145
refrigerant charge	kg	750	600	500	500
refrigerant cost first fill, average 2024-2036	€/kg	218.3	60	5	4
refrigerant cost first fill, average 2050	€/kg	524.4	60	5	4
refrigerant cost first fill, counterfactual scenario, 2014 pre-phase-down prices	€/kg	10	60	5	4
installation type is refilled?		yes	yes	yes	yes
refrigerant cost refill, average 2024-2036	€/kg	218.3	60	5	4
refrigerant cost refill, 2050	€/kg	524.4	60	5	4
refrigerant cost refill, counterfactual scenario, 2014 pre-phase-down prices	€/kg	10	60	5	4
leakage rate first fill / refill	kg/kg	0.5%	0.5%	0.5%	0.5%
leakage rate operation	1/a	6.0%	6.0%	6.0%	6.0%
technologically tolerable refrigerant loss	kg/kg	30%	30%	30%	30%
recovery rate end of life	kg/kg	76%	76%	76%	76%
Penetration rate in new installations, 2024-2036 average	%	2.2%	27.8%	25.1%	44.9%
Penetration rate in new installations, 2050	%	-	30.0%	25.0%	45.0%

Table 163: AnaFgas sector sheet for the maximum feasibility scenario: Mobile AC - Passenger cars

Mobile AC - Passenger cars				
considered gases / technologies:		**R-134a**	**HFO-1234yf**	**R-744**
GWP AR4 of refrigerant	[1]	1 430	4	1
refrigerating capacity	kW	4	4	4
electric/mechanic capacity	kW	4	4	3.6
installation lifetime	years	12	12	12
invest cost hardware (first fill ex-cluded)	€	300	303	450
annual operating hours	h/a	300	300	300
final energy cost	€/kWh	0.446	0.446	0.446
discount rate (societal view / emission reduction cost)	%	4%	4%	4%
HFC operators' cost for containment & recovery (FGR Art 3-8)	€/a	-	-	-
additional maintenance cost for non-HFCs	€/a	-	-	55
refrigerant charge	kg	0.5	0.5	0.34
refrigerant cost first fill, average 2024-2036	€/kg	109.3	70	2.5
refrigerant cost first fill, average 2050	€/kg	262.5	70	2.5
refrigerant cost first fill, counterfactual scenario, 2014 pre-phase-down prices	€/kg	5	70	2.5
installation type is refilled?		yes	yes	yes
refrigerant cost refill, average 2024-2036	€/kg	218.3	140	5
refrigerant cost refill, 2050	€/kg	524.4	140	5
refrigerant cost refill, counterfactual scenario, 2014 pre-phase-down prices	€/kg	10	140	5
leakage rate first fill / refill	kg/kg	0.5%	0.5%	0.5%
leakage rate operation	1/a	10.0%	10.0%	10.0%
technologically tolerable refrigerant loss	kg/kg	40%	40%	40%
recovery rate end of life	kg/kg	50%	50%	50%
Penetration rate in new installations, 2024-2036 average	%	-	90.8%	9.2%
Penetration rate in new installations, 2050	%	-	80.0%	20.0%

Table 164: AnaFgas sector sheet for the maximum feasibility scenario: Mobile AC – Buses

Mobile AC - Buses				
considered gases / technologies:		**R-134a**	**R-744**	**R-513A**
GWP AR4 of refrigerant	[1]	1 430	1	631.4
refrigerating capacity	kW	25	25	25
electric/mechanic capacity	kW	16.7	15.87	16.7
installation lifetime	years	10	10	10
invest cost hardware (first fill excluded)	€	13 000	23 400	13 650
annual operating hours	h/a	2 000	2 000	2 000
final energy cost	€/kWh	0.259	0.259	0.259
discount rate (societal view / emission reduction cost)	%	4%	4%	4%
HFC operators' cost for containment & recovery (FGR Art 3-8)	€/a	-	-	-
additional maintenance cost for non-HFCs	€/a	-	55	-
refrigerant charge	kg	10.4	6.97	10.4
refrigerant cost first fill, average 2024-2036	€/kg	109.3	2.5	76
refrigerant cost first fill, average 2050	€/kg	262.5	2.5	143.7
refrigerant cost first fill, counterfactual scenario, 2014 pre-phase-down prices	€/kg	5	2.5	30
installation type is refilled?		yes	yes	yes
refrigerant cost refill, average 2024-2036	€/kg	218.3	5	152.1
refrigerant cost refill, 2050	€/kg	524.4	5	287.4
refrigerant cost refill, counterfactual scenario, 2014 pre-phase-down prices	€/kg	10	5	60
leakage rate first fill / refill	kg/kg	0.0%	0.0%	0.0%
leakage rate operation	1/a	15.0%	15.0%	15.0%
technologically tolerable refrigerant loss	kg/kg	40%	40%	40%
recovery rate end of life	kg/kg	63%	63%	63%
Penetration rate in new installations, 2024-2036 average	%	4.9%	73.8%	21.4%
Penetration rate in new installations, 2050	%	-	95.0%	5.0%

Table 165: AnaFgas sector sheet for the maximum feasibility scenario: Mobile AC - Trucks N1

Mobile AC - Trucks N1				
considered gases / technologies:		**R-134a**	**R-744**	**HFO-1234yf**
GWP AR4 of refrigerant	[1]	1 430	1	4
refrigerating capacity	kW	8	8	8
electric/mechanic capacity	kW	8	7.6	8
installation lifetime	years	10	10	10
invest cost hardware (first fill ex-cluded)	€	300	450	304
annual operating hours	h/a	300	300	300
final energy cost	€/kWh	0.259	0.259	0.259
discount rate (societal view / emission reduction cost)	%	4%	4%	4%
HFC operators' cost for containment & recovery (FGR Art 3-8)	€/a	-	-	-
additional maintenance cost for non-HFCs	€/a	-	55	-
refrigerant charge	kg	1	0.67	1
refrigerant cost first fill, average 2024-2036	€/kg	109.3	2.5	70
refrigerant cost first fill, average 2050	€/kg	262.5	2.5	70
refrigerant cost first fill, counterfactual scenario, 2014 pre-phase-down prices	€/kg	5	2.5	70
installation type is refilled?		yes	yes	yes
refrigerant cost refill, average 2024-2036	€/kg	218.3	5	140
refrigerant cost refill, 2050	€/kg	524.4	5	140
refrigerant cost refill, counterfactual scenario, 2014 pre-phase-down prices	€/kg	10	5	140
leakage rate first fill / refill	kg/kg	0.0%	0.0%	0.0%
leakage rate operation	1/a	10.0%	10.0%	10.0%
technologically tolerable refrigerant loss	kg/kg	40%	40%	40%
recovery rate end of life	kg/kg	13%	13%	13%
Penetration rate in new installations, 2024-2036 average	%	8.5%	6.9%	84.6%
Penetration rate in new installations, 2050	%	-	10.0%	90.0%

Table 166: AnaFgas sector sheet for the maximum feasibility scenario: Mobile AC - Trucks N2

Mobile AC - Trucks N2				
considered gases / technologies:		**R-134a**	**R-744**	**HFO-1234yf**
GWP AR4 of refrigerant	[1]	1 430	1	4
refrigerating capacity	kW	8	8	8
electric/mechanic capacity	kW	8	7.6	8
installation lifetime	years	10	10	10
invest cost hardware (first fill excluded)	€	300	450	304
annual operating hours	h/a	300	300	300
final energy cost	€/kWh	0.259	0.259	0.259
discount rate (societal view / emission reduction cost)	%	4%	4%	4%
HFC operators' cost for containment & recovery (FGR Art 3-8)	€/a	-	-	-
additional maintenance cost for non-HFCs	€/a	-	55	-
refrigerant charge	kg	1	0.67	1
refrigerant cost first fill, average 2024-2036	€/kg	109.3	2.5	70
refrigerant cost first fill, average 2050	€/kg	262.5	2.5	70
refrigerant cost first fill, counterfactual scenario, 2014 pre-phase-down prices	€/kg	5	2.5	70
installation type is refilled?		yes	yes	yes
refrigerant cost refill, average 2024-2036	€/kg	218.3	5	140
refrigerant cost refill, 2050	€/kg	524.4	5	140
refrigerant cost refill, counterfactual scenario, 2014 pre-phase-down prices	€/kg	10	5	140
leakage rate first fill / refill	kg/kg	0.0%	0.0%	0.0%
leakage rate operation	1/a	15.0%	15.0%	15.0%
technologically tolerable refrigerant loss	kg/kg	40%	40%	40%
recovery rate end of life	kg/kg	13%	13%	13%
Penetration rate in new installations, 2024-2036 average	%	12.3%	7.7%	80.0%
Penetration rate in new installations, 2050	%	-	20.0%	80.0%

Table 167: AnaFgas sector sheet for the maximum feasibility scenario: Mobile AC - Trucks N3

Mobile AC - Trucks N3				
considered gases / technologies:		**R-134a**	**R-744**	**HFO-1234yf**
GWP AR4 of refrigerant	[1]	1 430	1	4
refrigerating capacity	kW	8	8	8
electric/mechanic capacity	kW	8	7.6	8
installation lifetime	years	10	10	10
invest cost hardware (first fill excluded)	€	300	450	304
annual operating hours	h/a	300	300	300
final energy cost	€/kWh	0.259	0.259	0.259
discount rate (societal view / emission reduction cost)	%	4%	4%	4%
HFC operators' cost for containment & recovery (FGR Art 3-8)	€/a	-	-	-
additional maintenance cost for non-HFCs	€/a	-	55	-
refrigerant charge	kg	1	0.67	1
refrigerant cost first fill, average 2024-2036	€/kg	109.3	2.5	70
refrigerant cost first fill, average 2050	€/kg	262.5	2.5	70
refrigerant cost first fill, counterfactual scenario, 2014 pre-phase-down prices	€/kg	5	2.5	70
installation type is refilled?		yes	yes	yes
refrigerant cost refill, average 2024-2036	€/kg	218.3	5	140
refrigerant cost refill, 2050	€/kg	524.4	5	140
refrigerant cost refill, counterfactual scenario, 2014 pre-phase-down prices	€/kg	10	5	140
leakage rate first fill / refill	kg/kg	0.0%	0.0%	0.0%
leakage rate operation	1/a	15.0%	15.0%	15.0%
technologically tolerable refrigerant loss	kg/kg	40%	40%	40%
recovery rate end of life	kg/kg	13%	13%	13%
Penetration rate in new installations, 2024-2036 average	%	15.3%	11.2%	73.5%
Penetration rate in new installations, 2050	%	-	25.0%	75.0%

Table 168: AnaFgas sector sheet for the maximum feasibility scenario: Mobile AC - Passenger ships

Mobile AC - Passenger ships				
considered gases / technologies:		**R-134a**	**R-513A**	**Naturals**
GWP AR4 of refrigerant	[1]	1 430	631.4	0.5
refrigerating capacity	kW	975	975	975
electric/mechanic capacity	kW	180	180	162
installation lifetime	years	30	30	30
invest cost hardware (first fill excluded)	€	123 500	129 675	172 900
annual operating hours	h/a	3 000	3 000	3 000
final energy cost	€/kWh	0.073	0.073	0.073
discount rate (societal view / emission reduction cost)	%	4%	4%	4%
HFC operators' cost for containment & recovery (FGR Art 3-8)	€/a	2 039	2 039	-
additional maintenance cost for non-HFCs	€/a	-	-	-
refrigerant charge	kg	520	520	468
refrigerant cost first fill, average 2024-2036	€/kg	218.3	152.1	4.5
refrigerant cost first fill, average 2050	€/kg	524.4	287.4	4.5
refrigerant cost first fill, counterfactual scenario, 2014 pre-phase-down prices	€/kg	10	60	4.5
installation type is refilled?		yes	yes	yes
refrigerant cost refill, average 2024-2036	€/kg	218.3	152.1	4.5
refrigerant cost refill, 2050	€/kg	524.4	287.4	4.5
refrigerant cost refill, counterfactual scenario, 2014 pre-phase-down prices	€/kg	10	60	4.5
leakage rate first fill / refill	kg/kg	0.0%	0.0%	0.0%
leakage rate operation	1/a	40.0%	40.0%	40.0%
technologically tolerable refrigerant loss	kg/kg	40%	40%	40%
recovery rate end of life	kg/kg	63%	63%	63%
Penetration rate in new installations, 2024-2036 average	%	1.5%	2.3%	96.2%
Penetration rate in new installations, 2050	%	-	-	100.0%

Table 169: AnaFgas sector sheet for the maximum feasibility scenario: Mobile AC - Cargo ships

Mobile AC - Cargo ships				
considered gases / technologies:		**R-134a**	**NH3/brine**	**R-513A**
GWP AR4 of refrigerant	[1]	1 430	0	631.4
refrigerating capacity	kW	300	300	300
electric/mechanic capacity	kW	55.3	47.01	55.3
installation lifetime	years	30	30	30
invest cost hardware (first fill excluded)	€	38 000	59 660	39 900
annual operating hours	h/a	3 000	3 000	3 000
final energy cost	€/kWh	0.073	0.073	0.073
discount rate (societal view / emission reduction cost)	%	4%	4%	4%
HFC operators' cost for containment & recovery (FGR Art 3-8)	€/a	778	-	778
additional maintenance cost for non-HFCs	€/a	-	1 000	-
refrigerant charge	kg	160	52.8	160
refrigerant cost first fill, average 2024-2036	€/kg	218.3	4	152.1
refrigerant cost first fill, average 2050	€/kg	524.4	4	287.4
refrigerant cost first fill, counterfactual scenario, 2014 pre-phase-down prices	€/kg	10	4	60
installation type is refilled?		yes	yes	yes
refrigerant cost refill, average 2024-2036	€/kg	218.3	4	152.1
refrigerant cost refill, 2050	€/kg	524.4	4	287.4
refrigerant cost refill, counterfactual scenario, 2014 pre-phase-down prices	€/kg	10	4	60
leakage rate first fill / refill	kg/kg	1.0%	1.0%	1.0%
leakage rate operation	1/a	40.0%	40.0%	40.0%
technologically tolerable refrigerant loss	kg/kg	40%	40%	40%
recovery rate end of life	kg/kg	63%	63%	63%
Penetration rate in new installations, 2024-2036 average	%	2.2%	90.8%	7.0%
Penetration rate in new installations, 2050	%	-	100.0%	-

Table 170: AnaFgas sector sheet for the maximum feasibility scenario: Mobile AC – Tram

Mobile AC - Tram					
considered gases / technologies:		**R-134a**	**R-744/CO2**	**R-513A**	**HCs**
GWP AR4 of refrigerant	[1]	1 430	1	631.4	4
refrigerating capacity	kW	35	35	35	35
electric/mechanic capacity	kW	15	13.5	15	14.55
installation lifetime	years	25	25	25	25
invest cost hardware (first fill excluded)	€	25 000	30 000	25 250	27 500
annual operating hours	h/a	2 000	2000	2 000	2 000
final energy cost	€/kWh	0.08	0.08	0.08	0.08
discount rate (societal view / emission reduction cost)	%	4%	4%	4%	4%
HFC operators' cost for contain-ment & recovery (FGR Art 3-8)	€/a	2	-	2	-
additional maintenance cost for non-HFCs	€/a	-	90	-	-
refrigerant charge	kg	8	6.4	8	8
refrigerant cost first fill, average 2024-2036	€/kg	109.3	2.5	76	10
refrigerant cost first fill, average 2050	€/kg	262.5	2.5	143.7	10
refrigerant cost first fill, counter-factual scenario, 2014 pre-phase-down prices	€/kg	5	2.5	30	10
installation type is refilled?		yes	yes	yes	yes
refrigerant cost refill, average 2024-2036	€/kg	218.3	5	152.1	20
refrigerant cost refill, 2050	€/kg	524.4	5	287.4	20
refrigerant cost refill, counter-factual scenario, 2014 pre-phase-down prices	€/kg	10	5	60	20
leakage rate first fill / refill	kg/kg	0.2%	0.2%	0.2%	0.2%
leakage rate operation	1/a	7.0%	7.0%	7.0%	7.0%
technologically tolerable refrig-erant loss	kg/kg	25%	25%	25%	25%
recovery rate end of life	kg/kg	66%	66%	66%	66%
Penetration rate in new installa-tions, 2024-2036 average	%	2.0%	77.7%	4.1%	16.3%
Penetration rate in new installa-tions, 2050	%	-	50.0%	-	50.0%

Table 171: AnaFgas sector sheet for the maximum feasibility scenario: Mobile AC – Metro

Mobile AC - Metro					
considered gases / technologies:		**R-134a**	**R-744/CO2**	**R-513A**	**R-729**
GWP AR4 of refrigerant	[1]	1 430	1	631.4	0
refrigerating capacity	kW	35	35	35	35
electric/mechanic capacity	kW	15	13.5	15	15
installation lifetime	years	25	25	25	25
invest cost hardware (first fill excluded)	€	25 000	30 000	25 250	32 500
annual operating hours	h/a	2 000	2 000	2 000	2 000
final energy cost	€/kWh	0.08	0.08	0.08	0.08
discount rate (societal view / emission reduction cost)	%	4%	4%	4%	4%
HFC operators' cost for contain-ment & recovery (FGR Art 3-8)	€/a	2	-	2	-
additional maintenance cost for non-HFCs	€/a	-	90	-	-
refrigerant charge	kg	8	6.4	8	8
refrigerant cost first fill, average 2024-2036	€/kg	109.3	2.5	76	2
refrigerant cost first fill, average 2050	€/kg	262.5	2.5	143.7	2
refrigerant cost first fill, counter-factual scenario, 2014 pre-phase-down prices	€/kg	5	2.5	30	2
installation type is refilled?		yes	yes	yes	yes
refrigerant cost refill, average 2024-2036	€/kg	218.3	5	152.1	4
refrigerant cost refill, 2050	€/kg	524.4	5	287.4	4
refrigerant cost refill, counter-factual scenario, 2014 pre-phase-down prices	€/kg	10	5	60	4
leakage rate first fill / refill	kg/kg	0.2%	0.2%	0.2%	0.2%
leakage rate operation	1/a	7.0%	7.0%	7.0%	7.0%
technologically tolerable refrig-erant loss	kg/kg	25%	25%	25%	25%
recovery rate end of life	kg/kg	66%	66%	66%	66%
Penetration rate in new installa-tions, 2024-2036 average	%	2.0%	80.6%	2.7%	14.7%
Penetration rate in new installa-tions, 2050	%	-	70.0%	-	30.0%

Table 172: AnaFgas sector sheet for the maximum feasibility scenario: Mobile AC – Train

Mobile AC - Train						
considered gases / technologies:		**R-134a**	**R-407C**	**R-744 / HCs**	**R-513A**	**R-729**
GWP AR4 of refrigerant	[1]	1 430	1 773.9	2.5	631.4	0
refrigerating capacity	kW	35	35	35	35	35
electric/mechanic capacity	kW	15	15	13.5	15	13.5
installation lifetime	years	25	25	25	25	25
invest cost hardware (first fill excluded)	€	25 000	25 000	30 000	25 250	50 000
annual operating hours	h/a	2 000	2 000	2 000	2 000	2 000
final energy cost	€/kWh	0.08	0.08	0.08	0.08	0.08
discount rate (societal view / emission reduction cost)	%	4%	4%	4%	4%	4%
HFC operators' cost for containment & recovery (FGR Art 3-8)	€/a	2	2	-	2	-
additional maintenance cost for non-HFCs	€/a	-	-	-	-	-
refrigerant charge	kg	8	8	8	8	8
refrigerant cost first fill, average 2024-2036	€/kg	109.3	134.3	6.3	76	2
refrigerant cost first fill, average 2050	€/kg	262.5	324.4	6.3	143.7	2
refrigerant cost first fill, counterfactual scenario, 2014 pre-phase-down prices	€/kg	5	5	6.3	30	2
installation type is refilled?		yes	yes	yes	yes	yes
refrigerant cost refill, average 2024-2036	€/kg	218.3	262.8	12.5	152.1	4
refrigerant cost refill, 2050	€/kg	524.4	634.3	12.5	287.4	4
refrigerant cost refill, counterfactual scenario, 2014 pre-phase-down prices	€/kg	10	10	12.5	60	4
leakage rate first fill / refill	kg/kg	0.2%	0.2%	0.2%	0.2%	0.2%
leakage rate operation	1/a	7.0%	7.0%	7.0%	7.0%	7.0%
technologically tolerable refrigerant loss	kg/kg	25%	25%	25%	25%	25%
recovery rate end of life	kg/kg	66%	66%	66%	66%	66%
Penetration rate in new installations, 2024-2036 average	%	1.7%	-	56.6%	4.1%	37.6%
Penetration rate in new installations, 2050	%	-	-	50.0%	-	50.0%

Table 173: AnaFgas sector sheet for the maximum feasibility scenario: Aerosols – technical

Aerosols - technical				
considered gases / technologies:		**HFC-134a**	**HFC-152a**	**HFC-1234ze**
GWP AR4 of propellant	[1]	1 430	124	7
preparation / canning cost (propellant excluded) per kg propellant	€/kg	20	20	20
propellant charge	kg	0.15	0.15	0.15
propellant cost first fill, average 2024-2036	€/kg	109.3	14.0	15.0
propellant cost first fill, 2050	€/kg	262.5	27.3	15.0
propellant cost first fill, counterfactual scenario, 2014 pre-phase-down prices	€/kg	5.0	5.0	15.0
emission rate on application	kg/kg	100%	100%	100%
Penetration rate (defined on HFC-based niche of sector), 2024-2036 average	%	-	8.7%	91.3%
Penetration rate (defined on HFC-based niche of sector), 2050	%	-	-	100.0%

Table 174: AnaFgas sector sheet for the maximum feasibility scenario: Aerosols – MDIs

Aerosols - MDIs					
considered gases / technologies:		**HFC-134a**	**HFC-227ea**	**HFC-1234ze**	**HFC-152a**
GWP AR4 of propellant	[1]	1 430	3 220	7	124
preparation / canning cost (propellant excluded) per kg propellant	€/kg	706	706	706	706
propellant charge	kg	0.005	0.005	0.005	0.005
propellant cost first fill, average 2024-2036	€/kg	112.3	242.8	24.0	17.0
propellant cost first fill, 2050	€/kg	265.5	587.9	24.0	30.3
propellant cost first fill, counterfactual scenario, 2014 pre-phase-down prices	€/kg	8.0	8.0	24.0	8.0
emission rate on application	kg/kg	100%	100%	100%	100%
Penetration rate (defined on HFC-based niche of sector), 2024-2036 average	%	46.5%	4.0%	2.7%	46.8%
Penetration rate (defined on HFC-based niche of sector), 2050	%	5.0%	2.0%	43.0%	50.0%

Table 175: AnaFgas sector sheet for the maximum feasibility scenario: Fire extinguishers

Fire extinguishers							
considered gases / technologies:		**HFC-227ea**	**HFC-23**	**HFC-125**	**HFC-236fa**	**HFC-134a**	**low-GWP alterna-tives (FK-5-1-12, in-ert gases)**
GWP AR4 of suppression agent	[1]	3 220	14 800	3 500	9 810	1 430	0.5
room size	m³	200	200	200	200	200	200
required gas concentration (for suppression of class C hazards (energized electrical equipment)	m³ / m³	5.8%	17.4%	9.0%	8.6%	15.3%	21.3%
molar mass of suppression agent	g/mol	170	70	120	152	102	175
molar volume at room te-marature	l/mol	24.47	24.47	24.47	24.47	24.47	24.47
installed gas quantity	kg	80.6	99.6	88.3	106.8	127.6	303.9
installation lifetime	years	20	20	20	20	20	20
invest cost hardware (first fill excluded)	€	14 000	11 500	14 000	14 000	14 000	14 000
discount rate (societal view / emission reduction cost)	%	4%	4%	4%	4%	4%	4%
HFC operators' cost for con-tainment & recovery (FGR Art 3-8)	€/a	117	117	117	117	117	-
additional maintenance cost for non-HFCs	€/a	-	-	-	-	-	-
suppression agent cost first fill, average 2024-2036	€/kg	248.8	1093.1	269.2	729.2	118.3	11
suppression agent cost first fill, 2050	€/kg	593.9	2679.2	644.3	1780.6	271.5	11
suppression agent cost first fill, counterfactual scenario, 2014 pre-phase-down prices	€/kg	14	14	14	14	14	11
installation type is refilled?		yes	yes	yes	yes	yes	yes
suppression agent cost refill, average 2024-2036	€/kg	248.8	1093.1	267.6	729.2	118.3	11
suppression agent cost refill, 2050	€/kg	593.9	2679.2	640.3	1780.6	271.5	11
suppression agent cost refill, counterfactual scenario, 2014 pre-phase-down prices	€/kg	14	14	14	14	14	11
leakage rate first fill / refill	kg/kg	0.1%	0.1%	0.1%	0.1%	0.1%	0.1%
leakage rate operation	1/a	2.0%	2.0%	2.0%	5.0%	4.0%	2.0%
recovery rate end of life	kg/kg	91%	91%	91%	91%	91%	91%
Penetration rate in new instal-lations (in HFC-based niche of sector), 2024-2036 aver-age	%	-	-	-	-	-	100.0%
Penetration rate in new instal-lations (in HFC-based niche of sector), 2050	%	-	-	-	-	-	100.0%

Table 176: AnaFgas sector sheet for the maximum feasibility scenario: Solvents

Solvents					
considered gases / technologies:		**HFC-43-10mee**	**HFC-365mfc**	**HFO-1233zd**	**Novec 7100**
GWP AR4 of solvent	[1]	1 640	794	4.5	297
preparation / canning cost (sol-vent excluded) per kg solvent	€/kg	20	20	20	20
solvent charge	kg	0.15	0.15	0.15	0.15
propellant cost first fill, average 2024-2036	€/kg	124.6	63.9	25.0	25.0
propellant cost first fill, 2050	€/kg	300.3	149.0	25.0	25.0
propellant cost first fill, counter-factual scenario, 2014 pre-phase-down prices	€/kg	5.0	6.0	25.0	25.0
emission rate on application	kg/kg	100%	100%	100%	100%
Penetration rate (defined on HFC-based niche of sector), 2024-2036 average	%	2.8%	0.1%	72.8%	24.3%
Penetration rate (defined on HFC-based niche of sector), 2050	%	-	-	73.7%	26.3%

Table 177: AnaFgas sector sheet for the maximum feasibility scenario: Foam OCF

Foam OCF (one component foam)			
considered gases / technologies:		**HFC-134a**	**HFO-1234ze**
GWP AR4 of blowing agent	[1]	1 430	7
product		OCF cans, 660g, hereof 110g propellant	OCF cans, 660g, hereof 110g propellant
production facility annual output	m³/a	10 000	10 000
thermal conductivity	mW/ (m * K)	30	30
production facility insulation capacity annual output	m³/ a * ((m * K) / mW))	333	333
product density	kg/m³	42	42
blowing agent in formulation	pbw	110	110
total weight of formulation	pbw	660	660
foam product lifetime	years	50	50
invest cost for conversion of production line including development	€	-	22 500
economic lifetime of conversion investment	years	15	15
discount rate (societal view / emission reduction cost)	%	4%	4%
blowing agent cost, average 2024-2036	€/kg	26.6	22.3
blowing agent cost, average 2050	€/kg	37.3	33.0
blowing agent cost, counterfactual scenario, 2014 pre-phase-down prices	€/kg	5.0	15.0
manufacturing emission factor of blowing agent	kg/kg	15%	15%
leakage rate in foam product lifetime, baseline scenario	1/a	1.0%	1.0%
Penetration rate (defined on HFC-based niche of sector), 2024-2036 average	%	-	100.0%
Penetration rate (defined on HFC-based niche of sector), 2050	%	-	100.0%

