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Predicted Hydrofluorocarbon (HFC) and Perfluorocarbon (PFC) Emissions for the Years 2010–2050 in the Czech Republic

Zuzana Rošková [1,2,*], Julieta Schneider [1] and Martin Štengel [2]

[1] NIS Department, Air Quality Division, Czech Hydrometeorological Institute, Na Šabatce 2050/17, 143 06 Prague, Czech Republic
[2] Department of Environmental Chemistry, Faculty of Environmental Technology, University of Chemistry and Technology Prague, Technická 5, 166 28 Prague, Czech Republic
* Correspondence: zuzana.roskova@chmi.cz; Tel.: +420-244-032-706

Abstract: Hydrofluorocarbons and perfluorocarbons (F-gases) play a substantial role in global warming via the greenhouse effect and thus have been under increased investigation recently. EU member states, including the Czech Republic, already have measures limiting F-gas use based on their GWP such as EU regulation No. 517/2014. This manuscript explains the current status of F-gas emissions and describes a methodology of their estimation for the years 2010 to 2050. The computational method is based on the IPCC 2006 Guidelines. Currently available data, distribution of F-gases and active policies are crucial parameters for standard greenhouse gas emission estimates as well as for long-term projections. The outcomes demonstrate the effectiveness of the regulations implemented and provides a prediction scenario for how F-gas emissions will develop. According to these projections, a total F-gas emission decline is expected in the Czech Republic. For F-gas applications in refrigeration and air-conditioning, the predicted downward trend is more significant compared to the other F-gas application sectors, as they are currently some of the biggest contributors in the actual state of emissions.

Keywords: hydrofluorocarbons; perfluorocarbons; refrigeration; air-conditioning; global warming; greenhouse effect; projections; emissions; the Czech Republic

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1. Introduction

Though global warming has been a pressing issue for decades, its impact on natural and human systems is now approaching a point of no return as the global surface temperature continues to increase steadily [1]. The current pace of increase would rapidly lead to critical scenarios of 1.5 °C and 2 °C global warming above pre-industrial levels [2–4]. The greenhouse gas effect is the main driver of the increasing temperature, produced by so-called greenhouse gases (GHGs), which primarily include carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O) and fluorinated greenhouse gases (F-gases) [5].

Of all of the above-mentioned GHGs, F-gases are now at the center of public concern. These are a family of anthropogenic gases composed of hydrocarbon chains where hydrogen atoms are fully or partly substituted by fluorine atoms. Depending on the fluorine content, these molecules are divided into perfluorocarbons (PFCs), which are fully fluorine-substituted hydrocarbons, or hydrofluorocarbons (HFCs), which are only partially substituted. F-gases have been used as a replacement for ODS, since they do not damage the stratospheric ozone layer [6]. However, these gases have a high global warming potential (GWP), thus contributing substantially to climate change. To contain and prevent their emissions, the European Union (EU) and the United Nations (UN) have adopted new legislation, which aims to control and slowly lower their production and application in new products [7]. The challenge remains how to manage F-gases stored in existing, functioning products and in waste. Fluorinated gases have been used mainly in refrigerating systems

to replace ODS, because of their low or even non-toxicity to humans and their null effect on the ozone layer [8,9].

Nevertheless, most F-gases can linger in the atmosphere for long periods of time (HFCs up to hundreds of years and PFCs up to thousands) and have high GWP, reaching values of up to 13,000 times greater than CO_2 over a 100 years, which means that F-gases capture up to thousands of times more energy than the same amount of CO_2 in the same time frame [10].

Though not manufactured in the Czech Republic, F-gases appear in final products in sectors, such as stationary air-conditioning (SAC), mobile air-conditioning (MAC), transport refrigeration, commercial refrigeration, industrial refrigeration, fire protection, foam blowing agents (FBA) and aerosols and solvents belonging to category 2.F of the Intergovernmental Panel on Climate Change (IPCC) methodology [11]. A list of the gases used in above mentioned categories are presented in the Table 1 [12].

Table 1. List of F-gases and their applications in the Czech Republic.