Table 178: AnaFgas sector sheet for the maximum feasibility scenario: Foam XPS

Foam XPS (extruded polystyrene)					
considered gases / technologies:		**XPS / HFC-134a**	**XPS / HFC-152a**	**XPS / HFO-1234ze**	**XPS / CO2**
GWP AR4 of blowing agent	[1]	1 430	124	7	1
product		XPS-134a Panel 1200 x 600 x 1400 mm, density 35	XPS Panel 1200 x 600 x 50 mm, density 35	XPS Panel 1200 x 600 x 1400 mm, density 40	XPS Panel 1200 x 600 x 50 mm, density 35
production facility annual output	m³/a	75 000	87 931	75 000	87 931
thermal conductivity	mW/ (m * K)	29	34	29	34
production facility insulation capacity annual output	m³/ a * ((m * K) / mW))	2 586	2 586	2 586	2 586
product density	kg/m³	35	35	40	35
blowing agent in formulation	pbw	7	10	8	10
total weight of formulation	pbw	100	90	100	90
foam product lifetime	years	50	50	50	50
invest cost for conversion of production line including development	€	-	-	1 000 000	1 500 000
economic lifetime of conversion investment	years	15	15	15	15
discount rate (societal view / emission reduction cost)	%	4%	4%	4%	4%
blowing agent cost, average 2024-2036	€/kg	26.6	13.5	22.3	9.8
blowing agent cost, average 2050	€/kg	37.3	24.2	33.0	20.5
blowing agent cost, counterfactual scenario, 2014 pre-phase-down prices	€/kg	5.0	5.0	15.0	2.5
manufacturing emission factor of blowing agent	kg/kg	30%	100%	30%	30%
leakage rate in foam product lifetime, baseline scenario	1/a	0.8%	0.8%	0.8%	0.8%
Penetration rate (defined on HFC-based niche of sector), 2024-2036 average	%	-	8.4%	91.6%	-
Penetration rate (defined on HFC-based niche of sector), 2050	%	-	-	100.0%	-

Table 179: AnaFgas sector sheet for the maximum feasibility scenario: Foam PU spray

Foam PU (polyurethane) spray				
considered gases / technologies:		**HFC-365mfc / HFC-245fa**	**HFO-1233zd / HFO-1336mzz**	**H2O**
GWP AR4 of blowing agent	[1]	864.8	4.5	0
product		spray foam, density 60	spray foam, density 60	spray foam, density 60
production facility annual output	m³/a	1 667	1 583	1 944
thermal conductivity	mW/ (m * K)	30	29	35
production facility insulation capacity annual output	m³/ a * ((m * K) / mW))	56	56	56
product density	kg/m³	60	60	60
blowing agent in formulation	pbw	15	15	15
total weight of formulation	pbw	245	245	245
foam product lifetime	years	50	50	50
invest cost for conversion of production line including development	€	-	22 500	22 500
economic lifetime of conversion investment	years	15	15	15
discount rate (societal view / emission reduction cost)	%	4%	4%	4%
blowing agent cost, average 2024-2036	€/kg	21.6	22.3	7.3
blowing agent cost, average 2050	€/kg	32.4	33.0	18.0
blowing agent cost, counterfactual scenario, 2014 pre-phase-down prices	€/kg	5.7	15.0	0.0
manufacturing emission factor of blowing agent	kg/kg	15%	15%	15%
leakage rate in foam product lifetime, baseline scenario	1/a	1.0%	1.0%	1.0%
Penetration rate (defined on HFC-based niche of sector), 2024-2036 average	%	-	90.0%	10.0%
Penetration rate (defined on HFC-based niche of sector), 2050	%	-	90.0%	10.0%

Table 180: AnaFgas sector sheet for the maximum feasibility scenario: Foam PU non-spray

Foam PU (polyurethane) non-spray			
considered gases / technologies:		**HFC-365mfc / HFC-245fa**	**HFO-1233zd / HFO-1336mzz**
GWP AR4 of blowing agent	[1]	864.8	4.5
product		Blockfoam 1 m^3, density 60	Blockfoam 1 m^3, density 60
production facility annual output	m^3/a	10 000	9 500
thermal conductivity	mW/ (m * K)	22	21
production facility insulation capacity annual output	m^3/ a * ((m * K) / mW))	455	455
product density	kg/m^3	60	60
blowing agent in formulation	pbw	12	14
total weight of formulation	pbw	242	244
foam product lifetime	years	50	50
invest cost for conversion of production line including development	€	-	480 000
economic lifetime of conversion investment	years	15	15
discount rate (societal view / emission reduction cost)	%	4%	4%
blowing agent cost, average 2024-2036	€/kg	21.6	22.3
blowing agent cost, average 2050	€/kg	32.4	33.0
blowing agent cost, counterfactual scenario, 2014 pre-phase-down prices	€/kg	5.7	15.0
manufacturing emission factor of blowing agent	kg/kg	15%	15%
leakage rate in foam product lifetime, baseline scenario	1/a	1.0%	1.0%
Penetration rate (defined on HFC-based niche of sector), 2024-2036 average	%	-	100.0%
Penetration rate (defined on HFC-based niche of sector), 2050	%	-	100.0%

Table 181: AnaFgas sector sheet for the maximum feasibility scenario: Electrical switchgear, medium voltage

Electrical switchgear, medium voltage				
considered gases / technologies:		**SF6**	**Air**	**Novec 5110**
GWP AR4 of insulation gas	[1]	22 800	0	1
rated voltage	kW	24	24	24
installation lifetime	years	40	40	40
invest cost hardware (first fill excluded)	€	15 000	18 000	17 250
discount rate (societal view / emission reduction cost)	%	4%	4%	4%
maintenance cost	€/a	-	-	-
insulation gas charge	kg	5	2	1
insulation gas cost first fill, average 2024-2036	€/kg	10	2	200
insulation gas cost first fill, average 2050	€/kg	10	2	200
insulation gas cost first fill, counterfactual scenario, 2014 pre-phase-down prices	€/kg	10	2	200
installation type is refilled?		no	no	no
insulation gas cost refill, average 2024-2036	€/kg	-	-	-
insulation gas cost refill, 2050	€/kg	-	-	-
insulation gas cost refill, counterfactual scenario, 2014 pre-phase-down prices	€/kg	-	-	-
leakage rate first fill / refill	kg/kg	0.9%	0.9%	0.9%
leakage rate operation	1/a	0.1%	0.1%	0.1%
technologically tolerable insulation gas loss	kg/kg	5%	5%	5%
recovery rate end of life	kg/kg	90%	90%	90%
Penetration rate in new installations, 2024-2036 average	%	61.4%	25.8%	12.9%
Penetration rate in new installations, 2050	%	5.0%	63.3%	31.7%

Table 182: AnaFgas sector sheet for the maximum feasibility scenario: Electrical switchgear, high voltage

Electrical switchgear, high voltage				
considered gases / technologies:		**SF6**	**Air**	**Novec 4710**
GWP AR4 of insulation gas	[1]	22 800	0	2 100
rated voltage	kW	110	110	110
installation lifetime	years	40	40	40
invest cost hardware (first fill excluded)	€	225 000	270 000	258 750
discount rate (societal view / emission reduction cost)	%	4%	4%	4%
maintenance cost	€/a	110	-	110
insulation gas charge	kg	90	36	21.6
insulation gas cost first fill, average 2024-2036	€/kg	10	2	500
insulation gas cost first fill, average 2050	€/kg	10	2	500
insulation gas cost first fill, counterfactual scenario, 2014 pre-phase-down prices	€/kg	10	2	500
installation type is refilled?		yes	yes	yes
insulation gas cost refill, average 2024-2036	€/kg	10	2	500
insulation gas cost refill, 2050	€/kg	10	2	500
insulation gas cost refill, counterfactual scenario, 2014 pre-phase-down prices	€/kg	10	2	500
leakage rate first fill / refill	kg/kg	0.9%	0.9%	0.9%
leakage rate operation	1/a	1.0%	1.0%	1.0%
technologically tolerable insulation gas loss	kg/kg	20%	20%	20%
recovery rate end of life	kg/kg	90%	90%	90%
Penetration rate in new installations, 2024-2036 average	%	61.4%	12.9%	25.8%
Penetration rate in new installations, 2050	%	5.0%	31.7%	63.3%

Annex 3: AnaFgas Cost Modelling results

Annex 3.1: Equipment operators' additional compliance cost at sub-sector level

Table 183: MP alignment scenario: Equipment operators' additional compliance cost, 2024 – 2036 average (costs difference to the baseline)

Sector	MP alignment scenario 2024-2036			
	total compliance cost vs baseline		thereof: additional cost of HFC price increase	thereof: cost of technological change (= net compliance cost)
	Mio EUR/a	% of baseline totex	Mio EUR/a	Mio EUR/a
Domestic Refrigeration	0.0	0.0%	0.0	0.0
Commercial refrigeration - Hermetics	0.0	0.0%	0.0	0.0
Commercial refrigeration - Condensing units	25.5	0.3%	24.5	0.9
Commercial refrigeration - Central systems	-33.2	-0.4%	-13.8	-19.3
Industrial refrigeration - small	-10.5	-0.4%	-4.7	-5.8
Industrial refrigeration - large	-8.7	-0.2%	-8.7	0.0
Transport refrigeration - Vans	-0.9	-0.2%	-0.9	0.0
Transport refrigeration - Trucks & Trailers	-4.1	-0.1%	-4.1	0.0
Transport refrigeration - Ships	-0.9	-0.5%	-0.9	0.0
Room AC - Moveables	0.0	0.0%	0.0	0.0
Room AC - Single split	12.5	0.1%	4.1	8.4
Room AC - Rooftop	1.7	0.0%	9.1	-7.3
Room AC - VRF	5.5	0.1%	18.1	-12.6
Minichillers	2.6	0.4%	0.3	2.4
Displacement chillers - small	2.0	0.1%	3.8	-1.8
Displacement chillers - large	12.3	0.2%	23.2	-10.9
Centrifugal chillers	-0.7	-0.1%	-0.7	0.0
Heat pumps - small	50.2	0.1%	15.4	34.8
Heat pumps - medium	34.0	0.3%	20.8	13.2
Heat pumps - large	-1.8	0.0%	-1.8	0.0
Mobile AC - Passenger cars	-11.9	-0.1%	-11.9	0.0
Mobile AC - Buses	-6.7	-0.1%	-6.7	0.0
Mobile AC - Trucks N1	-12.4	-0.2%	-12.4	0.0
Mobile AC - Trucks N2	-2.5	-0.3%	-2.5	0.0
Mobile AC - Trucks N3	-9.4	-0.3%	-9.4	0.0
Mobile AC - Passenger ships	-7.1	-3.4%	-7.1	0.0
Mobile AC - Cargo ships	-4.6	-3.5%	-4.6	0.0
Mobile AC - Tram	-0.2	-0.1%	-0.2	0.0
Mobile AC - Metro	0.0	-0.1%	0.0	0.0
Mobile AC - Train	-0.5	-0.1%	-0.5	0.0

Sector	MP alignment scenario 2024-2036			
	total compliance cost vs baseline		thereof: additional cost of HFC price increase	thereof: cost of technological change (= net compliance cost)
	Mio EUR/a	% of baseline totex	Mio EUR/a	Mio EUR/a
Aerosols - technical	-0.1	0.0%	-0.1	0.0
Aerosols - MDIs	186.6	0.0%	186.6	0.0
Fire extinguishers	-4.9	-2.3%	-4.9	0.0
Solvents	-0.2	-2.5%	-0.2	0.0
Foam OCF	0.0	0.0%	0.0	0.0
Foam XPS	-0.1	0.0%	-0.1	0.0
Foam PU spray	0.0	0.0%	0.0	0.0
Foam PU non-spray	0.0	0.0%	0.0	0.0
Switchgear MV	0.0	0.0%	0.0	0.0
Switchgear HV	0.0	0.0%	0.0	0.0
Total	**211.7**	**0.0%**	**209.8**	**1.9**

Table 184: MP alignment scenario: Equipment operators' additional compliance cost, 2050 (costs difference to the baseline)

Sector	MP alignment scenario 2050			
	total compliance cost vs baseline		thereof: additional cost of HFC price increase	thereof: cost of technological change (= net compliance cost)
	Mio EUR/a	% of baseline totex	Mio EUR/a	Mio EUR/a
Domestic Refrigeration	0.0	0.0%	0.0	0.0
Commercial refrigeration - Hermetics	0.0	0.0%	0.0	0.0
Commercial refrigeration - Condensing units	-20.0	-0.2%	4.9	-24.9
Commercial refrigeration - Central systems	-132.3	-1.6%	-53.9	-78.4
Industrial refrigeration - small	3.4	0.1%	4.2	-0.7
Industrial refrigeration - large	0.5	0.0%	0.5	0.0
Transport refrigeration - Vans	0.1	0.0%	0.1	0.0
Transport refrigeration - Trucks & Trailers	1.7	0.0%	1.7	0.0
Transport refrigeration - Ships	0.8	0.7%	0.8	0.0
Room AC - Moveables	0.0	0.0%	0.0	0.0
Room AC - Single split	-262.3	-1.0%	-171.3	-91.0
Room AC - Rooftop	-15.9	-0.1%	16.3	-32.2
Room AC - VRF	17.2	0.1%	30.1	-12.9
Minichillers	-2.8	-0.8%	0.2	-3.0
Displacement chillers - small	-1.2	-0.1%	1.2	-2.5
Displacement chillers - large	0.7	0.0%	10.5	-9.8
Centrifugal chillers	0.0	0.0%	0.0	0.0
Heat pumps - small	-85.9	-0.1%	-9.2	-76.7
Heat pumps - medium	-139.4	-0.7%	-15.4	-124.0
Heat pumps - large	0.0	0.0%	0.0	0.0
Mobile AC - Passenger cars	22.6	2.1%	22.6	0.0
Mobile AC - Buses	11.1	0.2%	11.1	0.0
Mobile AC - Trucks N1	24.8	0.3%	24.8	0.0
Mobile AC - Trucks N2	5.0	0.6%	5.0	0.0
Mobile AC - Trucks N3	19.7	0.7%	19.7	0.0
Mobile AC - Passenger ships	5.6	3.1%	5.6	0.0
Mobile AC - Cargo ships	3.3	3.0%	3.3	0.0
Mobile AC - Tram	0.1	0.1%	0.1	0.0
Mobile AC - Metro	0.1	0.3%	0.1	0.0
Mobile AC - Train	0.8	0.3%	0.8	0.0
Aerosols - technical	0.1	0.1%	0.1	0.0
Aerosols - MDIs	185.7	0.0%	185.7	0.0
Fire extinguishers	14.6	6.2%	14.6	0.0
Solvents	0.4	5.1%	0.4	0.0

Sector	MP alignment scenario 2050			
	total compliance cost vs baseline		thereof: additional cost of HFC price increase	thereof: cost of technological change (= net compliance cost)
	Mio EUR/a	% of baseline totex	Mio EUR/a	Mio EUR/a
Foam OCF	0.0	0.0%	0.0	0.0
Foam XPS	0.0	0.0%	0.0	0.0
Foam PU spray	0.0	0.0%	0.0	0.0
Foam PU non-spray	0.0	0.0%	0.0	0.0
Switchgear MV	0.0	0.0%	0.0	0.0
Switchgear HV	0.0	0.0%	0.0	0.0
Total	**-341.4**	**0.0%**	**114.6**	**-456.1**

Table 185: Proportionate action scenario: Equipment operators' additional compliance cost, 2024 – 2036 average (costs difference to the baseline)

Sector	proportionate action scenario 2024-2036			
	total compliance cost vs baseline		thereof: additional cost of HFC price increase	thereof: cost of technological change (= net compliance cost)
	Mio EUR/a	% of baseline totex	Mio EUR/a	Mio EUR/a
Domestic Refrigeration	0.0	0.0%	0.0	0.0
Commercial refrigeration - Hermetics	-2.8	-0.1%	-0.2	-2.6
Commercial refrigeration - Condensing units	3.6	0.0%	22.2	-18.7
Commercial refrigeration - Central systems	53.0	0.6%	75.4	-22.4
Industrial refrigeration - small	81.9	3.2%	80.8	1.1
Industrial refrigeration - large	54.0	1.2%	42.8	11.2
Transport refrigeration - Vans	-2.1	-0.4%	0.2	-2.3
Transport refrigeration - Trucks & Trailers	-27.1	-0.5%	6.7	-33.7
Transport refrigeration - Ships	2.1	1.2%	2.2	-0.1
Room AC - Moveables	0.0	0.0%	0.0	0.0
Room AC - Single split	-271.7	-1.1%	-200.7	-71.0
Room AC - Rooftop	7.2	0.0%	-26.0	33.2
Room AC - VRF	27.7	0.3%	-34.2	61.9
Minichillers	-4.1	-0.7%	0.0	-4.1
Displacement chillers - small	3.8	0.3%	-0.9	4.7
Displacement chillers - large	11.0	0.2%	-10.4	21.4
Centrifugal chillers	2.3	0.3%	4.3	-1.9
Heat pumps - small	-118.1	-0.3%	-15.7	-102.4
Heat pumps - medium	-24.0	-0.2%	-3.9	-20.1
Heat pumps - large	1.3	0.0%	5.6	-4.3
Mobile AC - Passenger cars	80.7	0.7%	80.7	0.0
Mobile AC - Buses	64.5	1.2%	23.2	41.3
Mobile AC - Trucks N1	69.4	1.0%	33.0	36.4
Mobile AC - Trucks N2	12.0	1.4%	3.9	8.1
Mobile AC - Trucks N3	58.9	2.1%	19.8	39.1
Mobile AC - Passenger ships	30.9	14.9%	34.6	-3.6
Mobile AC - Cargo ships	18.7	14.4%	20.7	-1.9
Mobile AC - Tram	3.5	2.4%	0.4	3.1
Mobile AC - Metro	0.9	2.9%	0.1	0.8
Mobile AC - Train	-11.7	-3.5%	2.3	-14.1
Aerosols - technical	0.4	0.2%	-0.2	0.6
Aerosols - MDIs	209.5	0.0%	207.5	2.0
Fire extinguishers	36.4	17.1%	36.4	0.0
Solvents	-0.9	-11.9%	-1.5	0.5

Sector	proportionate action scenario 2024-2036			
	total compliance cost vs baseline		thereof: additional cost of HFC price increase	thereof: cost of technological change (= net compliance cost)
	Mio EUR/a	% of baseline totex	Mio EUR/a	Mio EUR/a
Foam OCF	0.0	0.0%	0.0	0.0
Foam XPS	0.3	0.2%	0.3	0.0
Foam PU spray	0.0	0.0%	0.0	0.0
Foam PU non-spray	0.0	0.0%	0.0	0.0
Switchgear MV	26.2	3.5%	0.0	26.2
Switchgear HV	23.1	3.7%	0.0	23.1
Total	**420.8**	**0.1%**	**409.4**	**11.5**

Table 186: Proportionate action scenario: Equipment operators' additional compliance cost, 2050 (costs difference to the baseline)

Sector	proportionate action scenario 2050			
	total compliance cost vs baseline		thereof: additional cost of HFC price increase	thereof: cost of technological change (= net compliance cost)
	Mio EUR/a	% of baseline totex	Mio EUR/a	Mio EUR/a
Domestic Refrigeration	0.0	0.0%	0.0	0.0
Commercial refrigeration - Hermetics	0.0	0.0%	0.0	0.0
Commercial refrigeration - Condensing units	-137.7	-1.7%	-2.7	-135.0
Commercial refrigeration - Central systems	-134.0	-1.6%	-54.4	-79.6
Industrial refrigeration - small	10.5	0.4%	19.8	-9.3
Industrial refrigeration - large	-9.9	-0.4%	2.4	-12.4
Transport refrigeration - Vans	-2.1	-0.3%	0.4	-2.5
Transport refrigeration - Trucks & Trailers	-15.9	-0.2%	7.2	-23.1
Transport refrigeration - Ships	5.1	4.6%	5.4	-0.3
Room AC - Moveables	0.0	0.0%	0.0	0.0
Room AC - Single split	-512.6	-2.0%	-286.9	-225.7
Room AC - Rooftop	-209.9	-1.4%	-27.5	-182.4
Room AC - VRF	21.8	0.1%	27.2	-5.4
Minichillers	-41.4	-12.4%	-0.7	-40.8
Displacement chillers - small	-10.4	-0.7%	-5.0	-5.4
Displacement chillers - large	-64.2	-1.1%	-45.4	-18.9
Centrifugal chillers	-7.9	-1.0%	0.0	-7.9
Heat pumps - small	-456.6	-0.4%	-74.4	-382.2
Heat pumps - medium	-373.2	-1.8%	-107.8	-265.4
Heat pumps - large	0.0	0.0%	0.0	0.0
Mobile AC - Passenger cars	278.6	26.1%	278.6	0.0
Mobile AC - Buses	104.6	2.0%	90.5	14.1
Mobile AC - Trucks N1	147.6	2.0%	81.1	66.5
Mobile AC - Trucks N2	10.4	1.3%	-11.6	22.0
Mobile AC - Trucks N3	72.3	2.5%	-42.9	115.2
Mobile AC - Passenger ships	-14.0	-7.8%	7.5	-21.5
Mobile AC - Cargo ships	-7.8	-7.0%	4.4	-12.2
Mobile AC - Tram	-0.4	-0.3%	-0.3	-0.1
Mobile AC - Metro	0.7	3.1%	0.4	0.3
Mobile AC - Train	-11.2	-3.5%	7.6	-18.7
Aerosols - technical	0.6	0.2%	-0.6	1.1
Aerosols - MDIs	169.7	0.0%	138.5	31.2
Fire extinguishers	180.1	76.9%	180.1	0.0
Solvents	-1.2	-14.5%	-1.7	0.5

Sector	proportionate action scenario 2050			
	total compliance cost vs baseline		thereof: additional cost of HFC price increase	thereof: cost of technological change (= net compliance cost)
	Mio EUR/a	% of baseline totex	Mio EUR/a	Mio EUR/a
Foam OCF	0.0	0.0%	0.0	0.0
Foam XPS	0.0	0.0%	0.0	0.0
Foam PU spray	0.0	0.0%	0.0	0.0
Foam PU non-spray	0.0	0.0%	0.0	0.0
Switchgear MV	92.1	8.9%	0.0	92.1
Switchgear HV	81.2	9.3%	0.0	81.2
Total	**-835.2**	**-0.1%**	**189.4**	**-1024.6**

Table 187: Maximum feasibility scenario: Equipment operators' additional compliance cost, 2024 – 2036 average (costs difference to the baseline)

Sector	maximum feasibility scenario 2024-2036			
	total compliance cost vs baseline		thereof: additional cost of HFC price increase	thereof: cost of technological change (= net compliance cost)
	Mio EUR/a	% of baseline totex	Mio EUR/a	Mio EUR/a
Domestic Refrigeration	0.0	0.0%	0.0	0.0
Commercial refrigeration - Hermetics	-2.8	-0.1%	-0.2	-2.6
Commercial refrigeration - Condensing units	5.8	0.1%	30.0	-24.1
Commercial refrigeration - Central systems	-0.8	0.0%	49.8	-50.5
Industrial refrigeration - small	102.8	4.1%	101.7	1.1
Industrial refrigeration - large	64.3	1.5%	53.1	11.2
Transport refrigeration - Vans	-4.5	-0.8%	-0.1	-4.4
Transport refrigeration - Trucks & Trailers	-50.9	-0.9%	4.4	-55.3
Transport refrigeration - Ships	1.1	0.6%	1.2	-0.1
Room AC - Moveables	0.0	0.0%	0.0	0.0
Room AC - Single split	-265.7	-1.1%	-194.8	-71.0
Room AC - Rooftop	18.6	0.1%	-14.6	33.2
Room AC - VRF	53.3	0.5%	-8.6	61.9
Minichillers	-4.0	-0.7%	0.1	-4.1
Displacement chillers - small	4.4	0.3%	-0.3	4.7
Displacement chillers - large	15.5	0.3%	-5.9	21.4
Centrifugal chillers	3.4	0.4%	5.3	-1.9
Heat pumps - small	-114.2	-0.3%	-11.7	-102.4
Heat pumps - medium	-18.4	-0.1%	1.6	-20.1
Heat pumps - large	3.6	0.0%	7.8	-4.3
Mobile AC - Passenger cars	99.8	0.8%	99.8	0.0
Mobile AC - Buses	108.0	2.1%	12.2	95.8
Mobile AC - Trucks N1	70.0	1.0%	12.5	57.5
Mobile AC - Trucks N2	9.4	1.1%	-4.6	14.0
Mobile AC - Trucks N3	58.6	2.1%	-34.2	92.8
Mobile AC - Passenger ships	30.9	14.8%	38.1	-7.2
Mobile AC - Cargo ships	22.1	17.0%	24.7	-2.5
Mobile AC - Tram	3.8	2.6%	0.4	3.4
Mobile AC - Metro	1.3	4.1%	0.1	1.2
Mobile AC - Train	18.6	5.6%	2.9	15.7
Aerosols - technical	0.4	0.2%	-0.2	0.6
Aerosols - MDIs	228.1	0.0%	226.1	2.0
Fire extinguishers	46.0	21.6%	46.0	0.0
Solvents	-0.9	-11.9%	-1.5	0.5

Sector	maximum feasibility scenario 2024-2036			
	total compliance cost vs baseline		thereof: additional cost of HFC price increase	thereof: cost of technological change (= net compliance cost)
	Mio EUR/a	% of baseline totex	Mio EUR/a	Mio EUR/a
Foam OCF	0.0	0.0%	0.0	0.0
Foam XPS	0.3	0.3%	0.3	0.0
Foam PU spray	0.0	0.0%	0.0	0.0
Foam PU non-spray	0.0	0.0%	0.0	0.0
Switchgear MV	26.2	3.5%	0.0	26.2
Switchgear HV	23.1	3.7%	0.0	23.1
Total	**557.4**	**0.1%**	**441.7**	**115.7**

Table 188: Maximum feasibility scenario: Equipment operators' additional compliance cost, 2050 (costs difference to the baseline)

Sector	maximum feasibility scenario 2050			
	total compliance cost vs baseline		thereof: additional cost of HFC price increase	thereof: cost of technological change (= net compliance cost)
	Mio EUR/a	% of baseline totex	Mio EUR/a	Mio EUR/a
Domestic Refrigeration	0.0	0.0%	0.0	0.0
Commercial refrigeration - Hermetics	0.0	0.0%	0.0	0.0
Commercial refrigeration - Condensing units	-175.1	-2.2%	-5.2	-169.8
Commercial refrigeration - Central systems	-135.4	-1.6%	-55.2	-80.2
Industrial refrigeration - small	14.6	0.6%	23.9	-9.3
Industrial refrigeration - large	-9.4	-0.4%	3.0	-12.4
Transport refrigeration - Vans	-5.4	-0.8%	-0.4	-5.0
Transport refrigeration - Trucks & Trailers	-53.3	-0.7%	-7.2	-46.1
Transport refrigeration - Ships	3.6	3.2%	4.0	-0.4
Room AC - Moveables	0.0	0.0%	0.0	0.0
Room AC - Single split	-512.6	-2.0%	-286.9	-225.7
Room AC - Rooftop	-203.3	-1.3%	-20.8	-182.4
Room AC - VRF	53.0	0.3%	58.4	-5.4
Minichillers	-41.4	-12.4%	-0.6	-40.8
Displacement chillers - small	-10.4	-0.7%	-5.0	-5.4
Displacement chillers - large	-64.2	-1.1%	-45.3	-18.9
Centrifugal chillers	-7.9	-1.0%	0.0	-7.9
Heat pumps - small	-456.6	-0.4%	-74.4	-382.2
Heat pumps - medium	-372.5	-1.8%	-107.2	-265.4
Heat pumps - large	0.0	0.0%	0.0	0.0
Mobile AC - Passenger cars	322.1	30.2%	322.1	0.0
Mobile AC - Buses	-8.1	-0.2%	-23.6	15.6
Mobile AC - Trucks N1	159.4	2.1%	89.7	69.7
Mobile AC - Trucks N2	4.9	0.6%	-19.3	24.2
Mobile AC - Trucks N3	51.3	1.7%	-76.1	127.3
Mobile AC - Passenger ships	-28.4	-15.8%	-2.1	-26.3
Mobile AC - Cargo ships	-12.7	-11.4%	1.2	-13.9
Mobile AC - Tram	-0.4	-0.3%	-0.3	-0.1
Mobile AC - Metro	1.1	4.6%	0.5	0.6
Mobile AC - Train	22.6	7.1%	8.7	13.9
Aerosols - technical	0.6	0.2%	-0.6	1.1
Aerosols - MDIs	185.9	0.0%	154.7	31.2
Fire extinguishers	208.2	88.9%	208.2	0.0
Solvents	-1.2	-14.5%	-1.7	0.5
Foam OCF	0.0	0.0%	0.0	0.0

Sector	maximum feasibility scenario 2050			
	total compliance cost vs baseline		thereof: additional cost of HFC price increase	thereof: cost of technological change (= net compliance cost)
	Mio EUR/a	% of baseline totex	Mio EUR/a	Mio EUR/a
Foam XPS	0.0	0.0%	0.0	0.0
Foam PU spray	0.0	0.0%	0.0	0.0
Foam PU non-spray	0.0	0.0%	0.0	0.0
Switchgear MV	92.1	8.9%	0.0	92.1
Switchgear HV	81.2	9.3%	0.0	81.2
Total	**-897.8**	**-0.1%**	**142.2**	**-1040.1**

Annex 3.2: Emission reduction cost at sub-sector level

Table 189: MP alignment scenario: Emission reduction cost, new equipment installed in 2024 – 2036 average

Sector	MP alignment scenario		
	new equipment installed, annual average 2024-2036		
	lifetime-integrated emission reductions compared to baseline	Cost of technological change of lifetime-integrated emission reductions	Calculated emission reduction cost for technological change
	Mt CO_2e	Mio €	€ / t CO_2e
Domestic Refrigeration	0.00	0.0	NA
Commercial refrigeration - Hermetics	0.00	0.0	NA
Commercial refrigeration - Condensing units	-0.24	13.0	NA
Commercial refrigeration - Central systems	-1.53	-14.0	NA
Industrial refrigeration - small	-0.17	-4.5	NA
Industrial refrigeration - large	0.00	0.0	NA
Transport refrigeration - Vans	0.00	0.0	NA
Transport refrigeration - Trucks & Trailers	0.00	0.0	NA
Transport refrigeration - Ships	0.00	0.0	NA
Room AC - Moveables	0.00	0.0	NA
Room AC - Single split	-0.82	3.6	NA
Room AC - Rooftop	-0.19	-8.2	NA
Room AC - VRF	-0.64	-19.0	NA
Minichillers	-0.01	4.6	NA
Displacement chillers - small	-0.03	-0.3	NA
Displacement chillers - large	-0.27	-3.3	NA
Centrifugal chillers	0.00	0.0	NA
Heat pumps - small	-0.54	169.1	NA
Heat pumps - medium	-0.49	50.4	NA
Heat pumps - large	0.00	0.0	NA
Mobile AC - Passenger cars	0.00	0.0	NA
Mobile AC - Buses	0.00	0.0	NA
Mobile AC - Trucks N1	0.00	0.0	NA
Mobile AC - Trucks N2	0.00	0.0	NA
Mobile AC - Trucks N3	0.00	0.0	NA
Mobile AC - Passenger ships	0.00	0.0	NA
Mobile AC - Cargo ships	0.00	0.0	NA
Mobile AC - Tram	0.00	0.0	NA
Mobile AC - Metro	0.00	0.0	NA
Mobile AC - Train	0.00	0.0	NA
Aerosols - technical	0.00	0.0	NA

Sector	MP alignment scenario		
	new equipment installed, annual average 2024-2036		
	lifetime-integrated emission reductions compared to baseline	Cost of technological change of lifetime-integrated emission reductions	Calculated emission reduction cost for technological change
	Mt CO_2e	Mio €	€ / t CO_2e
Aerosols - MDIs	0.00	0.0	NA
Fire extinguishers	0.00	0.0	NA
Solvents	0.00	0.0	NA
Foam OCF	0.00	0.0	NA
Foam XPS	0.00	0.0	NA
Foam PU spray	0.00	0.0	NA
Foam PU non-spray	0.00	0.0	NA
Switchgear MV	0.00	0.0	NA
Switchgear HV	0.00	0.0	NA
Total	**-4.9**	**191.4**	**NA**

Table 190: MP alignment scenario: Emission reduction cost, new equipment installed in 2050

Sector	MP alignment scenario		
	new equipment installed in 2050		
	lifetime-integrated emission reductions compared to baseline	Cost of technological change of lifetime-integrated emission reductions	Calculated emission reduction cost for technological change
	Mt CO_2e	Mio €	€ / t CO_2e
Domestic Refrigeration	0.00	0.0	NA
Commercial refrigeration - Hermetics	0.00	0.0	NA
Commercial refrigeration - Condensing units	0.29	-27.6	-96.3
Commercial refrigeration - Central systems	0.40	-44.1	-111.3
Industrial refrigeration - small	0.00	0.2	NA
Industrial refrigeration - large	0.00	0.0	NA
Transport refrigeration - Vans	0.00	0.0	NA
Transport refrigeration - Trucks & Trailers	0.00	0.0	NA
Transport refrigeration - Ships	0.00	0.0	NA
Room AC - Moveables	0.00	0.0	NA
Room AC - Single split	2.69	-127.7	-47.5
Room AC - Rooftop	0.01	-33.5	-4460.0
Room AC - VRF	0.10	-6.0	-61.2
Minichillers	0.00	0.0	NA
Displacement chillers - small	0.00	0.0	NA
Displacement chillers - large	0.00	0.0	NA
Centrifugal chillers	0.00	0.0	NA
Heat pumps - small	0.45	-204.3	-451.3
Heat pumps - medium	0.46	-338.3	-734.2
Heat pumps - large	0.00	0.0	NA
Mobile AC - Passenger cars	0.00	0.0	NA
Mobile AC - Buses	0.00	0.0	NA
Mobile AC - Trucks N1	0.00	0.0	NA
Mobile AC - Trucks N2	0.00	0.0	NA
Mobile AC - Trucks N3	0.00	0.0	NA
Mobile AC - Passenger ships	0.00	0.0	NA
Mobile AC - Cargo ships	0.00	0.0	NA
Mobile AC - Tram	0.00	0.0	NA
Mobile AC - Metro	0.00	0.0	NA
Mobile AC - Train	0.00	0.0	NA
Aerosols - technical	0.00	0.0	NA
Aerosols - MDIs	0.00	0.0	NA
Fire extinguishers	0.00	0.0	NA
Solvents	0.00	0.0	NA

Sector	MP alignment scenario		
	new equipment installed in 2050		
	lifetime-integrated emission reductions compared to baseline	Cost of technological change of lifetime-integrated emission reductions	Calculated emission reduction cost for technological change
	Mt CO_2e	Mio €	€ / t CO_2e
Foam OCF	0.00	0.0	NA
Foam XPS	0.00	0.0	NA
Foam PU spray	0.00	0.0	NA
Foam PU non-spray	0.00	0.0	NA
Switchgear MV	0.00	0.0	NA
Switchgear HV	0.00	0.0	NA
Total	**4.4**	**-781.1**	**-178.1**

Table 191: Proportionate action scenario: Emission reduction cost, new equipment installed in 2024 – 2036 average

Sector	proportionate action scenario		
	new equipment installed, annual average 2024-2036		
	lifetime-integrated emission reductions compared to baseline	Cost of technological change of lifetime-integrated emission reductions	Calculated emission reduction cost for technological change
	Mt CO_2e	Mio €	€ / t CO_2e
Domestic Refrigeration	0.00	0.0	NA
Commercial refrigeration - Hermetics	0.00	-2.8	-2209.3
Commercial refrigeration - Condensing units	0.43	-54.1	-124.7
Commercial refrigeration - Central systems	0.83	-27.9	-33.6
Industrial refrigeration - small	0.15	0.7	4.6
Industrial refrigeration - large	0.05	1.9	40.1
Transport refrigeration - Vans	0.02	-2.4	-109.0
Transport refrigeration - Trucks & Trailers	0.13	-36.1	-285.5
Transport refrigeration - Ships	0.05	-0.2	-3.6
Room AC - Moveables	0.00	0.0	NA
Room AC - Single split	3.90	-168.3	-43.1
Room AC - Rooftop	0.48	26.4	54.5
Room AC - VRF	1.45	35.6	24.5
Minichillers	0.01	-19.9	-3955.8
Displacement chillers - small	0.02	0.5	21.6
Displacement chillers - large	0.25	4.2	16.6
Centrifugal chillers	0.00	-6.9	-2094.8
Heat pumps - small	0.76	-308.3	-408.0
Heat pumps - medium	0.42	-109.4	-260.5
Heat pumps - large	0.03	-13.2	-389.9
Mobile AC - Passenger cars	0.00	0.0	NA
Mobile AC - Buses	0.14	47.3	333.9
Mobile AC - Trucks N1	0.56	51.3	92.4
Mobile AC - Trucks N2	0.11	9.7	85.1
Mobile AC - Trucks N3	0.40	51.3	128.3
Mobile AC - Passenger ships	0.24	-21.7	-91.4
Mobile AC - Cargo ships	0.19	-16.3	-87.7
Mobile AC - Tram	0.01	2.6	219.1
Mobile AC - Metro	0.00	0.6	234.9
Mobile AC - Train	0.02	-28.5	-1809.3
Aerosols - technical	0.01	0.6	88.9
Aerosols - MDIs	2.42	2.1	0.9
Fire extinguishers	0.00	0.0	NA

Sector	proportionate action scenario		
	new equipment installed, annual average 2024-2036		
	lifetime-integrated emission reductions compared to baseline	Cost of technological change of lifetime-integrated emission reductions	Calculated emission reduction cost for technological change
	Mt CO_2e	Mio €	€ / t CO_2e
Solvents	0.04	0.5	13.4
Foam OCF	0.00	0.0	NA
Foam XPS	0.00	0.0	NA
Foam PU spray	0.00	0.0	NA
Foam PU non-spray	0.00	0.0	NA
Switchgear MV	0.16	53.0	335.8
Switchgear HV	0.53	26.6	50.2
Total	**13.8**	**-501.1**	**-36.3**

Table 192: Emission reduction cost, new equipment installed in 2050

Sector	proportionate action scenario		
	new equipment installed in 2050		
	lifetime-integrated emission reductions compared to baseline	Cost of technological change of lifetime-integrated emission reductions	Calculated emission reduction cost for technological change
	Mt CO_2e	Mio €	€ / t CO_2e
Domestic Refrigeration	0.00	0.0	NA
Commercial refrigeration - Hermetics	0.00	0.0	NA
Commercial refrigeration - Condensing units	0.06	-49.8	-862.7
Commercial refrigeration - Central systems	0.40	-44.1	-111.3
Industrial refrigeration - small	0.05	-5.2	-102.5
Industrial refrigeration - large	0.00	0.1	141.5
Transport refrigeration - Vans	0.00	-2.4	-951.4
Transport refrigeration - Trucks & Trailers	0.04	-20.9	-483.5
Transport refrigeration - Ships	0.00	0.0	NA
Room AC - Moveables	0.00	0.0	NA
Room AC - Single split	3.58	-170.2	-47.5
Room AC - Rooftop	0.36	-231.3	-637.3
Room AC - VRF	1.19	-3.4	-2.8
Minichillers	0.01	-46.6	-7917.3
Displacement chillers - small	0.02	-0.4	-16.9
Displacement chillers - large	0.28	-6.2	-22.2
Centrifugal chillers	0.00	-8.6	-96505.5
Heat pumps - small	1.36	-612.8	-451.3
Heat pumps - medium	1.25	-394.5	-315.8
Heat pumps - large	0.00	0.0	NA
Mobile AC - Passenger cars	0.00	0.0	NA
Mobile AC - Buses	0.08	25.7	333.9
Mobile AC - Trucks N1	0.82	64.0	78.4
Mobile AC - Trucks N2	0.20	17.4	87.0
Mobile AC - Trucks N3	1.01	129.3	128.2
Mobile AC - Passenger ships	0.00	0.0	NA
Mobile AC - Cargo ships	0.00	0.0	NA
Mobile AC - Tram	0.01	0.5	94.0
Mobile AC - Metro	0.00	0.3	261.7
Mobile AC - Train	0.01	-31.0	-3035.9
Aerosols - technical	0.01	1.2	88.9
Aerosols - MDIs	2.84	32.5	11.4
Fire extinguishers	0.00	0.0	NA
Solvents	0.04	0.5	13.5

Sector	proportionate action scenario		
	new equipment installed in 2050		
	lifetime-integrated emission reductions compared to baseline	Cost of technological change of lifetime-integrated emission reductions	Calculated emission reduction cost for technological change
	Mt CO_2e	Mio €	€ / t CO_2e
Foam OCF	0.00	0.0	NA
Foam XPS	0.00	0.0	NA
Foam PU spray	0.00	0.0	NA
Foam PU non-spray	0.00	0.0	NA
Switchgear MV	0.55	186.1	335.8
Switchgear HV	1.86	164.4	88.4
Total	**16.0**	**-1005.2**	**-62.7**

Table 193: Maximum feasibility scenario: Emission reduction cost, new equipment installed in 2024 – 2036 average

Sector	maximum feasibility scenario		
	new equipment installed, annual average 2024-2036		
	lifetime-integrated emission reductions compared to baseline	Cost of technological change of lifetime-integrated emission reductions	Calculated emission reduction cost for technological change
	Mt CO_2e	Mio €	€ / t CO_2e
Domestic Refrigeration	0.00	0.0	NA
Commercial refrigeration - Hermetics	0.00	-2.8	-2209.3
Commercial refrigeration - Condensing units	0.50	-68.8	-136.4
Commercial refrigeration - Central systems	1.08	-52.3	-48.4
Industrial refrigeration - small	0.15	0.7	4.6
Industrial refrigeration - large	0.05	1.9	40.1
Transport refrigeration - Vans	0.03	-4.8	-153.4
Transport refrigeration - Trucks & Trailers	0.16	-62.2	-376.9
Transport refrigeration - Ships	0.07	-0.3	-3.6
Room AC - Moveables	0.00	0.0	NA
Room AC - Single split	3.90	-168.3	-43.1
Room AC - Rooftop	0.48	26.4	54.5
Room AC - VRF	1.45	35.6	24.5
Minichillers	0.01	-19.9	-3955.8
Displacement chillers - small	0.02	0.5	21.6
Displacement chillers - large	0.25	4.2	16.6
Centrifugal chillers	0.00	-6.9	-2094.8
Heat pumps - small	0.76	-308.3	-408.0
Heat pumps - medium	0.42	-109.4	-260.5
Heat pumps - large	0.03	-13.2	-389.9
Mobile AC - Passenger cars	0.00	0.0	NA
Mobile AC - Buses	0.26	119.1	457.1
Mobile AC - Trucks N1	0.87	75.8	87.3
Mobile AC - Trucks N2	0.19	15.8	83.5
Mobile AC - Trucks N3	0.96	122.6	127.9
Mobile AC - Passenger ships	0.33	-32.2	-98.8
Mobile AC - Cargo ships	0.22	-19.5	-89.2
Mobile AC - Tram	0.01	2.9	204.6
Mobile AC - Metro	0.00	1.2	402.5
Mobile AC - Train	0.02	18.2	1030.2
Aerosols - technical	0.01	0.6	88.9
Aerosols - MDIs	2.42	2.1	0.9
Fire extinguishers	0.00	0.0	NA

Sector	**maximum feasibility scenario**		
	new equipment installed, annual average 2024-2036		
	lifetime-integrated emission reductions compared to baseline	**Cost of technological change of lifetime-integrated emission reductions**	**Calculated emission reduction cost for technological change**
	Mt CO_2e	**Mio €**	**€ / t CO_2e**
Solvents	0.04	0.5	13.4
Foam OCF	0.00	0.0	NA
Foam XPS	0.00	0.0	NA
Foam PU spray	0.00	0.0	NA
Foam PU non-spray	0.00	0.0	NA
Switchgear MV	0.16	53.0	335.8
Switchgear HV	0.53	26.6	50.2
Total	**15.4**	**-361.2**	**-23.4**

Table 194: Emission reduction cost, new equipment installed in 2050

Sector	maximum feasibility scenario		
	new equipment installed in 2050		
	lifetime-integrated emission reductions compared to baseline	Cost of technological change of lifetime-integrated emission reductions	Calculated emission reduction cost for technological change
	Mt CO_2e	Mio €	€ / t CO_2e
Domestic Refrigeration	0.00	0.0	NA
Commercial refrigeration - Hermetics	0.00	0.0	NA
Commercial refrigeration - Condensing units	0.00	-46.4	-22822.8
Commercial refrigeration - Central systems	0.40	-44.1	-111.3
Industrial refrigeration - small	0.05	-5.2	-102.5
Industrial refrigeration - large	0.00	0.1	141.5
Transport refrigeration - Vans	0.00	-4.7	-951.4
Transport refrigeration - Trucks & Trailers	0.09	-41.7	-483.5
Transport refrigeration - Ships	0.00	0.0	NA
Room AC - Moveables	0.00	0.0	NA
Room AC - Single split	3.58	-170.2	-47.5
Room AC - Rooftop	0.36	-231.3	-637.3
Room AC - VRF	1.19	-3.4	-2.8
Minichillers	0.01	-46.6	-7917.3
Displacement chillers - small	0.02	-0.4	-16.9
Displacement chillers - large	0.28	-6.2	-22.2
Centrifugal chillers	0.00	-8.6	-96505.5
Heat pumps - small	1.36	-612.8	-451.3
Heat pumps - medium	1.25	-394.5	-315.8
Heat pumps - large	0.00	0.0	NA
Mobile AC - Passenger cars	0.00	0.0	NA
Mobile AC - Buses	0.28	148.6	529.8
Mobile AC - Trucks N1	0.82	64.0	78.4
Mobile AC - Trucks N2	0.20	17.4	87.0
Mobile AC - Trucks N3	1.07	136.9	128.1
Mobile AC - Passenger ships	0.00	0.0	NA
Mobile AC - Cargo ships	0.00	0.0	NA
Mobile AC - Tram	0.01	0.5	94.0
Mobile AC - Metro	0.00	0.9	822.4
Mobile AC - Train	0.01	21.7	2111.0
Aerosols - technical	0.01	1.2	88.9
Aerosols - MDIs	2.84	32.5	11.4
Fire extinguishers	0.00	0.0	NA
Solvents	0.04	0.5	13.5

Sector	maximum feasibility scenario		
	new equipment installed in 2050		
	lifetime-integrated emission reductions compared to baseline	Cost of technological change of lifetime-integrated emission reductions	Calculated emission reduction cost for technological change
	Mt CO_2e	Mio €	€ / t CO_2e
Foam OCF	0.00	0.0	NA
Foam XPS	0.00	0.0	NA
Foam PU spray	0.00	0.0	NA
Foam PU non-spray	0.00	0.0	NA
Switchgear MV	0.55	186.1	335.8
Switchgear HV	1.86	164.4	88.4
Total	**16.3**	**-841.2**	**-51.7**

Annex 3.3: Equipment operators' baseline compliance cost

Table 195: Equipment operators' baseline compliance cost at subsector level, 2024 – 2036 average (costs difference to the counterfactual scenario assuming no 2014 FGR revision)

Sector	baseline scenario			
	total baseline compliance cost vs counterfactual scenario assuming no 2014 FGR revision		thereof: additional cost of HFC price increase	thereof: cost of technological change (= net compliance cost)
	Mio EUR/a	% of counterfactual totex	Mio EUR/a	Mio EUR/a
Domestic Refrigeration	-9.9	-1.3%	0.0	-9.9
Commercial refrigeration - Hermetics	-81.2	-3.6%	0.2	-81.4
Commercial refrigeration - Condensing units	152.5	1.8%	126.0	26.5
Commercial refrigeration - Central systems	410.0	5.2%	249.5	160.4
Industrial refrigeration - small	197.8	8.5%	121.8	76.1
Industrial refrigeration - large	141.6	3.3%	79.1	62.5
Transport refrigeration - Vans	8.5	1.6%	9.7	-1.1
Transport refrigeration - Trucks & Trailers	-76.2	-1.3%	40.5	-116.7

Sector	baseline scenario			
	total baseline compliance cost vs counterfactual scenario assuming no 2014 FGR revision		thereof: additional cost of HFC price increase	thereof: cost of technological change (= net compliance cost)
	Mio EUR/a	% of counterfactual totex	Mio EUR/a	Mio EUR/a
Transport refrigeration - Ships	11.0	6.7%	7.9	3.1
Room AC - Moveables	-3.3	-0.6%	0.0	-3.3
Room AC - Single split	355.4	1.4%	316.6	38.8
Room AC - Rooftop	81.0	0.5%	137.1	-56.0
Room AC - VRF	368.3	3.8%	291.6	76.6
Minichillers	-14.1	-2.3%	1.1	-15.2
Displacement chillers - small	15.1	1.0%	9.3	5.8
Displacement chillers - large	122.0	2.0%	71.8	50.2
Centrifugal chillers	-12.7	-1.5%	6.2	-18.9
Heat pumps - small	-146.9	-0.4%	62.4	-209.3
Heat pumps - medium	23.6	0.2%	64.0	-40.4
Heat pumps - large	56.5	0.5%	16.1	40.5
Mobile AC - Passenger cars	116.4	1.0%	116.4	0.0
Mobile AC - Buses	133.2	2.6%	54.8	78.4
Mobile AC - Trucks N1	122.1	1.8%	95.0	27.1
Mobile AC - Trucks N2	20.2	2.5%	19.0	1.2
Mobile AC - Trucks N3	74.9	2.8%	71.4	3.4
Mobile AC - Passenger ships	64.1	44.4%	55.0	9.0
Mobile AC - Cargo ships	40.9	45.9%	35.7	5.2
Mobile AC - Tram	5.7	4.1%	1.5	4.1
Mobile AC - Metro	1.4	4.5%	0.3	1.0
Mobile AC - Train	32.4	10.7%	3.7	28.7
Aerosols - technical	16.2	6.9%	0.5	15.7
Aerosols - MDIs	0.0	0.0%	0.0	0.0
Fire extinguishers	56.3	36.0%	34.0	22.2
Solvents	1.8	30.6%	1.5	0.3
Foam OCF	0.0	0.0%	0.0	0.0
Foam XPS	30.8	30.7%	0.9	29.9
Foam PU spray	17.9	10.4%	0.0	17.9
Foam PU non-spray	8.1	10.1%	0.0	8.1
Switchgear MV	0.0	0.0%	0.0	0.0
Switchgear HV	0.0	0.0%	0.0	0.0
Total	**2341.3**	**0.3%**	**2100.8**	**240.5**

Table 196: Equipment operators' baseline compliance cost at sector level, 2024 – 2036 average (costs difference to the counterfactual scenario assuming no 2014 FGR revision)

Sector	baseline scenario			
	total baseline compliance cost vs counterfactual scenario assuming no 2014 FGR revision		thereof: additional cost of HFC price increase	thereof: cost of technological change (= net compliance cost)
	Mio EUR/a	% of counterfactual totex	Mio EUR/a	Mio EUR/a
Refrigeration	754.1	2.3%	634.6	119.5
Stationary A/C	845.0	0.7%	976.2	-131.2
Mobile A/C	611.2	2.1%	453.0	158.1
Propellants, solvents & fire protection	74.3	0.0%	36.0	38.3
Foam	56.8	16.0%	0.9	55.9
Other HFCs	0.0	NA	0.0	0.0
SF6	0.0	0.0%	0.0	0.0
Total	**2341.3**	**0.3%**	**2100.8**	**240.5**

Table 197: Equipment operators' baseline compliance cost at subsector level, 2050 (costs difference to the counterfactual scenario assuming no 2014 FGR revision)

Sector	baseline scenario			
	total baseline compliance cost vs counterfactual scenario assuming no 2014 FGR revision		thereof: additional cost of HFC price increase	thereof: cost of technological change (= net compliance cost)
	Mio EUR/a	% of counterfactual totex	Mio EUR/a	Mio EUR/a
Domestic Refrigeration	-10.5	-1.7%	0.0	-10.5
Commercial refrigeration - Hermetics	-96.5	-4.5%	0.0	-96.5
Commercial refrigeration - Condensing units	-47.1	-0.6%	5.2	-52.3
Commercial refrigeration - Central systems	93.4	1.1%	55.2	38.2
Industrial refrigeration - small	53.7	2.1%	14.9	38.8
Industrial refrigeration - large	-4.3	-0.2%	2.1	-6.4
Transport refrigeration - Vans	-17.1	-2.5%	0.4	-17.5
Transport refrigeration - Trucks & Trailers	-362.8	-4.6%	7.2	-370.0
Transport refrigeration - Ships	3.1	2.8%	3.2	-0.2
Room AC - Moveables	-3.4	-0.6%	0.0	-3.4
Room AC - Single split	280.0	1.1%	286.9	-6.9
Room AC - Rooftop	29.0	0.2%	83.9	-54.9

Sector	baseline scenario			
	total baseline compliance cost vs counterfactual scenario assuming no 2014 FGR revision		thereof: additional cost of HFC price increase	thereof: cost of technological change (= net compliance cost)
	Mio EUR/a	% of counterfactual totex	Mio EUR/a	Mio EUR/a
Room AC - VRF	340.4	2.1%	239.1	101.3
Minichillers	-24.3	-6.8%	0.7	-25.0
Displacement chillers - small	-14.7	-1.0%	5.0	-19.8
Displacement chillers - large	24.8	0.4%	45.9	-21.1
Centrifugal chillers	-53.0	-6.3%	0.0	-53.1
Heat pumps - small	-1413.5	-1.1%	74.4	-1487.9
Heat pumps - medium	-279.9	-1.3%	113.7	-393.6
Heat pumps - large	-78.7	-0.2%	0.0	-78.7
Mobile AC - Passenger cars	92.6	9.5%	92.6	0.0
Mobile AC - Buses	134.7	2.7%	45.4	89.3
Mobile AC - Trucks N1	152.2	2.1%	101.7	50.5
Mobile AC - Trucks N2	24.5	3.0%	20.6	3.9
Mobile AC - Trucks N3	93.0	3.3%	80.5	12.6
Mobile AC - Passenger ships	37.4	26.2%	22.9	14.5
Mobile AC - Cargo ships	20.6	22.8%	13.6	7.0
Mobile AC - Tram	-0.2	-0.1%	0.4	-0.6
Mobile AC - Metro	0.7	2.9%	0.3	0.4
Mobile AC - Train	28.6	9.9%	3.3	25.4
Aerosols - technical	16.3	7.0%	0.6	15.7
Aerosols - MDIs	0.0	0.0%	0.0	0.0
Fire extinguishers	77.2	49.1%	59.8	17.4
Solvents	2.0	33.9%	1.7	0.4
Foam OCF	0.0	0.0%	0.0	0.0
Foam XPS	29.6	29.2%	0.0	29.6
Foam PU spray	17.7	10.3%	0.0	17.7
Foam PU non-spray	7.4	9.2%	0.0	7.4
Switchgear MV	0.0	0.0%	0.0	0.0
Switchgear HV	0.0	0.0%	0.0	0.0
Total	**-847.2**	**-0.1%**	**1381.1**	**-2228.3**

Table 198: Equipment operators' baseline compliance cost at sector level, 2050 (costs difference to the counterfactual scenario assuming no 2014 FGR revision)

Sector	baseline scenario			
	total baseline compliance cost vs counterfactual scenario assuming no 2014 FGR revision		thereof: additional cost of HFC price increase	thereof: cost of technological change (= net compliance cost)
	Mio EUR/a	% of counterfactual totex	Mio EUR/a	Mio EUR/a
Refrigeration	-388.1	-1.2%	88.3	-476.4
Stationary A/C	-1193.3	-0.5%	849.6	-2042.9
Mobile A/C	584.1	3.3%	381.1	203.0
Propellants, solvents & fire protection	95.5	0.0%	62.1	33.4
Foam	54.6	15.3%	0.0	54.6
Other HFCs	0.0	NA	0.0	0.0
SF6	0.0	0.0%	0.0	0.0
Total	**-847.2**	**-0.1%**	**1381.1**	**-2228.3**

Annex 4: Macroeconomic Analysis (JRC)

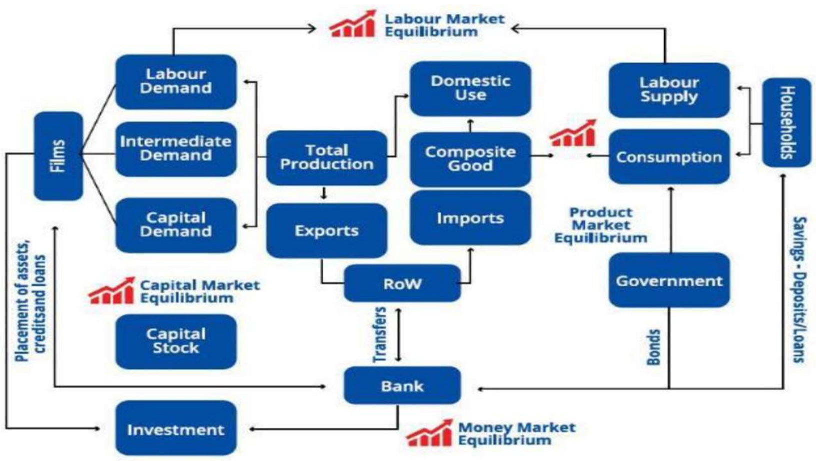
Annex 4.1 (Model description and scenario setup) and JRC-GEM-E3 model results (Annex 4.2) have been prepared by Matthias Weitzel, Marie Tamba and Toon Vandyck (European Commission, Joint Research Centre).

Annex 4.1: Model description and scenario setup (JRC)

Model Overview

JRC-GEM-E3[15] (General Equilibrium Model for Economy-Energy-Environment) is a recursive dynamic Computable General Equilibrium model. It is a global model, covering the 27 EU Member 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 15: A schematic representation of the JRC-GEM-E3 model.



Source: JRC-GEM-E3 model

The JRC-GEM-E3 model is normally used 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.

[15] https://ec.europa.eu/jrc/en/gem-e3/model

Description of the baseline

The starting point of the analysis is the EU Reference Scenario 2020[16], 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[17]. A more detailed description can be found in the impact assessment covering the revision of the ETS Directive[18].

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[19], 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[20]. These also take into account the macroeconomic consequences of COVID-19 and likely (persistent) changes in the transportation sector.

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 for the 2014 revision of the FGR[21]), 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

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[16] European Commission (2021). EU Reference Scenario 2020: Energy, transport and GHG emissions - Trends to 2050, doi: 10.2833/35750.

[17] The 2021 Ageing Report: Underlying assumptions and projection methodologies https://ec.europa.eu/info/publications/2021-ageing-report-underlying-assumptions-and-projection-methodologies_en

[18] SWD(2021)601

[19] See https://ec.europa.eu/jrc/en/macroeconomic.baselines.for.policy.assessments

[20] 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.

[21] SWD(2012) 364

limited number of specific downstream sectors that are affected.[22] Further, this approach better represents the situation with respect to trade of F-gases.[23] The end user 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. The detailed mapping and indicators used for regional downscaling are summarised in Table y. 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.[24] 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.[25] 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.

[22] 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.

[23] 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.

[24] 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.

[25] 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 199: Mapping of AnaFgas model sectors to JRC-GEM-E3 sectors and regions

AnaF-gas sector No	AnaFgas sector	Equipment operators / end users	Correspondence with JRC-GEM-E3 end users	Indicator used for allocation to Member States	Source for indicator
1	Domestic Refrigeration	Private Households	Households (purchase of appliances)	Population	European Commission 2021 Ageing Report
2	Commercial refrigeration - Hermetics	Commerce: Sale of food to customers	Market Services	Population	European Commission 2021 Ageing Report
3	Commercial refrigeration - Condensing units		Market Services	Population	European Commission 2021 Ageing Report
4	Commercial refrigeration - Central systems		Market Services	Population	European Commission 2021 Ageing Report
5	Industrial refrigeration - small	Cold storage in food industry and by retailers	Consumer goods (50%) & Market Services (50%)	Population	European Commission 2021 Ageing Report
6	Industrial refrigeration - large		Consumer goods (50%) & Market Services (50%)	Population	European Commission 2021 Ageing Report
7	Transport refrigeration - Vans	Distribution & delivery of food	Market Services	Population	European Commission 2021 Ageing Report
8	Transport refrigeration - Trucks & Trailers		Market Services	Population	European Commission 2021 Ageing Report
9	Transport refrigeration - Ships	Fishing vessels	Livestock	Distribution of fishing vessels by number (weight 50%) and size (weight 50%)	Eurostat [fish_fleet_alt]
11	Room AC - Moveables	Private homes & offices,	Households (purchase of appliances)	Energy use for cooling in residential buildings	EU Reference 2020
12	Room AC - Single split	equipment under control of inhabitants	Households (purchase of appliances)	Energy use for cooling in residential buildings	EU Reference 2020
13	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
14	Room AC - VRF		Services (Market and non-market)	Energy use for cooling in commercial buildings	EU Reference 2020
15	Minichillers	Commercial & industrial buildings, centrally operated equipment	Services (Market and non-market)	Energy use for cooling in commercial buildings	EU Reference 2020
16	Displacement chillers - small		Services (Market and non-market)	Energy use for cooling in commercial buildings	EU Reference 2020
17	Displacement chillers - large		Services (Market and non-market)	Energy use for cooling in commercial buildings	EU Reference 2020

18	Centrifugal chillers	Large commercial & industrial buildings, centrally operated equipment	Services (Market and non-market)	Energy use for cooling in commercial buildings	EU Reference 2020
19	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
39	Heat-pumps - medium	commercial buildings	Services (Market and non-market)	Energy use for heat pumps in commercial buildings	EU Reference 2020
20	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
21	Mobile AC - Passenger cars	Private & commercial owners of passenger cars	Households (1/3 to purchase of private vehicles, 2/3 to operation of private vehicles)	Stock of private cars	EU Reference 2020
22	Mobile AC - Buses	Bus transport undertakings	Land transport	Stock of buses	EU Reference 2020
23	Mobile AC - Trucks N1	Operators of road vehicles for commercial transport of goods	Land transport	Stock of light-duty vehicles	EU Reference 2020
24	Mobile AC - Trucks N2		Land transport	Stock of heavy-duty vehicles	EU Reference 2020
25	Mobile AC - Trucks N3		Land transport	Stock of heavy-duty vehicles	EU Reference 2020
26	Mobile AC - Passenger ships	Water transport undertakings: Ferries / cruise ships etc	Water transport	Activity (pkm) of passenger ships	EU Reference 2020
27	Mobile AC - Cargo ships	Water transport undertakings: transport of goods	Water transport	Activity (tkm) of freight ships	EU Reference 2020
28	Mobile AC - Tram	Public transport operators	Land transport	Activity (pkm) of trams and metro	EU Reference 2020
29	Mobile AC - Metro		Land transport	Activity (pkm) of trams and metro	EU Reference 2020
30	Mobile AC - Train		Land transport	Activity (pkm) of trains	EU Reference 2020
31	Aerosols - technical	Domestic & industrial applications	Chemicals	Output of chemical sector	JRC-GEM-E3 baseline
32	Aerosols - MDIs	Domestic use (pharmaceutical products)	Households (medical and health expenditures)	Population	European Commission 2021 Ageing Report

33	Fire extinguishers	Special commercial & industrial sectors	Other equipment manufacturing	Population	European Commission 2021 Ageing Report
34	Solvents	Special industrial applications	Chemicals	Output of chemical sector	JRC-GEM-E3 baseline
35	Foam OCF	Insulation of buildings and equipment (fridges, freezers etc)	Market Services	Population	European Commission 2021 Ageing Report
36	Foam XPS		Market Services	Population	European Commission 2021 Ageing Report
37	Foam PU spray		Market Services	Population	European Commission 2021 Ageing Report
38	Foam PU non-spray		Market Services	Population	European Commission 2021 Ageing Report
41	Switchgear MV	Operators of electrical transmission & distribution grid	Electricity supply	Output of electricity supply sector	JRC-GEM-E3 baseline
42	Switchgear HV		Electricity supply	Output of electricity supply sector	JRC-GEM-E3 baseline

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).[26] Obviously, the modelling outcome therefore would also be the same for any combination of fee and free allocation to industry.

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

Annex 4.2: Sectoral Modelling Outputs of JRC-GEM-E3

Table 200: JRC-GEM-E3 sectoral modelling results on output 2030 (bn USD 2014)

	Baseline	MP Alignment	Proportionate Action	Maximum Feasibility
Crops	287.02	287.03	287.04	287.04
Coal	13.96	13.97	13.96	13.96
Crude Oil	12.34	12.34	12.34	12.34
Oil	395.14	395.15	395.09	395.06
Gas	17.49	17.49	17.49	17.49
Electricity supply	509.38	509.69	508.73	508.65
Ferrous metals	497.92	497.76	498.07	498.09
Other Non-ferrous metals	199.28	199.24	199.34	199.35
Chemical Products	2 067.74	2 067.68	2 067.90	2 067.90
Paper Products	537.10	537.11	537.11	537.11
Other Non-metallic minerals	311.94	311.93	311.96	311.96
Electric Goods	1 484.21	1 484.22	1 484.38	1 484.38
Transport equipment	1 203.45	1 203.47	1 203.50	1 203.49
Other Equipment Goods	714.50	713.51	715.40	715.58
Consumer Goods Industries	3 710.20	3 710.28	3 710.21	3 710.16
Construction	2 472.67	2 472.69	2 472.73	2 472.73
Transport (Air)	361.39	361.40	361.39	361.39
Transport (Land)	1 477.88	1 477.94	1 477.73	1 477.64
Transport (Water)	257.89	257.91	257.85	257.85
Market Services	15 116.05	15 116.42	15 115.85	15 115.92
Non-Market Services	5 643.61	5 643.57	5 643.59	5 643.58
Livestock	283.18	283.16	283.20	283.21
Forestry	130.03	130.05	130.02	130.01
Cement and Lime	74.68	74.68	74.68	74.68
Glass	116.02	116.01	116.03	116.03
Fertilizer	71.04	71.04	71.04	71.04
Aluminium	120.33	120.30	120.36	120.36

Table 201: JRC-GEM-E3 sectoral modelling results on output 2050 (bn USD 2014)

	Baseline	MP Alignment	Proportionate Action	Maximum Feasibility
Crops	349.79	349.79	349.81	349.80
Coal	10.23	10.23	10.22	10.22
Crude Oil	6.03	6.03	6.03	6.02
Oil	315.14	315.14	315.08	315.01
Gas	18.05	18.05	18.04	18.04
Electricity supply	581.31	580.76	579.27	579.18
Ferrous metals	542.13	542.26	542.39	542.39
Other Non-ferrous metals	212.06	212.11	212.14	212.14
Chemical Products	2 506.42	2 506.32	2 506.69	2 506.64
Paper Products	636.41	636.42	636.45	636.46
Other Non-metallic minerals	370.73	370.74	370.77	370.77
Electric Goods	2 169.38	2 169.50	2 169.61	2 169.59
Transport equipment	1 387.44	1 387.48	1 387.49	1 387.48
Other Equipment Goods	924.14	924.99	925.93	925.94
Consumer Goods Industries	4 434.91	4 434.99	4 435.28	4 435.27
Construction	3 317.00	3 317.05	3 317.13	3 317.16
Transport (Air)	502.33	502.34	502.38	502.39
Transport (Land)	2 025.48	2 025.49	2 025.43	2 025.54
Transport (Water)	304.81	304.80	304.78	304.78
Market Services	20 231.71	20 231.78	20 233.02	20 233.41
Non-Market Services	7 230.60	7 230.62	7 230.88	7 230.93
Livestock	342.86	342.86	342.86	342.85
Forestry	184.53	184.50	184.40	184.40
Cement and Lime	88.90	88.90	88.91	88.91
Glass	136.99	137.00	137.01	137.01
Fertilizer	87.28	87.28	87.29	87.29
Aluminium	144.71	144.74	144.76	144.76

Table 202: JRC-GEM-E3 sectoral modelling results on exports 2030 (bn USD 2014)

	Baseline	MP Alignment	Proportionate Action	Maximum Feasibility
Crops	39.37	39.37	39.37	39.37
Coal	0.00	0.00	0.00	0.00
Crude Oil	0.71	0.71	0.71	0.71
Oil	79.93	79.93	79.93	79.93
Gas	3.48	3.48	3.48	3.48
Electricity supply	5.69	5.69	5.69	5.69
Ferrous metals	63.28	63.27	63.28	63.28
Other Non-ferrous metals	43.36	43.36	43.37	43.37
Chemical Products	598.64	598.63	598.68	598.68
Paper Products	57.12	57.12	57.12	57.12
Other Non-metallic minerals	62.28	62.28	62.28	62.28
Electric Goods	399.63	399.63	399.68	399.68
Transport equipment	485.13	485.13	485.15	485.15
Other Equipment Goods	83.65	83.66	83.63	83.63
Consumer Goods Industries	744.87	744.90	744.86	744.84
Construction	39.74	39.74	39.74	39.74
Transport (Air)	124.22	124.22	124.23	124.23
Transport (Land)	195.63	195.64	195.57	195.54
Transport (Water)	152.07	152.07	152.05	152.05
Market Services	707.86	707.88	707.93	707.95
Non-Market Services	125.07	125.06	125.08	125.08
Livestock	10.79	10.79	10.79	10.79
Forestry	2.25	2.25	2.25	2.25
Cement and Lime	3.21	3.21	3.21	3.21
Glass	16.61	16.61	16.61	16.61
Fertilizer	17.57	17.57	17.57	17.57
Aluminium	22.13	22.13	22.14	22.13

Table 203: JRC-GEM-E3 sectoral modelling results on exports 2050 (bn USD 2014)

	Baseline	MP Alignment	Proportionate Action	Maximum Feasibility
Crops	49.74	49.74	49.74	49.74
Coal	0.00	0.00	0.00	0.00
Crude Oil	0.51	0.51	0.51	0.51
Oil	77.84	77.84	77.84	77.84
Gas	6.02	6.02	6.02	6.02
Electricity supply	6.87	6.87	6.87	6.87
Ferrous metals	76.97	76.97	76.97	76.97
Other Non-ferrous metals	44.96	44.96	44.96	44.96
Chemical Products	781.96	781.97	782.02	782.01
Paper Products	70.11	70.11	70.11	70.11
Other Non-metallic minerals	77.85	77.85	77.85	77.85
Electric Goods	619.33	619.36	619.38	619.37
Transport equipment	630.36	630.38	630.38	630.37
Other Equipment Goods	134.75	134.74	134.57	134.55
Consumer Goods Industries	960.24	960.25	960.32	960.31
Construction	59.90	59.90	59.90	59.90
Transport (Air)	184.31	184.31	184.33	184.33
Transport (Land)	275.69	275.68	275.61	275.65
Transport (Water)	173.38	173.38	173.36	173.36
Market Services	1 013.79	1 013.86	1 014.10	1 014.11
Non-Market Services	189.15	189.15	189.18	189.17
Livestock	13.55	13.55	13.55	13.55
Forestry	2.57	2.57	2.57	2.57
Cement and Lime	3.63	3.63	3.63	3.63
Glass	19.50	19.51	19.51	19.51
Fertilizer	25.33	25.33	25.33	25.33
Aluminium	20.68	20.68	20.68	20.68

Table 204: JRC-GEM-E3 sectoral modelling results on imports 2030 (bn USD 2014)

	Baseline	MP Alignment	Proportionate Action	Maximum Feasibility
Crops	77.51	77.51	77.50	77.50
Coal	6.93	6.93	6.93	6.93
Crude Oil	246.07	246.08	246.04	246.02
Oil	92.69	92.70	92.68	92.67
Gas	69.59	69.60	69.58	69.58
Electricity supply	11.85	11.86	11.84	11.84
Ferrous metals	47.92	47.90	47.93	47.94
Other Non-ferrous metals	47.16	47.15	47.18	47.18
Chemical Products	372.69	372.68	372.69	372.69
Paper Products	25.48	25.48	25.48	25.48
Other Non-metallic minerals	69.70	69.69	69.70	69.70
Electric Goods	487.02	487.03	487.03	487.03
Transport equipment	205.35	205.35	205.34	205.34
Other Equipment Goods	55.50	55.40	55.61	55.63
Consumer Goods Industries	665.87	665.85	665.87	665.89
Construction	29.88	29.88	29.88	29.88
Transport (Air)	139.40	139.40	139.39	139.39
Transport (Land)	218.52	218.51	218.55	218.57
Transport (Water)	55.65	55.64	55.66	55.66
Market Services	847.59	847.59	847.53	847.51
Non-Market Services	128.36	128.36	128.35	128.35
Livestock	15.84	15.84	15.84	15.84
Forestry	5.33	5.33	5.33	5.33
Cement and Lime	1.48	1.48	1.48	1.48
Glass	10.98	10.98	10.98	10.98
Fertilizer	12.77	12.77	12.77	12.77
Aluminium	26.39	26.38	26.40	26.40

Table 205: JRC-GEM-E3 sectoral modelling results on imports 2050 (bn USD 2014)

	Baseline	MP Alignment	Proportionate Action	Maximum Feasibility
Crops	111.32	111.32	111.32	111.33
Coal	2.40	2.40	2.40	2.40
Crude Oil	196.35	196.35	196.31	196.27
Oil	83.60	83.60	83.58	83.56
Gas	68.27	68.27	68.24	68.24
Electricity supply	9.10	9.09	9.08	9.08
Ferrous metals	38.10	38.12	38.13	38.13
Other Non-ferrous metals	60.37	60.38	60.40	60.40
Chemical Products	461.90	461.86	461.93	461.92
Paper Products	30.10	30.10	30.10	30.10
Other Non-metallic minerals	80.28	80.29	80.29	80.29
Electric Goods	692.20	692.23	692.25	692.26
Transport equipment	298.26	298.26	298.27	298.27
Other Equipment Goods	81.80	81.90	82.16	82.17
Consumer Goods Industries	930.37	930.38	930.38	930.40
Construction	43.48	43.48	43.48	43.48
Transport (Air)	229.06	229.07	229.08	229.08
Transport (Land)	304.39	304.40	304.44	304.43
Transport (Water)	62.31	62.31	62.32	62.32
Market Services	1 263.97	1 263.91	1 263.77	1 263.77
Non-Market Services	186.44	186.43	186.43	186.43
Livestock	21.37	21.37	21.38	21.38
Forestry	8.99	8.99	8.99	8.99
Cement and Lime	1.88	1.88	1.88	1.88
Glass	12.79	12.79	12.79	12.79
Fertilizer	14.91	14.91	14.91	14.91
Aluminium	26.85	26.85	26.86	26.86

Table 206: JRC-GEM-E3 sectoral modelling results on investment 2030 (bn USD 2014)

	Baseline	MP Alignment	Proportionate Action	Maximum Feasibility
Crops	26.42	26.42	26.42	26.42
Coal	0.06	0.06	0.06	0.06
Crude Oil	0.13	0.13	0.13	0.13
Oil	1.72	1.72	1.72	1.72
Gas	0.94	0.94	0.94	0.94
Electricity supply	17.76	17.77	17.74	17.74
Ferrous metals	9.60	9.60	9.60	9.60
Other Non-ferrous metals	4.65	4.65	4.66	4.66
Chemical Products	135.21	135.21	135.22	135.22
Paper Products	30.43	30.43	30.43	30.43
Other Non-metallic minerals	22.21	22.21	22.21	22.21
Electric Goods	83.75	83.75	83.76	83.76
Transport equipment	45.00	45.00	45.00	45.00
Other Equipment Goods	33.85	33.81	33.90	33.91
Consumer Goods Industries	187.65	187.65	187.66	187.65
Construction	185.32	185.32	185.34	185.34
Transport (Air)	8.27	8.27	8.27	8.27
Transport (Land)	86.48	86.48	86.48	86.47
Transport (Water)	12.49	12.49	12.49	12.49
Market Services	2 062.27	2 062.30	2 062.28	2 062.29
Non-Market Services	433.12	433.11	433.14	433.14
Livestock	33.79	33.79	33.80	33.80
Forestry	23.03	23.03	23.03	23.03
Cement and Lime	3.16	3.16	3.16	3.16
Glass	5.16	5.16	5.16	5.16
Fertilizer	3.67	3.67	3.67	3.67
Aluminium	2.55	2.55	2.55	2.55
Power Generation	71.00	71.04	70.91	70.90

Table 207: JRC-GEM-E3 sectoral modelling results on investment 2050 (bn USD 2014)

	Baseline	MP Alignment	Proportionate Action	Maximum Feasibility
Crops	33.01	33.01	33.02	33.02
Coal	0.14	0.14	0.14	0.14
Crude Oil	0.89	0.89	0.89	0.89
Oil	11.62	11.62	11.62	11.62
Gas	1.16	1.16	1.16	1.16
Electricity supply	17.68	17.66	17.62	17.62
Ferrous metals	9.00	9.00	9.01	9.01
Other Non-ferrous metals	4.88	4.89	4.89	4.89
Chemical Products	161.61	161.61	161.63	161.63
Paper Products	34.12	34.12	34.12	34.12
Other Non-metallic minerals	25.51	25.52	25.52	25.52
Electric Goods	115.69	115.70	115.71	115.71
Transport equipment	52.70	52.70	52.70	52.70
Other Equipment Goods	43.28	43.32	43.37	43.37
Consumer Goods Industries	227.03	227.04	227.06	227.06
Construction	240.36	240.37	240.38	240.38
Transport (Air)	14.64	14.64	14.64	14.64
Transport (Land)	119.88	119.88	119.88	119.89
Transport (Water)	14.42	14.42	14.42	14.42
Market Services	2 829.73	2 829.74	2 829.96	2 830.02
Non-Market Services	552.36	552.36	552.40	552.40
Livestock	40.94	40.94	40.94	40.94
Forestry	29.57	29.57	29.55	29.55
Cement and Lime	3.71	3.71	3.71	3.71
Glass	6.02	6.02	6.02	6.02
Fertilizer	4.38	4.38	4.38	4.38
Aluminium	2.64	2.64	2.64	2.64
Power Generation	89.26	89.18	88.95	88.94

Table 208: JRC-GEM-E3 sectoral modelling results on employment 2030 (thousand persons)

	Baseline	**MP Alignment**	**Proportionate Action**	**Maximum Feasibility**
Crops	7 518	7 518	7 519	7 519
Coal	169	169	169	169
Crude Oil	118	118	118	118
Oil	120	120	120	120
Gas	99	99	99	99
Electricity supply	926	926	925	925
Ferrous metals	1 862	1 861	1 862	1 862
Other Non-ferrous metals	674	674	674	674
Chemical Products	8 322	8 322	8 323	8 323
Paper Products	3 245	3 245	3 245	3 245
Other Non-metallic minerals	2 161	2 161	2 161	2 161
Electric Goods	7 505	7 506	7 506	7 506
Transport equipment	5 048	5 049	5 048	5 048
Other Equipment Goods	5 335	5 328	5 342	5 343
Consumer Goods Industries	21 839	21 840	21 838	21 837
Construction	26 138	26 139	26 137	26 137
Transport (Air)	387	387	387	387
Transport (Land)	4 290	4 291	4 290	4 289
Transport (Water)	348	348	348	348
Market Services	48 138	48 141	48 135	48 135
Non-Market Services	35 884	35 884	35 883	35 883
Livestock	5 232	5 232	5 232	5 232
Forestry	1 419	1 420	1 419	1 419
Cement and Lime	537	537	537	537
Glass	766	766	766	766
Fertilizer	176	176	176	176
Aluminium	385	385	385	385
Power Generation	2 192	2 193	2 189	2 189

Table 209: JRC-GEM-E3 sectoral modelling results on employment 2050 (thousand persons)

	Baseline	MP Alignment	Proportionate Action	Maximum Feasibility
Crops	6 631	6 631	6 631	6 631
Coal	19	19	19	19
Crude Oil	66	66	66	66
Oil	99	99	99	99
Gas	96	96	96	96
Electricity supply	820	819	817	817
Ferrous metals	1 378	1 379	1 379	1 379
Other Non-ferrous metals	502	502	502	502
Chemical Products	6 937	6 936	6 937	6 937
Paper Products	2 675	2 675	2 676	2 676
Other Non-metallic minerals	1 718	1 718	1 718	1 718
Electric Goods	7 055	7 055	7 055	7 055
Transport equipment	4 336	4 336	4 336	4 336
Other Equipment Goods	4 786	4 790	4 795	4 795
Consumer Goods Industries	19 245	19 245	19 246	19 246
Construction	25 338	25 338	25 338	25 338
Transport (Air)	406	406	406	406
Transport (Land)	4 187	4 187	4 187	4 187
Transport (Water)	366	366	366	366
Market Services	47 722	47 721	47 723	47 724
Non-Market Services	34 158	34 158	34 159	34 159
Livestock	4 421	4 421	4 421	4 421
Forestry	1 499	1 499	1 498	1 498
Cement and Lime	428	428	428	428
Glass	614	614	614	614
Fertilizer	147	147	147	147
Aluminium	281	281	281	281
Power Generation	1 289	1 288	1 285	1 285

Table 210: JRC-GEM-E3 sectoral modelling results on consumption prices 2030 (percentage change vs. baseline)

	MP Alignment	Proportionate Action	Maximum Feasibility
Food beverages and tobacco	0.00	0.00	0.00
Clothing and footwear	0.00	0.00	0.00
Housing and water charges	0.00	0.00	0.00
*Fuels and power**	0.12	-0.26	-0.26
Household equipment and operation excl. heating and cooking appl	0.00	0.00	0.00
Heating and cooking appliances	-0.65	0.03	0.06
Medical care and health	0.05	0.04	0.05
Purchase of vehicles	0.00	0.01	0.02
*Operation of personal transport equipment**	0.00	0.01	0.01
Transport services	0.00	0.01	0.02
Communication	0.00	0.00	0.00
Recreational services	0.00	0.00	0.00
Miscellaneous goods and services	0.00	0.00	0.00
Education	0.00	0.00	0.00

Table 211: JRC-GEM-E3 sectoral modelling results on consumption prices 2050 (percentage change vs. baseline)

	MP Alignment	Proportionate Action	Maximum Feasibility
Food beverages and tobacco	0.00	0.00	0.00
Clothing and footwear	0.00	0.00	0.00
Housing and water charges	0.00	-0.01	-0.01
*Fuels and power**	-0.17	-0.68	-0.68
Household equipment and operation excl. heating and cooking appl	0.00	0.00	0.00
Heating and cooking appliances	-0.08	0.25	0.25
Medical care and health	0.03	0.03	0.03
Purchase of vehicles	0.00	0.05	0.05
*Operation of personal transport equipment**	0.00	0.03	0.03
Transport services	0.00	0.01	0.00
Communication	0.00	-0.01	-0.01
Recreational services	0.00	-0.01	-0.01
Miscellaneous goods and services	0.00	-0.01	-0.01
Education	0.00	-0.01	-0.01

Table 212: JRC-GEM-E3 sectoral modelling results on consumption quantities 2030 (percentage change vs. baseline)

	MP Alignment	Proportionate Action	Maximum Feasibility
Food beverages and tobacco	0.00	0.00	0.00
Clothing and footwear	0.00	0.00	0.00
Housing and water charges	0.00	0.00	0.00
*Fuels and power**	-0.01	0.13	0.12
Household equipment and operation excl. heating and cooking appl	0.00	0.00	0.00
Heating and cooking appliances	0.03	0.27	0.26
Medical care and health	-0.01	-0.02	-0.02
Purchase of vehicles	0.01	0.00	0.00
*Operation of personal transport equipment**	0.00	0.00	0.00
Transport services	0.01	-0.01	-0.01
Communication	0.00	0.00	0.00
Recreational services	0.01	0.00	0.00
Miscellaneous goods and services	0.01	0.00	0.00
Education	0.00	0.00	0.00

Table 213: JRC-GEM-E3 sectoral modelling results on consumption quantities 2050 (percentage change vs. baseline)

	MP Alignment	Proportionate Action	Maximum Feasibility
Food beverages and tobacco	0.00	0.01	0.01
Clothing and footwear	0.00	0.01	0.01
Housing and water charges	0.00	0.01	0.02
*Fuels and power**	0.09	0.29	0.30
Household equipment and operation excl. heating and cooking appl	0.00	0.01	0.01
Heating and cooking appliances	0.22	0.26	0.26
Medical care and health	-0.01	0.00	0.00
Purchase of vehicles	0.01	0.01	0.01
*Operation of personal transport equipment**	0.00	0.01	0.01
Transport services	0.00	0.01	0.01
Communication	0.00	0.01	0.01
Recreational services	0.00	0.01	0.02
Miscellaneous goods and services	0.00	0.01	0.02
Education	0.00	0.01	0.01

Table 214: JRC-GEM-E3 sectoral modelling results on CO_2 emissions 2030 (Mt CO2e)

	Baseline	MP Alignment	Proportionate Action	Maximum Feasibility
Crops	19.69	19.69	19.69	19.69
Coal	1.46	1.46	1.46	1.46
Crude Oil	1.12	1.12	1.12	1.12
Oil	64.97	64.97	64.96	64.95
Gas	6.27	6.27	6.27	6.27
Electricity supply	0.13	0.13	0.13	0.13
Ferrous metals	154.26	154.21	154.30	154.31
Other Non-ferrous metals	3.36	3.36	3.36	3.36
Chemical Products	72.69	72.69	72.69	72.69
Paper Products	13.09	13.09	13.09	13.09
Other Non-metallic minerals	18.29	18.29	18.29	18.29
Electric Goods	8.36	8.36	8.36	8.36
Transport equipment	4.45	4.45	4.45	4.45
Other Equipment Goods	5.79	5.78	5.79	5.80
Consumer Goods Industries	44.40	44.40	44.40	44.40
Construction	12.55	12.55	12.55	12.55
Transport (Air)	139.54	139.54	139.54	139.54
Transport (Land)	247.15	247.16	247.12	247.10
Transport (Water)	157.15	157.16	157.11	157.11
Market Services	64.30	64.30	64.30	64.30
Non-Market Services	28.19	28.19	28.19	28.19
Livestock	16.57	16.57	16.57	16.57
Forestry	9.09	9.09	9.09	9.09
Cement and Lime	129.79	129.79	129.79	129.79
Glass	14.03	14.03	14.04	14.04
Fertilizer	38.64	38.64	38.64	38.64
Aluminium	5.93	5.93	5.93	5.93
Coal fired	258.66	258.73	258.46	258.43
Oil fired (incl. derived gases)	76.67	76.71	76.59	76.58
Gas fired	172.02	172.12	171.82	171.79
CO2 Household Transport	342.61	342.62	342.61	342.60
CO2 Household Resid	212.33	212.32	212.53	212.52
Total	2 343.52	2 343.70	2 343.22	2 343.12

Table 215: JRC-GEM-E3 sectoral modelling results on CO_2 emissions 2050 (Mt CO2e)

	Baseline	MP Alignment	Proportionate Action	Maximum Feasibility
Crops	18.13	18.13	18.13	18.13
Coal	0.73	0.73	0.73	0.73
Crude Oil	0.60	0.60	0.60	0.60
Oil	45.35	45.35	45.34	45.33
Gas	6.28	6.28	6.28	6.28
Electricity supply	0.08	0.08	0.08	0.08
Ferrous metals	93.20	93.23	93.25	93.25
Other Non-ferrous metals	2.56	2.56	2.56	2.56
Chemical Products	41.28	41.27	41.28	41.28
Paper Products	10.09	10.09	10.09	10.09
Other Non-metallic minerals	13.59	13.59	13.60	13.60
Electric Goods	9.44	9.44	9.44	9.44
Transport equipment	4.30	4.30	4.30	4.30
Other Equipment Goods	6.22	6.23	6.23	6.23
Consumer Goods Industries	38.80	38.80	38.80	38.80
Construction	8.35	8.35	8.35	8.35
Transport (Air)	143.94	143.95	143.96	143.96
Transport (Land)	202.17	202.17	202.16	202.18
Transport (Water)	180.43	180.42	180.43	180.43
Market Services	48.13	48.13	48.13	48.13
Non-Market Services	20.36	20.36	20.36	20.36
Livestock	13.34	13.34	13.34	13.34
Forestry	8.46	8.45	8.45	8.45
Cement and Lime	104.93	104.93	104.93	104.94
Glass	11.15	11.15	11.15	11.15
Fertilizer	29.21	29.21	29.21	29.21
Aluminium	4.46	4.46	4.46	4.46
Coal fired	12.75	12.74	12.73	12.73
Oil fired (incl. derived gases)	60.95	60.90	60.77	60.76
Gas fired	168.64	168.49	168.08	168.07
CO2 Household Transport	201.75	201.75	201.76	201.76
CO2 Household Resid	152.82	152.92	153.15	153.15
Total	1 662.48	1 662.40	1 662.13	1 662.13

Annex 5: Background data on considered measures

Annex 5.1: Background data on options for the FGR HFC POM phase-down

Table 216: Options for the FGR phase-down schedule for the maximum quantity of HFCs placed on the EU27 market [t CO2e]

	Baseline	MP alignment	proportionate action	maximum feasibility
	quota-exempted sectors as under FGR 2014/517; constant extrapolation assumed for 2030ff.	quota exemption for MDIs lifted as of 2024	quota exemption for MDIs lifted as of 2024	quota exemption for MDIs, semiconductors and military lifted as of 2024
	t CO2e	t CO2e	t CO2e	t CO2e
2021 - 2023 (under the existing FGR 2014/517)	62 273 330	62 273 330	62 273 330	62 273 330
2024 - 2026	37 535 263	49 035 263	41 701 077	41 039 167
2027 - 2029	25 166 229	36 666 229	17 688 360	15 963 275
2030 - 2032	19 865 215	31 365 215	9 132 097	6 916 849
2033 - 2035	19 865 215	28 717 529	8 445 713	5 794 785
2036 - 2018	19 865 215	20 538 147	6 782 265	5 467 823
2039 - 2041	19 865 215	20 538 147	6 136 732	5 006 355
2042 - 2044	19 865 215	20 538 147	5 491 199	4 544 888
2045 - 2047	19 865 215	20 538 147	4 845 666	4 083 420
2048 onwards	19 865 215	20 538 147	4 200 133	3 621 953

Annex 6: Comparison of the FGR POM phase-down with the MP consumption phase-down

This annex discusses the likelihood of EU compliance with the HFC consumption phase-down under the MP given the present HFC POM phase-down under the EU F-gas Regulation (FGR).

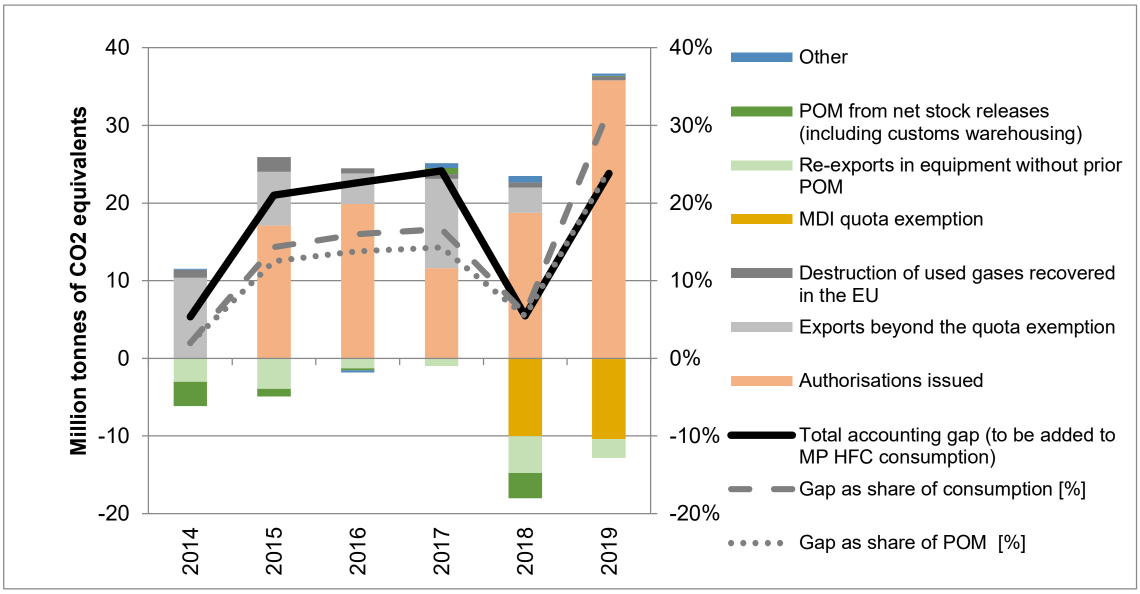
For that purpose, the consumption and POM metrics are compared, the EU27 pathways after Brexit under MP and FGR are quantified and two scenarios for EU27 consumption under the FGR POM limitation are developed.

We conclude that FGR POM phase-down does safeguard EU compliance with the MP consumption phase-down until 2030. However, for ensuring MP compliance also following the final MP reduction steps due in 2034 and 2036, the ambition of the FGR phase-down will need to be increased beyond the level presently set for 2030.

Annex 6.1: Comparison of consumption and POM metrics

The ***consumption*** metric used under the Montreal Protocol (MP) considerably deviates in definition from the ***placing on the market (POM)*** metric used under FGR phase-down. For a fully comparison, please refer to Annex 4 of the 2020 EEA-Gas-Report. Figure 16 identifies on EU28-level the most relevant transactions to be added (positive bars) or subtracted (negative bars) to consumption in order to derive the quota-relevant (=non-exempted) POM under the FGR. 2014 through 2019, EU28 quota-relevant POM of HFCs has always been higher than HFC consumption. However, this relation cannot be taken for granted, subject to further development of those activities that are accounted for differently under both metrics.

Figure 16: Accounting Gap: non-exempted POM vs. MP HFC consumption (EU-28)



Source: Confidential BDR dataset 2020, calculations by Öko-Institut

The transactions contributing most to the difference between EU28 HFC POM and consumption since 2014 have been:

- The amount of quota authorisation issued by quota holders to importers of refrigeration, air-conditioning and heat pump (RACHP) equipment pre-charged with HFCs. Under the FGR rules those amounts are accounted as POM at the point in time of issuing the authorisation. The actual import of RAC equipment may take place in later years.

- The amount of HFCs placed on the EU market under the MDI quota exemption (FGR Art 15(2)f).
- Bulk exports from the EU for which no quota exemption (FGR Art 15(2)c) was claimed by the respective producers or importers
- Re-export in equipment of imported HFC, where the HFCs had not been placed on the EU market prior to the export (inwards processing customs procedure)
- Destruction of HFCs recovered from installations in the EU
- Change in turn-of-year stocks of HFCs not yet placed on the EU market (net stock increases to be subtracted; net stock decreases to be added to consumption in order to derive POM)

Further transactions accounted differently for both metrics, but so far quantitatively hardly important, are in descending order of relevance:

- RAC equipment imports not covered by authorisations
- Net imports / exports of pre-blended polyols
- HFC-23 emissions in production facilities
- Semiconductor manufacturing quota exemption (FGR Art 15(2)e)
- Destruction of imports beyond the FGR exemption (FGR Art 15(2)a)
- Military use quota exemption (FGR Art 15(2)d)
- Net imports from / exports to dependent EU overseas territories
- POM of non-HFC shares of HFC mixtures
- MP exempted Feedstock Use beyond FGR exempted Feedstock use (FGR Art 15(2)b)
- Net Imports of reused/recycled HFCs
- HFC-161 consumption

Annex 6.2: EU consumption and POM limitations after Brexit

After the United Kingdom's withdrawal from the European Union (Brexit) the HFC reduction schedules both under the MP and under the FGR needed to be recalculated. As the Brexit transition period ended on 31st December 2020, the adapted ceilings apply as of 2021.

For the HFC consumption phase-down, the EU and the UK agreed on 11.2 % UK share to be applied to the common EU28 baseline established under the MP[27]. That UK share had been derived in an extensive data collection exercise by the EU and by the UK on the years 2015-2017.

Under the FGR phase-down, recalculation were made by DG CLIMA in the context of the quota allocation for 2021 and the respectively recalculation of the maximum quantity (MaxQ) for 2021: The UK share established in that context for EU28 POM in the 2009-2012 baseline period was 5.1 %[28]. The UK share in 2014-2017 quota exemptions, as used in the calculation of the MaxQ, was established as 3.9 %. Given the MaxQ calculation rules established in the FGR, the 2021 MaxQ for the EU27 was thus 5.4 % below the value that would have resulted for the EU28[29].

[27] Source: Communication by DG CLIMA to the UNEP Ozone Secretariat, ARES(2021)2167756 of 29/03/2021

[28] This share considerably differs from the 11.2 % share agreed under the MP because it is based only on data collected by the EU from UK companies for the years 2015-2017, and from EU28 companies for the years 2018 and 2019. However, data collected by the UK on HFC supplies to the UK by EU27 companies in the years 2015-2017 were not considered for this EU-internal exercise.

[29] Until 2030, that 'UK share in the EU28 MaxQ' is bound to increase to 6.1 %.

The respectively calculated quantities are summarised in Table 217:

Table 217: EU28 / EU27 HFC reduction schedules under FGR and MP

		EU HFC POM phase-down under the FGR		EU HFC consumption phase-down under the MP	
Year	EU scope	reduction schedule (2009-2012 baseline with separate consideration of quota exemptions)	Maximum Quantity of HFCs under FGR [Mt CO2e]	reduction schedule relative to 2011-2013 baseline	HFC consumption limit under the MP [Mt CO2e]
2015	EU 28	100 %	183.1	not defined	
2016		93 %	170.3	not defined	
2017		93 %	170.3	not defined	
2018		63 %	101.2	not defined	
2019		63 %	100.3	90 %	165.8
2020		63 %	100.3	90 %	165.8
2021	EU27	45 %	62.3	90 %	147.2
2022		45 %	62.3	90 %	147.2
2023		45 %	62.3	90 %	147.2
2024		31 %	37.5	60 %	98.2
2025		31 %	37.5	60 %	98.2
2026		31 %	37.5	60 %	98.2
2027		24 %	25.2	60 %	98.2
2028		24 %	25.2	60 %	98.2
2029		24 %	25.2	30 %	49.1
2030		21 %	19.9	30 %	49.1
2031		not defined		30 %	49.1
2032		not defined		30 %	49.1
2033		not defined		30 %	49.1
2034		not defined		20 %	32.7
2035		not defined		20 %	32.7
2036 ff.		not defined		15 %	24.5

Annex 6.3: Scenarios for EU HFC consumption resulting from the FGR POM phase-down

The EU (quota-relevant) POM as limited by the MaxQ under the FGR cannot be recalculated into future HFC consumption in an exact way, as both metrics are partly determined by differing transactions of EU industries (see section 0). For an assessment of the likelihood that the FGR POM phase-down will safeguard MP compliance, a ‘low-consumption’ scenario and a ‘high-consumption’ scenario are developed to ‘translate’ future EU POM, assumed to be compliant to the MaxQ as given in Table 217, into HFC consumption to be measured against the limitations under the MP: For each of transactions found to be quantitatively relevant for the accounting gap between consumption and POM in the years

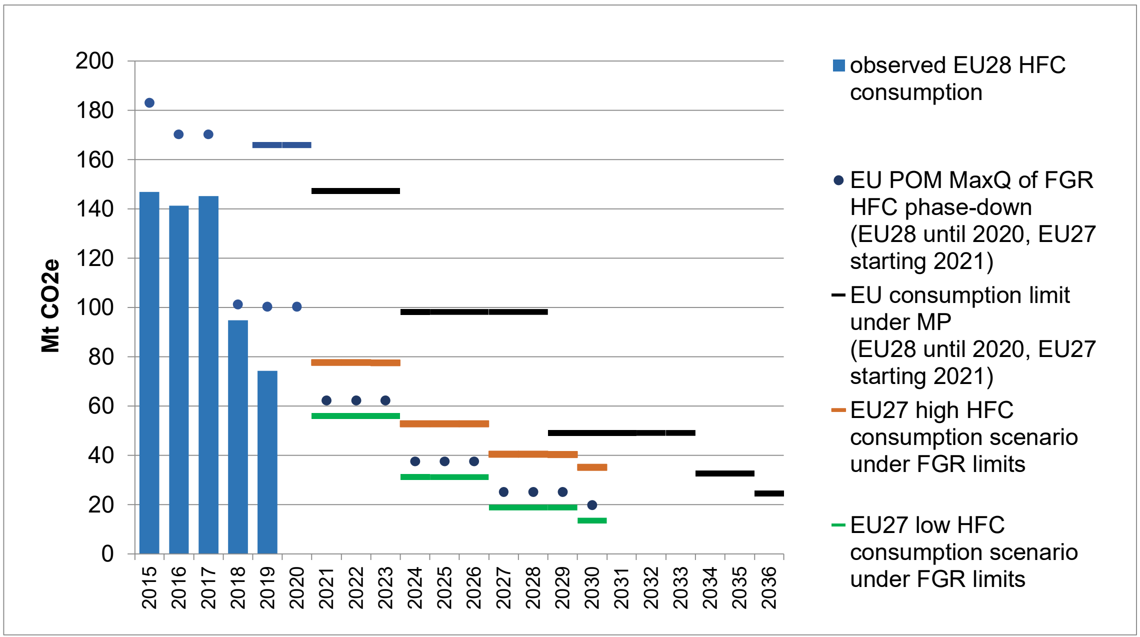
2014-2015, a high-consumption assumption and a low-consumption assumption is made in Table 218, based on evidence found for in 2014-2019.

Table 218: Assumptions for key transactions in low- and high-consumption scenarios for the EU27 2020-2030

Parameter	Coverage in low consumption scenario	Coverage in high consumption scenario	Comment
Development of HFC imports in pre-charged RAC equipment	Constant at 11.3 Mt CO_2e/year	decline proportional to FGR phase-down schedule: reduction from 11.4 (2020) to 4.4 Mt CO_2e (2030)	
Issue of additional quota authorisation beyond established bank	Constant at 5.7 Mt CO_2e/year	Almost constant at about 0.2 – 0.3 Mt CO_2e per year	By the end of 2020 the EU28 bank of authorisation amounted to 60.2 Mt CO2e of which 4.9 Mt CO_2e were re-allocated by holders to the UK quota system with the end of the Brexit transition period. Bank by the end of 2030 assumed to equal 2030 equipment imports.
Physical quota-relevant POM	Decline from 56.6 (2021) to 14.2 Mt CO_2e (2030)	Decline from 62.1 (2021) to 19.5 Mt CO_2e (2030)	All available quota not needed for authorisations assumed to be used for physical POM
Quota-exempted supply for MDIs	Constant at 6 Mt CO_2e/year	Constant at 12 Mt CO_2e/year	Including approx. 0.5 Mt CO_2e/year for quota exemptions for semiconductor manufacturing and military use
Bulk export beyond the quota exemption	Constant at 4 Mt CO_2e/year	Constant at 0 Mt CO_2e/year	
Re-export in equipment of imported gases, prior to POM (inwards processing)	Constant at 0.3 Mt CO_2e/year	Constant at 4 Mt CO_2e/year	
Downstream destruction beyond the quota-exemption	Constant at 3 Mt CO_2e/year	Constant at 0.5 Mt CO_2e/year	
Stocks effects	Constant at 0 Mt CO_2e/year	Constant at 0 Mt CO_2e/year	Neglected as this relates to inter-annual variations
Other	Constant at 0 Mt CO_2e/year	Constant at 0 Mt CO_2e/year	neglected

The calculated EU HFC consumption scenarios are summarised in Figure 17 and Table 219:

Figure 17: EU HFC consumption scenarios under the FGR POM limitation



Source: Confidential BDR dataset 2020, calculations by Öko-Institut

Table 219: EU HFC consumption scenarios under the FGR POM limitation

Year	EU scope	EU HFC consumption limit under the MP [Mt CO2e]	EU HFC consumption: low consumption scenario under FGR POM limitation [Mt CO2e]	EU HFC consumption: high consumption scenario under FGR POM limitation [Mt CO2e]
2021	EU27	147.2	55.9	77.6
2022		147.2	55.9	77.6
2023		147.2	55.9	77.5
2024		98.2	31.2	52.8
2025		98.2	31.2	52.7
2026		98.2	31.2	52.7
2027		98.2	18.8	40.4
2028		98.2	18.8	40.3
2029		49.1	18.8	40.3
2030		49.1	13.5	35.0
2031		49.1	not defined	
2032		49.1	not defined	
2033		49.1	not defined	
2034		32.7	not defined	
2035		32.7	not defined	
2036 ff.		24.5	not defined	

It is apparent that an EU compliance with the FGR POM phase-down will safeguard EU compliance with the MP HFC phase-down until 2030. In the low consumption scenario, EU 2030 consumption would reach a level significantly below the even the lowest step of the MP consumption phase-down due in 2036: EU 2030 HFC consumption would already be about 9 Mt CO_2e or 45% below that 2036 MP limitation. In the low-consumption scenario, a mere prolongation of the FGR POM phase-down beyond 2030 without increased ambition would thus suffice to provide compliance with the MP consumption phase-down.

However, in the high consumption scenario the EU consumption level reached in 2030 is higher than the MP limit as of 2034 by about 2 Mt CO_2e or 7 % and higher than the 2036 MP limit by about 10 Mt CO_2e or 40 %. In the high-consumption scenario, a significant increase of ambition in the FGR POM phase-down after 2030 is thus necessary to ensure MP compliance also after the latest MP reduction steps due 2034 and 2036. It should be noted that lifting the FGR quota exemption for MDIs (estimated at 12 Mt CO_2e/year in the high-consumption scenario or 6 Mt CO_2e/year in the low-consumption scenario) would suffice to provide that necessary rise in ambition.

Annex 6.4: Conclusion on EU compliance with the MP HFC consumption phase-down

The FGR POM phase-down does safeguard EU compliance with the MP consumption phase-down until 2030. For ensuring MP compliance also following the final MP reduction steps due in 2034 and 2036, the ambition of the FGR phase-down will need to be increased beyond the level presently set for 2030.

The degree of the necessary rise in ambition cannot be expressed in the metric of (quota-relevant) POM, but rather as 10 Mt CO_2e of HFC consumption, equivalent to 30 % of 2030 HFC consumption in the high-consumption scenario.

Annex 7: Administrative burden (SCM) – detailed tables

Annex 7.1: Industry

Table 220: Detail of the calculation and assumptions

Objective	Policy Measure	Scenario	Number of companies	Days/Year per Company	Total Days (Annual)	Total Days (One-off)	Total Annual Cost (EUR,M)	Total One Off Cost (EUR, M)	Explanation
A2.10	Apply requirements for prevention of emissions of fluorinated gases to some substances listed in Annex II	Policy Option 1: MP Alignment	Total: 13,075 User size not applicable to costs	Large: 1 Medium: 1 Small: 1	N/A	13,075	-	3	The policy measure is associated with 'Article 3 (Prevention of emissions)' and the costs are therefore expected to be predominately compliance costs. The number of companies impacted will be based upon the number of users of SO2F2, anaesthetics, NF3 and HCFO's. The bulk of the users are related to the use of anaesthetics. Based on data reported by the European Hospital and Healthcare Foundation, there are approximately 2.9 hospitals per 100,000 inhabitants. Based upon the current population of the EU this would equate to approximately 13,000 hospitals. The use of SFOF2 (predominately logistics companies for wood storage and fumigation), NF3 (solar /PV energy and semi-conductor industry) and HCFO's (refrigeration sector/EV battery cooling) represent only a small number of EU users, estimated to be approximately 50 – 100. A small one-off administrative cost is expected to record the implementation of the new equipment necessary to prevent a leakage of emissions. This cost is expected to be approximately 1 day, and will be consistent across all users regardless of size. There are not expected to be any ongoing reporting requirements associated with the policy measure.
A2.11	Apply requirements for prevention of emissions of F-gases to manufacturing, transport, transfer and storage of bulk gases also to non-producers	Policy option 2: Proportionate Action	Total: 19,016 Large: 1711 Medium: 380 Small: 13,501	Large: 1 Medium: 1 Small: 1	19,016	-	4.4	-	As a result of the policy measure, the requirement will be extended to service companies, importers and distributors. Although the measure will be a legal requirement, it is already considered to be best practice within industry, and therefore it is estimated that approximately 85% of relevant companies will not be impacted. The number of service companies has been based a survey by AREA and complementary information from MS authorities. . The number of importers has been based upon BDR reporting, and the number of distributors through expert judge-

Objective	Policy Measure	Scenario	Number of companies	Days/Year per Company	Total Days (Annual)	Total Days (One-off)	Total Annual Cost (EUR,M)	Total One Off Cost (EUR, M)	Explanation
									ment of the sector. The administrative burden has been estimated to be approximately 1 day linked to identifying and regular checking of processes in place to avoid emissions". The breakdown of company size has been based upon a German industrial survey determining the number of employees at German service operators.
B2.2	Remove the limit for reporting on production, import, export and destruction of Annex I and II gases (HFCs only)	Policy Option 1: MP Alignment	Total: 100 Large:1 Medium:4 Small:94	1 day	100	-	0.02	-	The removal of the reporting limit is expected to impact approximately 100 companies. This has been based upon checks conducted by of the Polish CBR database for imports/exports (to which no threshold applies) for which no entries were found which were below the current threshold definition. Production & destruction below the threshold are very unlikely (as those who operate such facilities have higher amounts per year). It has therefore been concluded that there will be a very low number of affected companies: Those companies affected would be those which buy a few bottles per year abroad. The policy change would require these additional companies to now submit an additional report, with an expected additional administrative burden of approximately three days expected over the course of the year for a medium sized company, based upon current reporting costs and the fact that the report will consist of very little input data.
C1.1 & C1.2	F-gas certification programmes also to include HCFOs and F-gas free alternatives and practical training on all alternatives and add energy efficiency issues to be part of training (stationary RACHP)	Policy Option 2: Proportionate Action	Total:125,649 Large: 1,425 Medium: 5,101 Small: 119,122	Large: 6 Medium: 2 Small: 0.6	90,225		20.8		The number of companies impacted is based upon the number of company certificates in the RACHP sector as determined by a survey by AREA and complementary information from MS authorities. Large companies are expected to train 3 employees per year, medium sized companies 1 and small companies between 0 – 1 employee. These extra costs may also be regarded as compliance costs and following the training is not explicitly required, only certification is.
C1.1 & C1.2	F-gas certification programmes also to include HCFOs and F-gas free alternatives and practical training on all alternatives and	Policy Option 2: Proportionate Action	Total:125,649 Large: 1,425 Medium: 5,101 Small: 119,122	0.2 (a couple of hours per company only)	25,130		5.8		The number of companies impacted is based upon the number of company certificates in the RACHP sector as determined by a survey by AREA and complementary information from MS authorities. The current administrative costs linked to certification are based upon data collected through stakeholder engagement for the evaluation of the Regulation. Certification will become more

Objec-tive	Policy Measure	Scenario	Number of com-panies	Days/Year per Com-pany	Total Days (Annual)	Total Days (One-off)	Total An-nual Cost (EUR,M)	Total One Off Cost (EUR, M)	Explanation
	add energy efficiency issues to be part of training (stationary RACHP)								expensive for those companies that wish to train their personnel in the future, as the training is more extensive (practical training) and the scope is wider. True admin costs related to obtaining and presenting certificates are very small. The requirement C1.3 to in-stall etc. stat RAC only by certified personnel only has an addi-tional bearing if such equipment holds pure HCFOs, rather than HFC blends with HCFOs which are already covered by today's obli-gations. This is the case in very few applications. The administra-tive cost linked to energy efficiency issues are expected to be very minor as this will entail only an additional aspect of the training curriculum.
C3.1	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	Policy Option 1: MP Align-ment	Total: 204 Large: 2 Medium: 8 Small: 193	Large: 1 Medium:1 Small:1	204	-	0.05	-	Administrative burden for those respecting the rules and using best practice as importers will not be impacted as companies should be using re-fillable cylinders for HCFOs. The number of companies impacted has been based upon the number of bulk importers registered in 2019 based on BDR reporting. It has been estimated that approximately 5% of importers are not currently conducting best practice and will therefore incur additional ad-ministrative cost. The admin burden upon these companies is ex-pected to be minimal, with the burden more significant for public authorities required to enforce the policy.
C3.3	Mandatory registra-tion in the HFC Regis-try for importers and exporters of bulk HFCs under all cus-toms procedures, prior to importing/ex-porting	Policy Option 3: Maximum Feasibility	Total: 19,016 Large: 1711 Medium: 380 Small: 1,350	Large: 1 Medium: 1 Small:1	19,016	-	4.4		The number of companies impacted has been aligned with policy option A2.11.Based on expert judgement an admin burden of ap-proximately 1 day per company is expected.
C3.4	Add obligation for certification for natu-ral persons and un-dertakings selling bulk F-gases online	Policy Option 3: Maximum Feasibility	Total: 500 Large:7 Medium: 20 Small: 473	Annual: 0.2 (a cou-ple hours	100	3063	0.02	0.7	As noted in Commission Implementing Regulation EU 2015/2067 there are currently four categories relating to environment-friendly handling of the system and refrigerant during installation, maintenance, servicing or recovery and leakage checks. The policy option will require company compliance with category III. The

Objective	Policy Measure	Scenario	Number of companies	Days/Year per Company	Total Days (Annual)	Total Days (One-off)	Total Annual Cost (EUR,M)	Total One Off Cost (EUR, M)	Explanation
				per company only) One Off: Large:10 Medium: 8 Small: 6					number of companies involved in selling F-gases online has been based upon desk-based research through examining the number of sellers on sites such as Alibaba. The administrative costs linked to certification were based upon expert understanding of the costs of the activity.
C3.5	Add obligation for documentation for downstream sales for bulk HFC/F-gases (e.g. "declaration of conformity") and record keeping	Policy Option 3: Maximum Feasibility	Calculated based upon costs to German industry rather than to specific companies.	n/a:	1641	-	0.38	-	The policy option is expected to lead to an increase in administrative costs across all actors in the supply chain, including service companies and gas distributors. The policy has been adopted by the German government. As a result of the policy option, additional administrative costs are anticipated as a result of the need for companies to submit further documentation. The estimated costs have been based upon costs accrued by German industry, as this requirement has been previously adopted by the German government. The costs have been attributed to bureaucratic costs from information obligations and estimated to be an annual cost of 70,000 EUR. The costs for the German economy have been extrapolated across the EU based upon population size to give an estimated total annual cost of 377,500 EUR. This is the equivalent of 1,641 days per year a rate of 230 EUR per day.
C3.6	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	Policy Option 1: MP Alignment	Total: 1694 Large: 19 Medium: 69 Small:1606	Large:1 Medium: 1 Small: 1	1694	-	0.39	-	The policy option will require exporters and importers to schedule trade to ensure that their quotas are not over-exceeded. This could, for instance, lead to a delay in importing (to ensure the correct amount has been exported) and a subsequent administrative cost will be associated with ensuring this is planned. The number of companies impacted has been based upon the number of reporting bulk importers in 2020 as determined through the BDR database. The administrative impact of undertaking the additional planning is expected to be approximately 1 day for a medium sized company based upon expert judgement.
C3.7	Add obligation for importers to have quota-exempted quantities labelled during POM/physical entry into territory	Policy Option 1: MP Alignment	Total: 65	Large:1 Medium: 1 Small: 1	65	-	0.01	-	The policy option will extend the labelling requirements for importers across all sectors. As importers are already required to comply with labelling requirements, the policy is expected to lead to only a minimal additional burden for companies based upon additional labelling requirements for previously exempted gases.

Objec-tive	Policy Measure	Scenario	Number of com-panies	Days/Year per Com-pany	Total Days (Annual)	Total Days (One-off)	Total An-nual Cost (EUR,M)	Total One Off Cost (EUR, M)	Explanation
	and that gases must be explicitly labelled as "exempted from quota"								This is expected to impact approximately 65 companies., with the equivalent number of companies impacted by the measure C5.4 .
C3.8	Strengthen the obli-gation on destruction of HFC-23 by-produc-tion	Policy option 2: Proportion-ate Action	Total:1694 Large: 19 Medium: 69 Small:1606	Large:2 Medium: 0.5 Small: 0.3 Small: 0.1	552	-	0.1	-	The policy option will lead to a small additional administrative burden for importers as additional information will be required to be provided. The administrative burden of this policy is however expected to be small and will require only outlining additional in-formation to document compliance (for compliant companies).
C4.2	Align the establish-ment of the annual declaration-based quota allocation with the frequency of the quota allocation based on reference values	Policy Option 1: MP Align-ment	Total: 1800 Large:20 Medium: 73 Small: 1707	Large: 3 Medium: 3 Small: 3	-5,400		-1.2	-	Annual quota application requirements will be required once every three years, leading to a reduction in administrative burden for reporting companies. This will lead to a reduction in adminis-trative for the estimated 1800 current quota holders. . Based upon stakeholder and an understanding of the expected cost of the measure a time saving of 3 days per year is expected.
C4.3	Introduction of a reg-istration fee and/or quota allocation price linked to CO2 equiva-lents	Policy option 2: Proportion-ate Action	Total: 2,000 Large: 23 Medium: 81 Small: 1,896	Large:5 Medium: 3 Small: 1	2,253		0.5		The admin burden is linked to the requirements for companies having to pay for their quota. The number of companies impacted is estimated to be 2000 quota companies (aligned with measure C5.2), The admin burden is due to making internal consultations and arrangements that in order for amounts of money to be transferred.
C5.1	Labelling require-ments for HFCOs, NF_3, SO_2F_2 and anaesthet-ics.	Policy option 2: Proportion-ate Action	Total: 20 Large: 20	Large:3	60		0.01		Extending the labelling requirements for the gases HFCOs, NF_3, SO_2F_2 and anaesthetics will lead to an increase in administrative costs for a small number of producers and importers. The produc-tion and importation of these gases is considered relatively un-common, with, for example, only one producer for SO_2F_2 known to reside within the EU. The additional costs are therefore ex-pected to impact approximately 10 – 20 companies, all of which would be expected to be large. The administrative cost associated with the labelling requirements has been based upon a mixture of expert judgement of labelling costs and consideration of stake-holder feedback for the evaluation of the Regulation.

Objective	Policy Measure	Scenario	Number of companies	Days/Year per Company	Total Days (Annual)	Total Days (One-off)	Total Annual Cost (EUR,M)	Total One Off Cost (EUR, M)	Explanation
C5.2	Registration and reporting obligation for exporters of products and equipment containing F-gases and other fluorinated substances	Policy Option 3: Maximum Feasibility	Total: 2,000 Large: 23 Medium: 81 Small: 1,896	Large:15 Medium: 4 Small:0.5	1,581	-	0.4	-	Based on expert judgement a significant number of companies are expected be impacted by the policy option, with an estimate of 2000 companies expected to be impacted. The costs of registration and reporting are estimated to be 4 days based initially upon stakeholder feedback indicating the number of days required for reporting under article 19 and revised downward based on judgement of the costs for the policy option.
C5.3	Reporting obligation for recipients of quota-exempted HFCs	Policy option 2: Proportionate Action	Total: 65 Large: 45 Medium: 13 Small: 7	Large:4 Medium: 1 Small:0.5	188	-	0.04	-	The additional requirement is expected to impact approximately 65 companies based upon reporting assessed inthe BDR database. The administrative burden is expected to be minimal, with a small report required only. The breakdown of companies by size has been based upon expert judgement of the sector, and knowledge that the majority of the companies impacted will be large.
C5.4	Reporting obligation for undertakings performing reclamation of F-gases	Policy option 2: Proportionate Action	Total: 50 Large:35 Medium:10 Small:5	Large:2 Medium: 1 Small: 0.5	83	-	0.02	-	The policy option will lead to an increased admin burden for both companies reporting on reclamation. In terms of companies reporting on reclamation it is estimated that approximately 50 companies will be affected, based upon expert judgement. An annual administrative cost of approximately 1 day per year is expected to account for the additional reporting for a medium sized company. Reclamation companies can be assumed to have already in place an internal monitoring system on the data to be reported and thus the cost is expected to be smaller than for recycling companies. The breakdown of companies by size has been based upon expert judgement of the sector, and knowledge that the majority of the companies impacted will be large.
C5.5	Reporting obligation for undertakings performing recycling of F-gases	Policy Option 3: Maximum Feasibility	Total: 750 Large: 9 Medium: 30 Small: 711	Large:5 Medium: 3 Small: 1	845		0.2	-	A larger number of companies reporting on recycling will be impacted, with an estimate of 750 companies expected to be impacted, based upon the current number of certified technicians and expert judgement. The annual cost for recycling companies is expected to be higher than for reclamation and has been based upon expert judgement of the sector.
C5.6	Reporting obligation for operators of HV switchgear and electrical equipment (< 52 kV) with regard to SF6	Policy Option 3: Maximum Feasibility	Total: 2475 Large:28 Medium:100 Small:1016	Large:5 Medium: 3 Small: 1	2788	-	0.6	-	The administrative burden will apply to the switchgear sector and decommissioning companies. In addition, the policy will also impact distribution grid operators. Based on expert judgement there is expected to be a 5 day/year administrative burden associ-

Objective	Policy Measure	Scenario	Number of companies	Days/Year per Company	Total Days (Annual)	Total Days (One-off)	Total Annual Cost (EUR,M)	Total One Off Cost (EUR, M)	Explanation
	emissions during lifetime and for operators in cooperation with certified personnel of electrical equipment for decommissioning of such equipment								ated with this requirement for a large sized company. The administrative burden is primarily associated with the installation of new equipment which will now need to be accounted for. The switchgear sector is estimated to account for approximately 50 - 100 companies, and 2400 distribution grid operators.
C5.7	Lower the threshold for verification of bulk HFCs placed on the market	Policy Option 1: MP Alignment	Total: 1,072 Large: 12 Medium: 44 Small: 1,016	Large: 6 Medium: 4 Small: 2	2295	-	0.5	-	The current threshold has been set at >10,000t CO2e, with the threshold set to be lowered to >1,000t CO2e. The current number of companies impacted is estimated to be 19% of quota holders (estimated to be 19% of 1800 companies). Following the reduction of the threshold, the number of companies impacted is expected to increase to 86% of quota holders. It should also be noted that approximately 134 companies are known to be voluntarily reporting in 2020, and therefore the potential additional cost to these companies has been removed as they are already incurring the burden. The additional costs for the companies impacted is estimated to be 1000 - 3000 EUR per year (based on feedback collected through consultation with an auditor) which has been converted into days per year based on a rate of 230 EUR per day.
C5.8	Add obligation to submit verification reports for bulk HFCs	Policy Option 1: MP Alignment	Total: 1694 Large: 19 Medium: 69 Small: 1606	Large: 0.5 Medium: 0.5 Small: 0.5	847	-	0.2	-	The obligation to record the information is already included within the current Regulation and therefore the obligation to submit this will only lead to a small increase in administrative burden. Based on expert judgement this will be estimated to impact approximately 2000 companies.
C5.9	Partially align reporting thresholds for placing on the market products and equipment with bulk thresholds	Policy Option 1: MP Alignment	Total: 41 Large: 1 Medium: 2 Small: 38	Large:5 Medium: 3 Small:1	46	-	0.01	-	The reporting threshold is changing from 500 t CO2e of Annex I & II to 100 t CO_2e of HFCs or 500 t CO_2e of Annex I & II. This is expected to likely impact a small number of companies which import equipment now captured by the amended threshold. The total number of importers has been based upon data from BDR reporting. The reporting requirements are estimated to be approximately 5 days/year for all sized companies.
C5.9		Policy Option 3: Maximum Feasibility	Total: 100 Large: 1	Large:5 Medium: 3	113	-	0.03	-	The reporting threshold is changing from 500 t CO2e of Annex I & II to 1t / 100 t CO2e

Objective	Policy Measure	Scenario	Number of companies	Days/Year per Company	Total Days (Annual)	Total Days (One-off)	Total Annual Cost (EUR,M)	Total One Off Cost (EUR, M)	Explanation
			Medium: 4 Small: 95	Small:1					of Annex I & II. This is expected to impact likely to additionally affect approximately 50-100 companies which import equipment using low-GWP annex II gases then captured by the 1 t/year threshold. The reporting requirements are estimated to be approximately 5 days/year for all sized companies.
C5.9	Raise verification thresholds for placing on the market products and equipment to align with bulk threshold	Policy Option 1: MP Alignment	Total: -1428 Large: -16 Medium: -58 Small: - 1,354	Large:10 Medium: 8 Small:6	-7395 -		-1.7		The current de-facto threshold of 100t CO_2e threshold is increased to 1,000 t CO_2e. The total number of companies will reduce from 83% of importers to 48% of importers. The total number of importers has been based upon data from BDR reporting. The verification requirements are estimated to be approximately 10 days/year for a large sized company.
C5.9		Policy Option 3: Maximum Feasibility	Total: -898 Large: -10 Medium: -37 Small: -851	Large:10 Medium: 8 Small:6	-4650	-	-1.1	-	The current de-facto threshold of 100t CO_2e threshold is increased to 500 t CO_2e. The total number of companies will reduce from 83% of importers to 61% of importers. The total number of importers has been based upon data from BDR reporting. The reporting requirements are estimated to be approximately 10 days/year for a large sized company.
C5.10	Align reporting and verification dates (separately for bulk and pre-charged products and equipment)	Policy Option 1: MP Alignment	Total: 6,535 Large: 74 Medium: 265 Small: 6,196	Negligible	Negligible	-	Negligible	-	For bulk, the accuracy of the data is verified by an independent auditor by 30 June each year, while reporting is, however, set to take place by 31 March each year. For equipment, it is 31 March for both. The option relaxes the time to deliver the verification to may (for equipment) and anticipates it for bulk. The additional costs for companies is expected to be minimal as companies will undertake the verification shortly after data has been collected (and reported). It will nominally impact time pressures only and will not represent an additional burden for reporting companies.
C5.11	Add legal basis for electronic verification process (separately for bulk and pre-charged products and equipment)	Policy option 2: Proportionate Action	Total: 6,535 Large: 74 Medium: 265 Small: 6,196	Large:1 Medium: 1 Small:1	-6535	-	-1.5	-	As a result of the policy option there is expected to be a slight saving for a small number of companies that are compliant with current verification rules once the system has been introduced, which is expected to be approximately 10% of current costs. This is due to the auditor's role and task becoming clearer, and because the relevant data will now be readily available through the electronic process. It is considered inefficient for companies to adopt different approaches. Utilising an electronic verification system will enable synergies to be accrued and better help to ensure the availability of auditors. The saving to each company has been based upon an expert understanding of the system.

Objective	Policy Measure	Scenario	Number of companies	Days/Year per Company	Total Days (Annual)	Total Days (One-off)	Total Annual Cost (EUR,M)	Total One Off Cost (EUR, M)	Explanation
C5.12	Align verification and quota authorisation thresholds for placing pre-charged products and equipment on the market	Policy Option 1: MP Alignment	Total: -358 Large: - 4 Medium: -15 Small: -399	Large:5 Medium: 3 Small:1	-404	-	-0.09	-	The current threshold is set at >100t CO2e with the policy option set to increase this to >1 000 t CO2. Currently 17% of companies are below the threshold and this number will rise to 52%as the threshold rises. The total number of equipment importers (1024) has been based upon the BDR reporting database.
C5.13	Obligation to provide NIL reports for quota holders	Policy Option 1: MP Alignment	Total: 300 Large: 3 Medium:12 Small:284	Large:0.25 Medium: 0.25 Small:0.25	75	-	0.02	-	The impact upon administrative costs is expected to be insignificant as the obligation to provide a NIL report will be a straightforward and simple task. Based upon expert judgement and the current number of quota holders this is expected to impact approximately 300 companies based on expert judgement.
C5.14	Encourage or require Member States to use electronic reporting systems for collection of F-gas service intervention, technicians, sale of non-hermetic equipment and emissions data	Policy Option 3: Maximum Feasibility	Total: 65,717 Large: 5915 Medium: 13,143 Small: 46,559	Large:0.25 Medium: 0.25 Small:0.25	-16,429	65717	-3.8	15.1	The policy will have an impact upon all companies which are required to currently maintain reporting system records. The requirement to use a common electronic tool at national level will be expected to lead to an initial implementation cost of approximately 1 days based on an understanding of the costs to implement the system in Poland and expert judgement. Upon the implementation of the new system the ongoing annual administrative burden is expected to decrease slightly, due to the more efficient process of the electronic reporting recording tool. Based upon stakeholder consultation it is estimated that approximately one third of Member States already have the system in place, and therefore no further cost is expected. The number of companies impacted has been based upon the number of reporting companies with Slovakia and extrapolated across the EU, taking into account the Member States for which a system is in place. The breakdown of company size has been based upon a German industrial survey determining the number of employees at German service operators.
C5.15	Include new substances in Annex I	Policy Option 1: MP Alignment	Total: 20 Large: 8 Medium: 8 Small: 4	Large:5 Medium: 3 Small:1	68	-	0.02	-	This option refers to perfluorodecalin, SO_2F_2 and a list of relatively special long-chain PFCs. Reporting requirements will mainly include production, import, export companies. As a result of the policy option there will be one some additional substance which will require additional reporting. Expert judgement has determined that 20 companies will be impacted by this policy change (i.e. will have to register for reporting), with one known EU SO_2F_2 license holder, a few relevant companies for perfluorodecalin and

Objec-tive	Policy Measure	Scenario	Number of com-panies	Days/Year per Com-pany	Total Days (Annual)	Total Days (One-off)	Total An-nual Cost (EUR,M)	Total One Off Cost (EUR, M)	Explanation
									a large number of long-chain PFC importers. The costs and break-down of company size have been based upon expert judgement of the sector.
C5.16	Include new sub-stances in Annex II and require reporting by companies	Policy Option 1: MP Align-ment	Total: 500 Large: 6 Medium: 20 Small: 474	Large:5 Medium: 3 Small:1	563	-	0.1	-	A number of substances which are fluorinated greenhouse gases are not yet covered by the Regulation. There will be an increase in administrative costs due to an increase in the number of compa-nies require to report on these additional substances. Note: Specific number of companies required to report to be de-termined for each substance. Approximately 500 companies will have to register for reporting with an annual administrative cost of approximately 1 day per year for a medium company expected to account for the additional reporting.

In addition to the administrative costs calculated in Table 220, compliance costs have also been calculated for the measures below. The costs detailed in Table 221 have not been included within the final administrative costs total, but are illustrative of the additional costs which will be incurred by industry as a result of complying with the measures in Objective A.

Table 221: Additional Compliance Costs

Objective	Policy Measure	Scenario	Costs	Explanation
A	Destruction of HFCs in steel-faced panels or reuse from 2024	Policy Option 1: MP Alignment	EUR 5.37 per panel	The cost has been based upon the economic assumptions used for the analysis of the ODS Regulation. Due to an absence of quantitative data the ODS impact assessment has calculated compliance costs only to determine the economic impact of the policy option. The compliance costs calculated in the ODS have been amended to take into account only HFC's. The costs represent the compliance costs associated with one steel-faced panel. The compliance costs have not been included within the aggregated administrative costs.
A	Destruction (or reuse) of HFCs in laminated boards in built-up structures and cavities, unless feasibility is proven by the building owner/demolition company	Policy option 2: Proportionate Action	EUR 35 per board	The cost has been based upon the economic assumptions used for the analysis of the ODS Regulation. Due to an absence of quantitative data the ODS impact assessment has calculated compliance costs only to determine the economic impact of the policy option. The compliance costs calculated in the ODS have been amended to take into account only HFC's. The costs represent the compliance costs associated with one laminated board. The compliance costs have not been included within the aggregated administrative costs.

The table below shows the aggregated change in annual administrative costs under each of the three ambition scenarios. The total costs have been outlined per both objective and policy scenario. In addition, a separate cost has been calculated to determine the total cost including the attendance of training to comply with measure C1.1/C1.2. Due to the high cost of this single measure, it was considered useful to illustrate the difference in the total cost when this measure is excluded.

Table 222: Total annual administrative costs to industry

EURO	Low	Medium	High
Objective A	-	19 016	19 016
Objective B	100	100	100
Objective C	-7 341	14 390	26 743
Total Days/Year	-7 241	33 506	45 859
Total Cost (€)	-1 665 516	7 706 297	10 547 457
Total Cost (€) (inc training days)	-1 665 516	28 457 960	31 299 120

The table below shows the aggregated change in one-off administrative costs as a result of implementing the policy measures under each of the three ambition scenarios.

Table 223: Total implementation administrative costs to industry

EURO	Low	Medium	High
Objective A	13 075	13 075	13 075
Objective B	-	-	-
Objective C			68 781
Total Days/Year	1 ,075	13 075	13 075
Total Cost	3 007 250	3 007 250	18 826 790

Annex 7.2: European Commission

Table 224: Detail of the calculation and assumptions

Objec-tive	Policy Measure	Scenario	Total Days (Annual)	Total Days (One-off)	Explanation
A1.1	Increase ambition of the EU HFC phase-down beyond the requirements under the Montreal Protocol by tightening reduction steps until 2030 and introducing additional reduction steps beyond 2030	Low	28	0	There is a lot of compliance checking also on EC side to ensure compliance with the phase down, alongside support provided to and communications with stakeholders to support compliance. Assume 10% increase in enforcement and support efforts for EC relative to evaluation baseline (expert judgement).
A2.2, A2.4, A2.6, a2.X	Additional prohibitions - Low Introduce a placing on the market prohibition for small stationary refrigeration hermetic units for commercial and household use that contain or whose functioning relies upon fluorinated greenhouse gases from 1 January 2024 Introduce a placing on the market prohibition for fire protection equipment containing or relying on HFCs, except when required to meet national safety standards from 1 January 2024 Introduce a placing on the market prohibition for RACHP equipment which use PFCs and blends containing PFCs from 1 January 2024	Low	9	0	For each prohibition, CLIMA incurs costs for communicating with Member States and stakeholders. There will also be additional costs for additional advice and traffic through the Help Desk. Cost data was taken from the evaluation for these items under the existing Regulation, combined with the number of existing prohibitions to calculate a cost per prohibition. It is assumed that half of the costs related to these activities from the evaluation are for prohibitions (expert judgement). In addition, further derogations are anticipated in the future due to more complex rules. Time required per derogation is taken from the ODS IA (40 days per derogation). It is assumed there is roughly one derogation every 3 years, split across the 9 new prohibition proposals.

Objective	Policy Measure	Scenario	Total Days (Annual)	Total Days (One-off)	Explanation
	Prohibit placing on the market of skin cooling equipment with F-gases used for purposes that are not required for strictly medical reasons and whose functioning relies upon F-gases				
A2.1, A2.3, A2.5, A2.7, A2.8, A2.9	Additional prohibitions - Medium Introduce a placing in the market prohibition for stationary air conditioning and heat pump equipment from 1 January 2025 Remove the existing exemption for servicing and maintenance of refrigeration equipment with a charge size below 40 tonnes of CO2 eq with virgin fluorinated gases from 1 January 2024 Introduce a placing on the market prohibition for personal care products containing fluorinated greenhouse gases from 1 January 2024 Introduce a placing on the market prohibition for new medium voltage electrical switchgear for primary and secondary distribution, differentiated by voltage level, from 1 January 2030, using SF6 as insulating or breaking medium; other fluorinated compounds with GWP > 500 can be used; unless evidence is provided that no other suitable alternative is available on technical grounds Introduce a placing on the market prohibition for new high voltage electrical switchgear, differentiated by voltage level, from 1 January 2028 or 2031, respectively, using SF6 as insulating or breaking medium; other fluorinated compounds with GWP > 1,000 can be used, unless evidence is provided that no other suitable alternative is available on technical grounds Introduce a use prohibition for some inhalation anaesthetics containing other fluorinated greenhouse gases listed in Annex II with GWP > 500 from 1 January 2024	Medium	36	0	

Objective	Policy Measure	Scenario	Total Days (Annual)	Total Days (One-off)	Explanation
b1.3, b2.1, b2.2	Removal of exemptions and thresholds – low Remove exemption from placing on the market restrictions under the phase-down for HFCs for use in metered dose inhalers Remove limit of 100 tonnes of CO2 eq for producers or importers that place HFCs on the market Remove the limit for reporting on production, import, export and destruction of F-gases and other gases listed in Annex II	Low	23	0	Measures will incur minor additional costs for CLIMA. Some companies are already receiving quota, but there will be some new companies that require quota. Additional administrative costs will be incurred as more companies come under the reporting requirements. In addition, there will be additional helpdesk traffic and compliance cases. Cost estimates are based on expert judgement uplift from baseline costs calculated in the evaluation. The main cost increases are linked to the MDI exemption as exempted sectors (MDIs, military, semiconductors) comprise roughly 6% of the total market (with MDIs representing the vast majority of this exempted proportion). As such it is assumed that phase-down compliance costs (e.g. calculation of reference values, and enforcement of compliance with bulk quota) from the evaluation would increase by around 6%
b1.1, b1.2	Removal of exemptions and thresholds – high Remove POM exemption for military equipment Remove the exemption from placing on the market restrictions under the phase-down for HFCs for etching of semiconductor material or cleaning of chemicals vapour deposition chambers within the semiconductor manufacturing sector	High	2.3	0	Measures will incur minor additional costs for CLIMA. Some companies are already receiving quota, but there will be some new companies that require quota. Additional administrative costs will be incurred as more companies come under the reporting requirements. In addition, there will be additional helpdesk traffic and compliance cases. The additional removal of exemptions would add very little additional admin burden as compared to the "removal" in LOW scenario, as quantities and companies are low. Cost estimates are based on expert judgement uplift from costs calculated for measures b1.3/b2.1/b2.2 below – assume 10% of these costs.
b3.1	Implement an EU-wide HFC production phase-down	Low	10	10	CLIMA would incur additional costs, but these are anticipated to be smaller than for the POM phase down. No yearly allocation would be required. Costs would be driven by compliance with the new rules, awareness raising and discussion with industry. To calculate the costs, we have assumed these are 10% of the evaluation costs of enforcing compliance with the POM phase-down. There would also be initial one-off costs of communicating the phase-down obligations to affected stakeholders (expert judgement – assume same as ongoing cost).

Objec-tive	Policy Measure	Scenario	Total Days (Annual)	Total Days (One-off)	Explanation
b4.1	Introduce prohibition for HFC bulk imports to/exports from the EU to any country not Party to the Montreal Protocol (Kigali Amendment)	Low	With automisation: 10 Without automisation: 248	With automisation: 0 Without automisation: 667	Several measures imply additional costs for CLIMA if controls are to be automised and thus require further development of Certex. There will be additional costs for development and maintenance (assume 100 days/year), plus external assistance per year (assume €100,000), plus a one-time costs to develop the expert function and adjust to the new Regulation (assume €500,000) (all values based on expert judgement). In addition, these changes will also imply additional data security costs. Quantitative estimates (15 days pa) were taken from the ODS IA). The costs without automising (which is not necessarily required by the Regulation) would be significantly more moderate and do not exceed much current costs (expert judgement suggests 10 days additional pa).
c2.2	Control special procedures (including transit, storage, specific use and processing) for F-gases through the EU with destination to non-EU countries and transit through some Member States with destination in another Member State Controlling customs special procedures. Only permit transit and other procedures for: a) Goods sent to particular destination custom offices b) Transaction where the minimum of 8-digit CN codes are indicated by the importer or exporter	Low			
c3.6	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	Low			
c3.2	Prohibition for (offline and online) sales and possession of HFCs/F-gases that were illegally placed on the market	Low	10	0	Costs will mainly be for MS enforcement, although in practice some costs may fall on CLIMA (e.g. through OLAF or industry, consulting or providing advice to MS, potential engagement with website hosts). Assume implementation of 5-10 days per annum (expert judgement).
c3.9	Include minimum penalties to be enforced by EU Member States for quota exceedance, quota authorisation deficits, illegal issuance of authorisations, non-compliance with reporting deadlines and verification obligations and transport, storage and use of HFCs not covered by quota	Low	40	0	Will imply additional costs to CLIMA of around 30-50 days per annum on an ongoing basis to enforce the Regulation (infringement procedures).
c4.1	Limit issuing quota authorisations to incumbents, i.e. based on reference-based quota	Low	-1	0	Issuing authoritsations to incumbents only may lead to some cost savings through reduced compliance checks (less undertakings to check), although savings will be limited (expert judgement suggests savings of around 5% of 20 days per annum).

Objec-tive	Policy Measure	Scenario	Total Days (Annual)	Total Days (One-off)	Explanation
c4.3	Introduction of a registration fee and/or quota allocation price linked to CO2 equivalents	Medium	2 200	2,200	This measure could increase costs significantly. Costs would be incurred for collection and distribution of funds, in addition to systems design and construction, registration and tracking, relying on a suitable IT system. Many of these costs may be outsourced and will be fully offset by revenues collected. But these still imply an administrative burden. Expert judgement suggests this may be equivalent to as many as 10 FTEs on an upfront and ongoing basis.
c5.2	Registration and reporting obligation for exporters of products and equipment containing F-gases and other fluorinated substances	High	7.1	0	Costs will be linked to advising company on legal obligations. Existing reporting costs for CLIMA are taken from the evaluation and scaled by the number of new companies that would potentially fall under the new requirement. In this case, expert judgement suggests there may be around 1,000 – 2,000 additional companies (relative to around 2,100 existing companies that are obligated to report).
c5.3	Reporting obligation for recipients of quota-exempted HFCs	Medium	0.3	0	Reporting costs for CLIMA (i.e. providing guidance) are taken from the evaluation and scaled by the number of new companies that would potentially fall under the new requirement. In this case, expert judgement suggests there may be around 65 additional companies (relative to around 2,100 existing companies that are obligated to report).
c5.4	Reporting obligation for undertakings performing reclamation of F-gases	Medium	0.2	0	Reporting costs for CLIMA are taken from the evaluation and scaled by the number of new companies that would potentially fall under the new requirement. In this case, expert judgement suggests there may be around 50 additional companies (relative to around 2,100 existing companies that are obligated to report).
c5.5	Reporting obligation for undertakings performing recycling of F-gases	High	3.6	0	Reporting costs for CLIMA are taken from the evaluation and scaled by the number of new companies that would potentially fall under the new requirement. In this case, expert judgement suggests there may be around 750 additional companies (relative to around 2,100 existing companies that are obligated to report).
c5.6	Reporting obligation for operators of HV switchgear and electrical equipment (< 52 kV) with regard to SF6 emissions during lifetime and for operators in cooperation with certified personnel of electrical equipment for decommissioning of such equipment	High	12	0	Reporting costs for CLIMA are taken from the evaluation and scaled by the number of new companies that would potentially fall under the new requirement. In this case, expert judgement suggests there may be around 50-100 additional companies, in addition to ~50 transmission and 2400 distribution companies (relative to around 2,100 existing companies that are obligated to report).
c5.9		Low	-21.1	0	Measure would result in a saving for CLIMA. Raising the threshold from 100 to 1000 tCO2e (low/medium) or 500 tCO2e (high) would

Objec-tive	Policy Measure	Scenario	Total Days (Annual)	Total Days (One-off)	Explanation
	Align reporting and verification thresholds for placing on the market products and equipment: a) No existing threshold for POM of HFCs in RAC equipment, although de facto threshold of 100 tCO2e based on Art. 15. b) Verification obligation for POM of HFCs in RAC equipment defined on Declarations of Conformity (FGR Art14, DoC), not on Art 19 report c) Threshold for product and equipment impacts of 500 tCO2e.	High	-10.2	0	reduce the coverage from 83% to either 48% or 61% (respectively) of the 1,500 relevant companies. Analysis scales the costs from the evaluation covering assessment of registrations and declarations (assuming half of these costs are relevant for verification). Clarify verification obligation to apply to both Art 19 report & DoCs implies no additional cost Reporting threshold for product and equipment imports is slightly lower than in the present FGR, should lead to slightly higher cost for BDR submission of the report. Additional data collection does not take place as all affected companies are already under the verification obligation. Note the somewhat more stringent threshold in option 3. Option 3 likely to additionally affect ~50-100 companies which import equipment using low-GWP annex II gases., then captured by the 1 t/year threshold
c5.11	Add electronic verification process (separately for bulk and pre-charged products and equipment)	Medium	-25	5	Measure would result in a saving for CLIMA. Analysis scales the costs from the evaluation covering compliance checking of verification reports (assuming half of these costs are relevant for verification). Expert judgement assumes a reduction in verification costs of 25% There will also be some costs linked to conceptual development – assume 5 days (expert judgement)
c5.12	Align quota authorisation with reporting thresholds for placing pre-charged products and equipment on the market	Low	-3.5	0	Measure would result in a saving for CLIMA. Changing the threshold from 100 to 1,000 tCO2e will reduce the number of companies covered by around 360 (relative to baseline of just over 1,000 companies). Analysis applies this scaling factor to reporting costs captured in the evaluation.
c5.13	Obligation to provide NIL reports for quota holders	Low	-5	0	Measure would result in a saving for CLIMA. Analysis scales the costs from the evaluation covering assessment of registrations and declarations (assuming half of these costs are relevant for verification). Expert judgement assumes a reduction in verification costs of 5%

Annex 7.3: EEA

Table 225: Detail of calculation and assumptions

Objective	Policy Measure	Scenario	Total Days (Annual)	Total Days (One-off)	Explanation
b2.2	Remove the limit for reporting on production, import, export and destruction of F-gases and other gases listed in Annex II	Low	2.2	0	EEA's current F-gas reporting system could fairly easily be adapted at low costs if new reporting thresholds are applied. This may result in a small increase in cost through additional traffic for the BDR Helpdesk (Stakeholder feedback). Expert judgement suggests costs could increase by 5% from costs reported in the evaluation for in house Helpdesk support.
c5.15	Include new substances in Annex I	Low			
c5.16	Include new substances in Annex II and require reporting by companies	Low			
b3.1	Implement an EU-wide HFC production phase-down in addition to the POM phase-down which would be quantitatively adapted to the Montreal Protocol (same ambition level), quota allocation at entity level based on HFC production 2011-2013 plus 15 % CFC/HCFC production 2011-2013	Low	0	21	Stakeholder feedback suggests measure would imply additional, one-off costs for making changes to the web reporting form. Costs were collated in the evaluation for development of the new form alongside the 2014 Regulation. Expert judgement assumes costs will be at most 10% relative to these costs.
c5.2	Registration and reporting obligation for exporters of products and equipment containing F-gases and other fluorinated substances	High	157	50	Additional reporting obligations could increase EEA's costs more substantially (Stakeholder feedback). E.g. for exporters of products and equipment containing F-gases, for recipients of quota-exempted HFCs, and for undertakings performing recycling and reclamation of F-gases, EEA's system could be extended step-wise as in the past at an envisaged annual cost corresponding to the average for 2015-2019. This captures an expected increase in a range of EEA activities, including: greater traffic to the BDR helpdesk, more IT troubleshooting, greater project management and external IT consultancy support. Total costs for EEA are scaled up from existing costs (from the Evaluation), based on the number of companies falling under the new obligations (based on expert judgement) relative to those already reporting to the EEA (around 4,750 in 2019 based on EEA data). C5.2 assumes 1500 additional companies, c5.4 65 additional, c5.5 (reclamation) 50 additional and c5.5 (recycling) 750 additional companies covered. In addition, there would be a one-off cost associated with the development and implementation of questionnaires to gather the data. No cost estimate was gathered from stakeholders, but expert judgement suggests costs may be around 50 days per new obligation.
c5.3	Reporting obligation for recipients of quota-exempted HFCs	Medium	7	50	
c5.4	Reporting obligation for undertakings performing reclamation of F-gases	Medium	5	50	
c5.5	Reporting obligation for undertakings performing recycling of F-gases	High	78	50	
c5.6	Reporting obligation for operators of HV switchgear and electrical equipment (< 52 kV) with regard to SF6 emissions during lifetime and for operators in cooperation with certified personnel of electrical equipment for decommissioning of such equipment	High	84	50	

Objective	Policy Measure	Scenario	Total Days (Annual)	Total Days (One-off)	Explanation
c5.9, c5.10, c5.11, c5.12, c5.13	Align reporting and verification thresholds for placing on the market products and equipment: a) No existing threshold for POM of HFCs in RAC equipment, although de facto threshold of 100 tCO_2e based on Art. 15. b) Verification obligation for POM of HFCs in RAC equipment defined on Declarations of Conformity (FGR Art14, DoC), not on Art 19 report c) Threshold for product and equipment impacts of 500tCO_2e. Align reporting and verification dates (separately for bulk and pre-charged products and equipment) Add legal basis for electronic verification process (separately for bulk and pre-charged products and equipment) Align reporting and quota authorisation thresholds for placing pre-charged products and equipment on the market Obligation to provide NIL reports for quota holders	Low	-4	0	Measure could result in cost saving for EEA. Reduced complexity will result in less BDR helpdesk traffic (Stakeholder feedback). NO cost estimates were gathered from stakeholders. Expert judgement suggests savings will be small, around 10% reduction in traffic.
C5.15 C5.16 C5.17	Include new substances in Annex I Include new substances in Annex II and require reporting, emission prevention, labelling by companies Include a new Annex III and require reporting by companies	Low	0	21	EEA's current F-gas reporting system could fairly easily be adapted at low costs if new F-gases are added to the current F-gas Regulation (Annex I or II). This would incur a one-off cost to adapt the BDR questionnaire and the QC rules (Stakeholder feedback). No quantitative estimates were put forward by EEA. Expert judgement suggests costs could increase in a similar order of magnitude to measure b3.1.

Annex 7.4: Member State Competent Authorities

Table 226: Details of calculation and assumptions

Objective	Policy Measure	Sce-nario	Total Days (Annual)	Total Days (One-off)	Explanation
a1.1	Increase ambition of the EU HFC phase-down beyond the requirements under the Montreal Protocol by tightening reduction steps until 2030 and introducing additional reduction steps beyond 2030	Low	2 134	0	Additional costs for compliance checking of companies. No insights or estimation provided by stakeholders. Expert judgement – assumes 20% increase in costs of non-compliance with quota authorisations and phase down (as presented in the evaluation for existing Regulation).
a2.2, a2.4, a2.6, a2.X	Additional prohibitions - Low Introduce a placing on the market prohibition for small stationary refrigeration hermetic units for commercial and household use that contain or whose functioning relies upon fluorinated greenhouse gases from 1 January 2024 Introduce a placing on the market prohibition for fire protection equipment containing or relying on HFCs, except when required to meet national safety standards from 1 January 2024 Introduce a placing on the market prohibition for RACHP equipment which use PFCs and blends containing PFCs from 1 January 2024 Prohibit placing on the market of skin cooling equipment with F-gases used for purposes that are not required for strictly medical reasons and whose functioning relies upon F-gases	Low	160	0	Stakeholder feedback suggests costs of new POM prohibitions could range from ‚slight‘ to ‚very significant‘. This would depend on the prohibition. Some resources would be needed for awareness raising alongside compliance. In addition, there may be further costs for derogation. Where prohibitions are time-staggered, as older prohibitions establish themselves, recurrent costs are likely to go down significantly as the prohibition date passes as most actors will learn to respect the new rules.. Resources can be re-invested in new prohibitions. No estimation of costs was provided by stakeholders. Analysis takes costs of enforcing prohibitions from the evaluation of the existing Regulation, plus the costs of awareness raising. Additional costs are also added for derogations, based on the evidence developed for the ODS IA (23 days per derogation assumed). Some prohibitions will be more impactful than others. Costs are then scaled based on expert judgement, depending on how significant the application is in the market, relative to existing prohibitions.
A2.1, a2.3, a2.5, a2.7, a2.8, a2.9	Additional prohibitions - Medium Introduce a placing in the market prohibition for stationary air conditioning and heat pump equipment from 1 January 2025 Remove the existing exemption for servicing and maintenance of refrigeration equipment with a charge size below 40 tonnes of CO2 eq with virgin fluorinated gases from 1 January 2024	Me-dium	2 475	0	

Objective	Policy Measure	Scenario	Total Days (Annual)	Total Days (One-off)	Explanation
	Introduce a placing on the market prohibition for personal care products containing fluorinated greenhouse gases from 1 January 2024 POM prohibition for new medium voltage electrical switchgear • for primary distribution, differentiated by voltage level – up to 24 kV from 2026 and 24-52 kV from 2030, using F-gases with GWP > 2000 as insulating or breaking medium; for secondary distribution, differentiated by voltage level – up to 24 kV from 2026 and 24-52 kV from 2030, using F-gases with GWP >2000 as insulating or breaking medium. POM prohibition for new high voltage electrical switchgear • in the range of 52-145 kV and up to 50 kA short circuit current from 2028, using F-gases with GWP >2000 as insulating or breaking medium; • in the range of more than 145 kV or more than 50 kA short circuit current from 2031, using F-gases with GWP >2000 as insulating or breaking medium. Introduce a use prohibition for some inhalation anaesthetics containing other fluorinated greenhouse gases listed in Annex II with GWP > 500 from 1 January 2024				
A2.10	Apply requirements for prevention of emissions of fluorinated gases to substances listed in Annex II	Low	51	0	No insights or estimation provided by stakeholders. Quantification based on expert judgement. Annex II gases represent around 6% of total supply in 2019, hence scale up MS compliance costs for enforcing containment measures from evaluation by this factor. This measure only relates to Article 3 – data not available for costs of Article 3 specifically. Expert judgement anticipates that

Objective	Policy Measure	Sce-nario	Total Days (Annual)	Total Days (One-off)	Explanation
					the majority of the costs for MS are related to leak checks and reporting (Articles 4-6), with Article 3 presenting only minor costs. Hence assume 10% of reported costs for containment measures from evaluation relate to Article 3.
A2.11	Apply requirements for prevention of emissions of F-gases to manufacturing, transport, transfer and storage of bulk gases also to non-producers	Me-dium	34	0	No insights or estimation provided by stakeholders. Member States incur additional costs to check and enforce compliance with the extended requirements. Extension is being considered to equipment manufacturers & upstream companies (e.g. gas traders etc). These costs will be an order far below the number of equipment operators. For industry admin burden, assume additional 1,000 companies. Number of producers and equipment operators (covered by existing requirements) is unknown, estimates for operators suggest this could be around 230,000. Expert judgement, assume 0.4% additional cost for enforcing compliance with containment measures.
A3.1	Destruction of HFCs from steel-faced panels or reuse, from 2024	Low	No quantitative estimate	No quantitative estimate	For Member States, some significant costs are expected due to the need for awareness raising, monitoring and enforcement activities (of thousands of demolition projects a year).
A3.2	Destruction (or reuse) of HFCs in laminated boards in built-up structures and cavititescavities, unless feasibility is proven by the building owner / demolition company, from 2024	Me-dium			
B1.1	Remove POM exemption for military equipment	High	20	0	Quota system is run by DG CLIMA, but in practice MS still incur costs of compliance checking. Stakeholders suggest measure could imply increase in costs, but did not provide estimation. MS spend around 8,000 days pa checking compliance with phase down covering ~2,000 companies – assume 4 days per company. Around 5 military undertakings currently received quota exempted supply
B1.2	Remove the exemption from placing on the market restrictions under the phase-down for HFCs for etching of semiconductor material or cleaning of chemicals vapour deposition chambers within the semiconductor manufacturing sector	High	120	0	Quota system is run by DG CLIMA, but in practice MS still incur costs of compliance checking. Stakeholders suggest measure could imply increase in costs, but did not provide estimation. Analysis scales up costs from evaluation associated with non-compliance with the phase-down. MS spend around 8,000 days pa checking compliance with phase down covering ~2,000 companies – assume 4 days per company. Around 60 semiconductors currently received quota exempted supply. Given activity is concentrated in few MS< expert judgement assumes there may be efficiencies of scale, so costs would be around half if they were spread across many MS.

Objective	Policy Measure	Sce-nario	Total Days (Annual)	Total Days (One-off)	Explanation
B1.3	Remove exemption from placing on the market restrictions under the phase-down for HFCs for use in metered dose inhalers	Low	100	0	Quota system is run by DG CLIMA, but in practice MS still incur costs of compliance checking. Stakeholders suggest measure could imply increase in costs, but did not provide estimation. MS spend around 8,000 days pa checking compliance with phase down covering ~2,000 companies – assume 4 days per company. Around 25 MDI undertakings currently received quota exempted supply
B3.1	Implement an EU-wide HFC production phase-down	Low	30	0	No insights provided by stakeholders. Production has always been centred in few countries which have high expenses. Expert judgement suggests there may be around 5 companies across 2 MS which undertake production at present. Hence additional burden likely to be small. Estimate based on existing costs of non-compliance with POM phase-down, but scaled down by smaller number of companies that will be covered (5 vs 1,800 under POM phase down).
B4.1	Introduce prohibition for HFC bulk imports to/exports from the EU to any country not Party to the Montreal Protocol (Kigali Amendment)	Low	109	0	No insights provided by stakeholders. Costs for MS will increase associated with additional import compliance checks. That said, most countries are anticipated to be signatories to Kigali by 2030. Expert judgement: assume 1% increase in costs of checking imports (as reported in the evaluation). Only from 2028 onwards. Can be done automatically with Single Window, which would reduce these costs very significantly
C1.1 & C1.2	Certification requirement for unsaturated HFCs and H(C)FCs and other F-gas free alternatives, while F-gas certification programmes also to include practical training on all alternatives and add energy efficiency issues to be part of training (stationary RACHP)	Me-dium	1 924	0	Stakeholder feedback suggested costs would increase, with a range of opinions from ‚no change‘ to ‚significant increase (40%)‘. Scheme is extension of existing programmes. Expert judgement – take mid-point of stakeholder opinion and assume 20% increase in costs of training and certification for MS from evaluation.
C1.3	Installation/servicing/repair/maintenance of equipment that contains fluorinated greenhouse gases or whose functioning relies upon those gases for which certification or attestation is required under Article 10only by certified personnel	Me-dium	27	0	measure will imply additional compliance checking cost for MS. No feedback or cost information provided by stakeholders. This measure implies an extension of the requirements of Article 11(4) to include other substances, in particular HCFOs. However, this extension is anticipated to be relatively minor, given many HCFOs are used in blends which are already covered by the Regulation. Pure use of HCFOs is fairly negligible. Assume 1 day per MS additional effort required.
c2.1	Include specific requirements for customs regarding the treatment of products and equipment illegally placed on the market and illegal F-gas containers once confiscated	Low	2 174	0	Stakeholder feedback suggested this measure would pace additional administrative burden on customs. Costs estimates by stakeholders ranged from ‚no change‘ to ‚significant increase‘ (40%).

Objective	Policy Measure	Sce-nario	Total Days (Annual)	Total Days (One-off)	Explanation
					Costs can be kept low by requiring non-compliant company to cover destruction and by auctioning – i.e. costs should be put onto the illegal importer, but in practice this might not be possible. Custom costs depend mostly on the risk profiling of the goods, and thus the controls actually carried out. In theory, illegal imports should already be dealt with in an effective way – i.e. confiscation and destruction, but in practice this does not always happen. Hence these costs in theory should already be incurred today, and hence are not truly additional to the option considered here, but are not in practice. Expert judgement – take mid-point of stakeholder opinion and assume 20% increase in costs of checking imports from evaluation.
c2.2	Control special procedures (including transit, storage, specific use and processing) for F-gases through the EU with destination to non-EU countries and transit through some Member States with destination in another Member State Controlling customs special procedures. Only permit transit and other procedures for: a) Goods sent to particular destination custom offices b) Transaction where the minimum of 8-digit CN codes are indicated by the importer or exporter	Low	109	0	Administrative costs for Member States may change at customs offices as a result of the changes. If implemented in the EU CSW, the SW system may already provide with the procedures that enable better control. If illegal trade reduces, then this may also reduce the use of some customs procedures, resulting in a lower cost. Any additional cost would be associated with follow-up, which would be performed on the basis of risk profiles. Stakeholder comments suggests costs range from ‚no change‘ to ‚slight increase‘. On the basis of evidence provided, a slight increase in costs (1%) has been quantified, scaling up from the costs presented in the evaluation for checking imports.
c3.1	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 and unsaturated HCFCs	Low	544	0	Stakeholder feedback varied around this measure. Some suggested this measure may lead to a cost reduction (due to the introduction of clearer Regulations) to a significant cost increase (due to the need for complementary awareness raising, and greater checking as well as the extension to gases that were not covered so far). Under the existing Regulation, the prohibition relates to placing non-refillable containers on the market. This extends the prohibition into the territory, which in theory is a small change with negligible costs. Given this is a small change, most import-

Objective	Policy Measure	Sce-nario	Total Days (Annual)	Total Days (One-off)	Explanation
					ers are anticipated to already comply. But a small number (estimated to be approximately 5% of importers are) not currently conducting this practice and will therefore incur additional administrative cost. That said, given these actors should already comply with the Regulation, these costs are not truly additional and associated with this measure. Expert judgement – costs for checking imports will also increase by at most 5%, but generally also depend on risk profiling The second part of this measure is to extend the requirements to HCFOs. However, given the majority of HCFOs are used in blends already covered by the Regulation, these additional costs are anticipated to be negligible.
c3.2	Prohibition for (offline and online) sales and possession of HFCs/F-gases that were illegally placed on the market	Low	364	0	Stakeholder feedback suggested that the costs of this measure could range from a slight decrease to a significant increase (with the latter due to the complexity of the checks required, plus additional awareness raising that would be needed). That said, MS should already be monitoring the market for illegal goods to a sufficient degree already. This measure would add more legal certainty around taking enforcement action, and in that way could lead to cost savings. Only additional costs would arise only from enforcement of internet sales. Expert judgement – assume additional (net) cost of around 10 days per MS per annum, in addition to additional costs for awareness raising (10% of those reported in the evaluation associated with existing Regulation).
c3.5	Add obligation for documentation for downstream sales for bulk HFC/F-gases (e.g. "declaration of conformity") and record keeping	High	No additional if implemented with c5.14 (in absence of c5.14, additional days required could be around 3 600)	No additional if implemented with c5.14	Stakeholder feedback suggests costs could range from no change to significant cost (20-30%). However, when implemented alongside option c5.14, expert judgement suggests this measure will incur no additional costs on top of the electronic reporting system developed under that option. In the absence of c5.14, there will likely be additional costs, however costs will depend in part on what level of resource CA's opt to invest in enforcement. As an illustration, assume 20% increase on top of existing enforcement costs reported in the evaluation.
c3.7	Add obligation for importers to have quota-exempted quantities labelled as exempted during POM	Low	109	0	Stakeholder feedback suggests costs could range from no change to ‚increase', but predominant qualitative responses was ‚slight increase'. No quantitative estimation provided by stakeholders.

Objective	Policy Measure	Sce-nario	Total Days (Annual)	Total Days (One-off)	Explanation
					Quota-exemptions represent around 10% of current quota. That said, not all quota is checked, so controls would not increase by the same amount. Expert judgement assumes costs of checking imports could increase by 1% relative to the baseline (i.e. costs reported in the evaluation) Costs depend greatly on risk profiling.
c3.8	Strengthen the obligation on destruction of HFC-23 by-production	Medium	109	0	No stakeholder feedback or estimation regarding this measure. Expert judgement assumes costs of could be around 1% of overall baseline customs checks (i.e. costs reported in the evaluation)
c3.9	Include minimum penalties to be enforced by EU Member States for quota exceedance, quota authorisation deficits, illegal issuance of authorisations, non-compliance with reporting deadlines and verification obligations and transport, storage and use of HFCs not covered by quota	Low	0	246	Stakeholder feedback suggested costs could range from ‚no change‘ to ‚slight increase‘. No estimation provided. The majority of Member States should have legislation in place to facilitate the issuance of penalties under the existing Regulation. As such, it is anticipated that to strengthen penalties and/or set a minimum level would imply a minor change to the legislation. Expert judgement suggests could result in one-off costs to change legislation. Assume 1% of baseline compliance costs
c5.1	Extend labelling requirement to Annex II gases	Medium	694	0	Stakeholder feedback suggested costs could range from ‚no change‘ to ‚increase‘ – predominant response was ‚slight increase‘. Annex II gases represent around 6% of total F-gas supply in 2019. Analysis applies expert judgement to scale up baseline (i.e. from evaluation) labelling costs by this factor
c5.9	Align reporting and verification thresholds for placing on the market products and equipment: a) No existing threshold for POM of HFCs in RAC equipment, although de facto threshold of 100 t CO2e based on Art. 15. b) Verification obligation for POM of HFCs in RAC equipment defined on Declarations of Conformity (FGR Art14, DoC), not on Art 19 report c) Threshold for product and equipment imports of 500 t CO2e.	Low	-2 250	0	No stakeholder feedback provided on this measure. In practice, MS incur costs for follow-up on quota compliance issues. Analysis has applied expert judgement to scale down baseline (i.e. from the evaluation) compliance costs for quota authorisations and Phase-down. Raising the threshold from 100 to 1 000 t CO2e (low/medium) or 500 t CO2e (high) would reduce the coverage from 83% to either 48% or 61% (respectively) of the 1 500 relevant companies.
		High	-1 093	0	
c5.13	Obligation to provide NIL reports for quota holders	Low	-533	0	No stakeholder feedback provided on this measure. In practice, MS incur costs for follow-up on ‚NIL‘ reports. CLIMA passes a list to MS to follow-up. Analysis has applied expert judgement to scale down baseline (i.e. from the evaluation)

Objective	Policy Measure	Sce-nario	Total Days (Annual)	Total Days (One-off)	Explanation
					compliance costs for quota authorisations and Phase-down. Costs are scaled down by 5% (expert judgement)
c5.14	Encourage / require Member States to use electronic reporting systems for collection of F-gas service intervention, technicians, sale of non-hermetic equipment and emissions data	Me-dium / high	Medium: 0 High: 4 140	Medium: 0 High: 8 846	The evaluation identified that 4 MS already have electronic re-porting systems in place, each collecting different coverage of metrics. A further 2 MS have data collection systems in place, but it unclear if these are electronic. Of these MS, only one MS (PO) provided quantitative cost estimates in the evaluation, both upfront and ongoing. Analysis assumes costs for MS with existing electronic systems are negligible, and applies the costs for PO to the remaining 23 MS. However, it is important to note that implementation costs in PO are generally lower than in other MS, hence using this as a basis from which to scale could produce an underestimation of costs. Full cost is only included in the high scenario, as use of these systems is not mandated in the medium scenario. Under the medium scenario, costs will scale depending on the number of MS who take up these systems, which is uncertain (in particu-lar given only a small sample of MS have unilaterally taken up systems to date). As such no additional costs are assumed.

Annex 9: Initial long list of policy options

The proposed initial long list of policy option groups and policy measures is shown. The policy option groups and measures were designed on the basis of expert and stakeholder input and the initial long list was further screened to take out any unfeasible options. For policy options that have been retained, the label in brackets (e.g. A1) reflects the numbering as used in the short list.

Annex 9.1: Objective A: Raising ambition in line with European Green Deal

a) Increase HFC phase-down ambition

Policy measure	Description of policy measure
Before 2030: Increase ambition of remaining HFC phase-down steps **(A1.1)**	Amending Article 15, Annex V • Amend remaining phase-down steps until 2030 • Phase-down steps to be defined
After 2030: Increase ambition of future HFC phase-down steps **(A1.1)**	Amending Article 15, Annex V • Introduce phase-down steps (i.e. reduction of maximum quantities) for 2034 and 2036 which are more ambitious than those required under the Montreal Protocol • Phase-down steps to be defined

b) Prohibit F-gases in products or equipment, where these gases are no longer needed

Policy measure	Description of policy measure
New prohibitions on F-gases in products and equipment, where these gases are no longer needed and <u>where the F-gas typically used is an HFC, which is also covered by the phase-down</u>	
POM prohibition for stationary air-conditioning and heat pump equipment **(A2.1)**	Amending Annex III Strengthen existing POM prohibition: **Stationary air conditioning systems and (air to air) heat pumps** - **of a rated capacity of up to 12 kW that contain, or whose functioning relies upon fluorinated greenhouse gases with a GWP of 150 or more from 1 January 2025** - **>12 kW that contain, or whose functioning relies upon fluorinated greenhouse gases with a GWP of 750 or more from 1 January 2025**
New POM prohibition for stationary refrigeration **(A2.2a and b)**	Amending Annex III • Add POM prohibition of refrigeration equipment containing or relying on F-gases (other from the equipment for which the bans are already in place or will enter into force) for which alternative technologies exist and are mature enough • POM prohibition might foresee a GWP threshold or relate to certain sub applications such as **<u>Potential areas:</u>** **<u>Refrigeration equipment in the maritime sector (ships, boats, ferries, platforms)</u>** **Refrigeration systems in trucks and trailers** **Small hermetic refrigeration systems in household and commercial products: Ice-makers, water/beer/wine/juice coolers,**

Policy measure	Description of policy measure
	milk coolers at coffee machines, Chantilly machines, gelato makers etc.: Ban (see domestic refrigeration) of HFCs (without GWP threshold), 2023/25 **Skin cooling equipment**
Remove exemption for stationary refrigeration below – 50 °C	Amending Annex III (12) • Remove the existing exemption for use of HFCs with GWP of 2 500 or more in stationary refrigeration equipment below – 50 °C (i.e. use of HFCs with GWP ≥ 2 500 should be prohibited irrespective of the cooling temperature) • Especially refers to R23, R508 • Adjustment might be needed for a different ultra-low temperature range or certain specific applications **Remove exemption from 2025, only reclaimed HFCs to be allowed in new stationary refrigeration equipment**
Remove exemption for servicing and maintenance of refrigeration equipment with virgin gases **(A2.3)**	Amending Article 13 (3) • Remove the existing exemption for servicing and maintenance of refrigeration equipment with a charge size below 40 t CO_2 eq (i.e. use of F-gases with GWP ≥ 2 500 should be prohibited irrespective of the charge size) **Remove exemption and application of service and maintenance prohibition for all equipment as of 2023**
Strengthen use prohibition for servicing and maintenance of refrigeration equipment with recycled or reclaimed gases	Amending Article 13 (3)(a) • Add use prohibition on servicing and maintenance of refrigeration equipment with recycled F-gases • Potential GWP threshold to be assessed Amending Article 13 (3)(b) • Add use prohibition on servicing and maintenance of refrigeration equipment with reclaimed F-gases • Potential GWP threshold to be assessed **Additional use prohibition for servicing and maintenance to the one already included, e.g. reclaimed F-gases with GWP of 1 500 or more (targeting R410A) or GWP of 1 000 or more (targeting R134a) – after 2030**

Policy measure	Description of policy measure
New POM prohibition for fire projection equipment **(A2.4)**	Amending Annex III • Add POM prohibition of certain fire protection equipment containing high GWP HFCs for which alternative technologies exist and are mature enough • POM prohibition might foresee a GWP threshold or relate to certain sub applications **Current POM prohibition only applies to R23 (not in use for many years), HFC-227ea and HFC-125 can be replaced by Novec-1230 or other alternatives (HFC-236fa too?)** **Other effective alternative: inert gases, 2-BTP (bromofluoroolefine), CF_3I** **General POM prohibition of products and equipment containing or relying on HFCs and PFCs, with exceptions for certain areas (mining, military, nuclear power plants, aviation, etc.) – "except when required specific safety standards" (see wording in foam POM)**
New POM prohibition for personal care products **(A2.5)**	Amending Annex III • Add POM prohibition for HFCs in personal products where alternatives exist
Prohibiting the POM and or use of F-gases in products and equipment where these gases are no longer needed and <u>where the F-gas typically used is not covered by the phase-down</u> (e.g. SF_6)	
New POM prohibition for refrigeration, air conditioning and heat pump equipment which use PFCs and blends containing PFCs **(A2.6)**	Amending Annex III • Add POM prohibition on the use of PFCs and blends containing PFCs in all refrigeration, air-conditioning and heat pumps equipment from a certain date **Complete PFC prohibition for refrigeration and AC as of 2023**
New POM prohibition for new medium voltage switchgear for primary distribution which use SF_6 **(A2.7)**	Amending Annex III • Add POM prohibition on the use of SF_6 in new medium voltage (MV) switchgear for primary distribution to be effective from a certain date
New POM prohibition for new medium voltage switchgear for secondary distribution which use SF_6 **(A2.7)**	Amending Annex III • Add POM prohibition on the use of SF_6 in new medium voltage (MV) switchgear for secondary distribution to be effective from a certain date
New POM prohibition for new high voltage switchgear which use SF_6 **(A2.8)**	Amending Annex III • Add POM prohibition on the use of SF_6 in new high voltage (HV) switchgear to be effective from a certain date
New use prohibition for the use of some inhalation anaesthetics **(A2.9)**	Amending Annex III • Add use prohibition of some inhalation anaesthetics containing high GWP HFEs/HCFEs (desflurane, sevoflurane and isoflurane) for which alternatives exist and are mature enough • Reporting on Annex II gases • Use prohibition might be linked to a GWP threshold • Alternatively, add an obligation to mandatorily capture used gases

Apply requirements for prevention of emissions of F-gases to substances listed in Annex II **(A2.10)**	Amending Article 3 • Extend coverage of emission prevention requirements to include all substances listed in Annex II
Apply requirements for prevention of emissions of F-gases also to manufacturing, storage and transport (bulk gases) **(A2.11)**	Amending Article 3 (2) and Article 3 (3) • Add requirements for precautionary measures and obligation to repair leakages without undue delay also for manufacturers and those possessing the equipment under transport and storage
Recovery of insulation foam blown with HFCs	
Destruction of HFCs in steel-faced panels or reuse **(A3.1)**	Amending Article 8. Major emissions from certain foam products containing HFCs will occur at EoL. Current legislation and recovery practices in several Member States do not require the recovery of HFCs from insulation foams such as steel-faced panels.
Destruction (or reuse) of HFCs in laminated boards in built-up structures and cavities, unless feasibility is proven by the building owner/demolition company **(A3.2)**	Major emissions from certain foam products containing HFCs will occur at EoL. Current legislation and recovery practices in several Member States do not require the recovery of HFCs from insulation foams such as laminated boards.

Annex 9.2 Objective B: Seeking alignment with the Montreal Protocol

a) To achieve full alignment, add new phase-down steps beyond 2030

Policy measure	Description of policy measure
Introduce steps in 2034 and 2036 to assure long-term compliance with MP (plus safety margin) **(A1.1)**	Amending Article 15, Annex V • Introduce phase-down reduction steps for 2034 and 2036 (in alignment with the Montreal Protocol

b) To achieve full alignment, remove some exemptions and thresholds not foreseen by the Montreal Protocol

Policy measure n	Description of policy measure
Remove exemption from POM restriction under the phase-down for HFCs for the use of military equipment (B1.1)	Removing Article 15(2)(d) • Remove exemption from placing on the market restrictions under the phase-down for HFCs for military equipment Remove corresponding labelling requirement in Article 12(9) • Will become irrelevant once Article 15(2)(d) is removed
Remove exemption from the HFC phase-down for semiconductors **(B1.2)**	Removing Article 15(2)(e) • Remove exemption from placing on the market restrictions under the phase-down for HFCs for etching of semiconductor material or cleaning of chemicals vapour deposition chambers within the semiconductor manufacturing sector Removing Article 12(10)

Policy measure n	Description of policy measure
	• Remove labelling requirement as it becomes irrelevant once the exemption is removed
Remove exemption from HFC phase-down for metered dose inhalers (MDIs) (B1.3)	Removing 15(2)(f) • Remove exemption from placing on the market restrictions under the phase-down for HFCs for use in metered dose inhalers (e.g. from 2025) Removing Article 12(12) • Remove labelling requirement as it becomes irrelevant once the exemption is removed
Remove threshold for placing HFC on the market **(B2.1)**	Amending Article 15(2) • Remove limit of 100 tonnes of CO_2 eq for producers or importers that place HFCs on the market Amending Article 14 • Include an exemption for import of pre-charged equipment for private use (e.g. importing a car (with AC) for private use), while private import of bulk HFCs should not be allowed
Remove threshold for reporting on production, import and export **(B2.2)**	Amending Article 19(1) • Remove the limit of 1 metric tonne or 100 tonnes of CO_2 eq for reporting on production, import and export of F-gases and other gases listed in Annex II
Remove threshold for reporting on destruction **(B2.2)**	Amending Article 19(2) • Remove the limit of 1 metric tonne or 1 000 tonnes of CO_2 eq of F-gases and other gases listed in Annex II for reporting on destruction
Remove threshold for reporting on feedstock	Amending Article 19(3) • Remove the limit of 1 000 tonnes of CO_2 eq of F-gases for reporting on feedstock

c) To achieve full alignment, make separate phasing down of HFC production

Policy option	Description of policy option
Implement HFC production phase-down in addition to POM phase-down **(B3.1)** **OR**	New Article (and Annex) • Add an EU-wide production phase-down, which would be quantitatively adapted to the Montreal Protocol (same ambition level) • Introduce quota for HFC production
Split POM phase-down into production and import phase-down	Amending Article 15 • Replace the POM phase-down by production phase-down and an import phase-down

Policy option	Description of policy option
	• The metric of "imports phase-down" would need to be designed to account also for exports (and possibly destruction/feedstock use) for consistency with the Montreal Protocol (net imports) • Imported HFCs pre-charged in equipment would be covered by the import phase-down

d) Add flexibility to be able to align with future Montreal Protocol decisions

Policy option	Description of policy option
Add flexibility to integrate future decisions under the Montreal Protocol	• Maintain/include the possibility to adopt delegated acts to adapt the FGR to allow alignment with potential future decisions under the Montreal Protocol (e.g. related to exemptions from the HFC phase-down, adjustment of GWP values to more recent scientific data (IPCC AR5 or AR6 instead of AR4)

e) Other

Policy option	Description of policy option
New prohibition for exports of bulk HFCs from the EU to any country not Party to the Kigali Amendment as of 2033 **(B3.2)**	

Annex 9.3: Objective C: Improve implementation and enforcement

a) Certification of technicians to include skills on the use of low-GWP alternatives

Policy measure	Description of policy measure
Certification requirement for unsaturated HFCs and HCFCs and other alternatives **(C1.2)**	Amending Article 10 • Extend the current certification scheme to installation, servicing, maintenance, repair, decommissioning, leak checks and recovery of other F-gases listed in Section 1 Annex II and other alternatives
F-gas certification programmes also to include practical know-how on all alternatives **(C1.2)**	Amending Article 10(3) • Supplement minimum skills and knowledge requirements to be assessed by the evaluation bodies with the requirement that certification programmes and training shall also include theoretical and practical tests for handling products and equipment based on all alternatives
Adding energy efficiency issues to be part of training **(C1.1)**	
Installation/servicing/repair/maintenance only be certified personnel for unsaturated H(C)FCs **(C1.3)**	

b) Including detailed rules to empower customs and market surveillance authorities in the EU Member States and facilitate the use of the EU "Single Window environment for Customs"

Policy measure	Description of policy measure
Extend 'placing on the market"	
Clear instructions on custom authorities' and market surveillance authorities' role **(C2.2)**	• Include rules on role and procedures for customs authorities, possibly also on access to HFC registry for real-time checks of quota • Incl. border checks using TAXUD toolbox language and customs' cooperation with other authorities (market surveillance, ENV competent authorities)
Treatment of products and equipment illegally placed on the market and illegal containers **(C2.1)**	• Add requirement to confiscate illegally traded products and equipment as well as containers Options for further process: • Destruction of confiscated containers • Auctioning of confiscated containers (bidding procedure) → *in case of use/auctioning of containers quota coverage required* • Include minimum EU-wide rules for MS and customs authorities for enforcement of the requirements
Confidentiality obligations for MS	• Article 17 and 19

Minimum penalties (C 3.9)

Policy measure	Description of policy measure
Include minimum penalties for quota exceedances	Amending Article 25(1) • Include minimum penalties to be enforced by EU Member States for quota exceedance • Put in a fixed, number, to be changed by DA
Include minimum penalties for quota authorisation deficit	Amending Article 25(1) • Include minimum penalties to be enforced by EU Member States for quota authorisation deficit
Include minimum penalties for illegal issuance of authorisations	Amending Article 25(1) • Include minimum penalties to be enforced by EU Member States for illegal issuance of authorisations
Include minimum penalties for non-compliance with reporting deadlines, lack of verification	Amending Article 25 • Include minimum penalties to be enforced by EU Member States in case of non-compliance with reporting deadlines
Include minimum penalties for trading, storage and use of HFCs not covered by quota	Amending Article 25(1) • Include minimum penalties to enforced by EU Member States in case of transport, storage and use of HFC not covered by quota

Policy measure	Description of policy measure
	• Promote harmonisation and publication of penalties for illegal trade activities across all EU Member States

c) Strengthening obligations of economics operators to prevent illegal trade

Policy measure	Description of policy measure
New prohibitions	
Extending the current POM prohibition for non-refillable F-gas containers also to their transport, storage and use when intended for uses covered by the POM prohibition **(C3.1)**	Amending Annex III • Add prohibition on the transport, storage and use of all non-refillable containers for F-gases (Annex I) and other F-gases (Annex II) from a certain date, while allowing exemptions for individual gases (if necessary) Amending Article 2(13) • Adjust definition of non-refillable containers accordingly **General ban on non-refillable containers, i.e. may not enter the territory of the Union under any custom procedure unless for transit and direct export**
Prohibition for (offline and online) sales and possession of F-gases that were illegally placed on the market **(C3.2)**	• Add prohibition to make available a product or equipment covered in Annex III to a third party in the Union • Add prohibition to make HFCs available to third parties, to transfer HFCs to third parties or to use HFCs which have been placed on the market in violation of the requirements of Article 15 (1), with the exception of provision, transfer or use for return or disposal.inlcuding by interent sales
Prohibition for (offline and online) sales of products listed Annex III one year after the date from which the placing on the market restriction applies **(C3.2)**	• See previous policy option
Limitations for transit (T1) and similar procedures	• E.g. limit use of transit (T1) procedures to "authorised consignees" unless for direct export
Introduce specification of 10-digit code for transit (T1)	Introduce specification of 10-digit code for transit (T1)
New obligations for importers of bulk HFCs and products and equipment pre-charged with HFCs	
Mandatory certification for importers of bulk HFCs	• Amending Article 10 with respect to certification need
Mandatory registration for all importers of pre-charged products and equipment	Amending Article 17(1) • Add requirement for all importers of pre-charged products and equipment to register, while allowing an exemption for private consumption

Policy measure	Description of policy measure
Requirement for non-EU importers of pre-charged products and equipment to mandate an "only representative" and have an Economic Operators' Registration and Identification (EORI)	• Add the OR approach to non-EU equipment importers receiving an authorisation
Requirement to add and the F-gas ID and F-gas quantities expressed in CO_2 eq in customs documents for both bulk and products and equipment (registry)	• Add requirement that F-gas ID and F-gas quantities expressed in CO2 eq are included in customs documents for both bulk and products and equipment
New obligations for selling F-gases	
Mandatory certification for natural persons and undertakings selling bulk F-gases online **(C3.4)**	Amending Article 10 • Add requirement for all natural and legal persons to hold a certificate for selling F-gases online • Ban online sales
Mandatory documentation for downstream sales for bulk HFC/F-gases (e.g. "declaration of conformity") and record keeping **(C3.5)**	• Add requirement for "declaration of conformity" for downstream sales of bulk HFCs that includes relevant information (e.g. about producer or importer, HFCs covered by quota, exemptions, delivery exclusively for return or disposal) • Add requirement for record keeping
Other requirements	
Requirement for producers and importers to hold sufficient quota at the time of release for free circulation/placing on the market (automatic in case of import phase-down) **(C3.6)**	

Policy measure	Description of policy measure
Strengthen the obligation on destruction of HFC-23 by-production **(C3.8)**	• Specify the evidence that producers and importers have to provide to proof HFC-23 by-product destruction • "Declaration on Conformity" for import (Article 7)

d) Limiting the market players to legitimate participants

Policy measure	Description of policy measure
Enshrine the BO principle to limit market players	• Move BO-related provisions from the Implementing regulation into the Regulation
Limit issuing quota authorisations to incumbents **(C4.1)**	• Limit issuing authorisations to RV-based quota
Change of the frequency of quota allocation from once a year to twice a year	• Rather withholding of quotas for certain reasons (penalties, etc..) – to be specified
Align declaration-based quota allocation with the frequency of the quota allocation based on reference values (i.e. for three years) **(C4.2)**	Amending Article 16(2) • Producers and importers that are not incumbents should declare their intention to place HFCs on the market for the following three years

Policy measure	Description of policy measure
	• Probably needs to be combined with reserve for yearly finetuning • However, penalties remain yearly
Introduction of a registration and/or quota allocation price linked to CO_2 eq **(C4.3)**	• Allocate HFC quota at cost • Introduce a fixed quota-price, related to CO_2 eq, to be paid by the producers/importers

e) More comprehensive monitoring

Policy measure	Description of policy measure
Labelling	
Labelling requirement for HFOs and NF_3 and possibly other F-gases **(C5.1)**	Amending Article 12(1) • Add requirement that products and equipment that contain, or whose functioning relies upon HFOs shall not be placed on the market and sold unless they are labelled Amending Article 12(1) • Add requirement that HFO containers shall not be placed on the market unless they are labelled • Remove exemptions from labelling for metered dose inhalers Amending Article 12(3),(4) • Add requirement that the label should indicate the same information as required for F-gases
Reporting and verification	
New reporting and registration obligation for exporters of products and equipment containing F-gases and other fluorinated substances **(C5.2)**	• Add obligation to report for exporters of products and equipment containing F-gases and other fluorinated substances • Set limit of 1000 tonnes of CO_2 eq
New reporting obligation for recipients of quota-exempted HFCs **(C5.3)**	Amending Article 19 • Add reporting requirement for recipients of quota-exempted gases • (conditional on retaining exemptions (see Objective B(b))
New reporting obligation for undertakings performing recycling and reclamation of F-gases **(C5.4)**	Amending Article 19 • Add a reporting requirement for companies performing recycling and reclamation
New reporting obligation for operators of switchgear and electrical equipment with regard to SF_6 emissions **(C5.5)**	• Mandatory reporting requirement for operators of electrical equipment on leakage, recovery, recycling and end-of life treatment of equipment

Policy measure	Description of policy measure
Remove or lower the threshold for verification of bulk HFCs placed on the market **(C5.6)**	Amending Article 19(6) • Removing or lowering the threshold of 10 000 t CO_2 eq for verification of HFCs placed on the market by an independent auditor
Add obligation for to submit verification reports for bulk HFCs **(C5.7)**	Amending Article 19 • Amend respective provision
Align reporting and verification thresholds for placing on the market products and equipment **(C5.8)**	• Introduce a threshold value for the need for independent verification for pre-charged equipment • Possibly align verification thresholds between bulk & equipment
Align reporting and quota authorisation thresholds for placing pre-charged products and equipment on the market **(C5.9)**	Article 19(4) • Change the limit of 500 tonnes of CO_2 eq to 100 tonnes CO_2 eq for reporting by producers and importers of products and equipment containing F-gases and other F-gases, while exempting the import of pre-charged equipment for private use
Align reporting and verification dates (separately for bulk and pre-charged products and equipment) **(C5.11)**	• Align reporting and verification dates, separately for bulk (Article 19) and equipment (Article 14) Could be linked to adding a legal basis for electronic verification in order to strengthen the processes
Add legal basis for electronic verification process (separately for bulk and pre-charged products and equipment) **(C5.10)**	• Add legal basis for electronic verification process, separately for bulk (Article 19) and equipment (Article 14)
Obligation to provide NIL reports if you hold quota **(C5.12)**	
Data collection and publication	
Encourage or require EU Member States to use electronic reporting systems for collection of F-gas emissions data **(C5.13)**	• Encourage the use of electronic tools for leakage monitoring; • Link to emission reporting to the UNFCCC
Substances	
Include new substances in Annex I **(C5.14)**	• Perfluorodecalin ($C_{10}F_{18}$) should be added to Annex I, Section 2 **Also long-chain PFCs (e.g. $C_{14}F_{24}$)!** • Add sulfuryl fluoride (SO_2F_2, GWP 4 630, AR6) to Section 2 of Annex I (link) – optional add to Annex II
Include new substances in Annex II **(C5.15)**	• Add sevoflurane (HFE-347mnz1 (GWP 195, AR6) to Section 2 of Annex II • Add enflurane (HCFE-235ca2, GWP 654, AR6) to Section 2 of Annex II

Policy measure	Description of policy measure
	• Cis-1-chloro-2,3,3,3-tetrafluoroprop-1-ene (HCFC-1224yd (Z)), which has been commercially produced since 2018, shall be included in Annex II, Section 1 • 2,3,3,3-tetrafluoro-2-(trifluoromethyl)propanenitrile (C_4F_7N), used as a replacement for SF_6, should be included in Annex II because it has a GWP of 2 750 (AR6) **Also $C_9F_{21}N$ and $C_5F_{11}NO$, $C_{12}F_{27}N$** • Add sulfurylfluoride (SO_2F_2, GWP 4 630, AR6) to Section 2 of Annex II
Move substances from Annex II to Annex I **(C5.16)**	• Move HFOs from Annex II to a new section in Annex I • Nitrogen trifluoride (NF_3) and perfluoro-cyclopropane ($c\text{-}C_3F_6$) should be moved from Annex II to Annex I as these substances are covered by Regulation (EU) No 525/2013 and UNFCCC
Add flexibility to amend Annex II	• Delegated act in line with scientific findings

Annex 9.4: Objective D: Other improvements and clarifications

Policy measure	Description of policy measure
Include GWP20 values for substances listed in Annex I and Annex II	Amending Annex I and Annex II • Including the GWP20 value in addition to the currently listed GWP100 value for each substance listed in Annex I and Annex II
Requirements related to imports of pre-charged equipment should be explained more clearly in the FGR	• E.g. some of the content now explained in guidance documents should be included in the legal text
Close loopholes on selling gases to garages	Amending Article 11(4) • Selling gas to companies doing such activities, including garages, shall be prohibited
Remove definition "undertaking"	
Clarify "aerosol"	
Clarify "medical" vs. "cosmetic"	
Clarify "destruction"	
Clarify "consignee"	
Authorisations: "exclusively" to be addressed	
Date for next review	
Clarify that no export credit for equipment	
Starlight issue: certification requirement also for click-fix AC installations	
Introduce verification threshold for PCE, aligned with reporting	
Make sure pseudo-hermetical equipment not exempted from bans	

Policy measure	Description of policy measure
Gases imported always considered virgin, need quota and cannot be used for servicing	
Clarification that quotas also for production-emitted gases	
Clarify how past exemptions are used for calculating maximum quantity	
Clarify import/export (entry of goods, exit of goods)	
Clarifications on refrigeration bans (e.g. ice cream, water chillers etc.,), incl. removing domestic/commercial etc. qualifiers	
Small corrections in Annex II on formulas, names	