Application	F-Gas
Commercial Refrigeration	HFC-125, HFC-152a, HFC-32, HFC-143a, HFC-134a, HFC-23, C_3F_8, C_2F_6, C_6F_{14}, HFC-227ea,
Domestic Refrigeration	HFC-134a,
Industrial Refrigeration	HFC-125, HFC-32, HFC-143a, HFC-134a
Transport Refrigeration	HFC-125, HFC-32, HFC-143a, HFC-134a
MAC	HFC-134a,
SAC	HFC-125, HFC-32, HFC-143a, HFC-134a
FBA	HFC-134a, HFC-227ea, HFC-245fa
Fire Protection	HFC-227ea, HFC-236fa, C_3F_8
Aerosols and Metered-dose Inhalers	HFC-134a, HFC-227ea
Solvents	HFC-152a, HFC-134a, HFC-245fa

You can see from Table 1 that HFCs are prevalent in the Czech F-gas market. Only three PCFs are present (C_2F_6, C_3F_8 and C_6F_{14}), and as will be shown later in the text, they have very little impact on overall F-gas emissions. They are found in products like commercial refrigeration and fire retardants.

The aim of this research was to project both HFC and PFC emissions based on the current trade situation, actual input activity data and active laws in the Czech Republic.

2. Methodologies of F-Gas Emission Projections in the Czech Republic

Projections of GHG emissions are a significant component of national emission reduction policy. More precise emission projections better reflect the effect of planned and implemented regulations.

Category 2.F is the center of concern for these emission predictions in the Czech Republic, as it is the major category of F-gas use. The Introduction Section categorized the many 2.F application areas. It is worth emphasizing that the 2.F category is responsible for the highest amount of F-gas emissions in the country. However, overall F-gas emissions are still quite low, primarily due to the lack of significant industrial sources. The biggest source of emissions is subcategory 2.F.1, which covers 99% of overall 2.F emissions.

In the Czech Republic, we have three separate available models for F-gas emission estimations: Phoenix, MAC emissions and Other F-gas emissions models.

For standard inventory, there are three data sources: ISPOP (the "Integrated system of reporting obligations"), the F-gas register (Questionnaire on production, import, export, feedstock use and destruction of the substances listed in Annexes I or II of the F-gas regulation) and custom data (database of cross-border movements of goods). These data sources provide information on the number of pure F-gases or their blends, which differs according to each data source. Other important information obtained from data reports is whether the F-gas was imported, exported or destroyed, as well as if it was EU or non-EU

trade. These data were used for emission estimation in the Phoenix and the Other F-gas emissions models for years 2010–2020.

The traditional F-gas emission inventory from MAC has additional data sources. The number of vehicles equipped with MAC is the principal information based on the real number of vehicles, percentages of vehicles with AC and average charge of refrigerant per vehicle. The number of newly manufactured vehicles is obtained from the Automotive Industry Association. Further information is obtained from annual reports from Czech car producers (Skoda Auto, Inc., Mladá Boleslav, Czech Republic, Toyota Motors Manufacturing, Ltd., Průmyslová zóna Ovčáry, Czechia and Hyundai Motor Manufacturing, Ltd., Nižní Lhoty, Czechia), bus producers (IVECO Czech Republic, Inc., Pražské Předměstí, Czechia, SOR Libchavy, Ltd., Libchavy, Czech Republic and others) and TATRA TRUCKS, Inc. (Kopřivnice, Czechia) as the sole Czech truck producer.

A brief description of each F-gas model emission projection is provided below.

2.1. Model Phoenix

The Phoenix model [13] was created for standard emission inventory using estimation of emissions from SAC and four types of refrigeration: commercial, domestic, industrial and transport. This model was developed according to the methodology developed by the IPCC [11] and serves as a tool for emission projections as well.

The model is divided into three main segments: input, emission estimates and output. Input works with annual F-gas consumption (activity data), emission factors (EFs) and active policies and measures (PAMs). Activity data for the years 2010–2020 are described above. Data for the years 2021–2050 were estimated in accordance with the Kigali Amendment to the Montreal Protocol (KA), which asks for a reduction in usage to 15% of the average consumption from years 2011–2013 by the year 2036 for industrialized countries, which includes the Czech Republic [14]. The effect of the KA on F-gas consumption is shown in Figure 1 and Table 2.

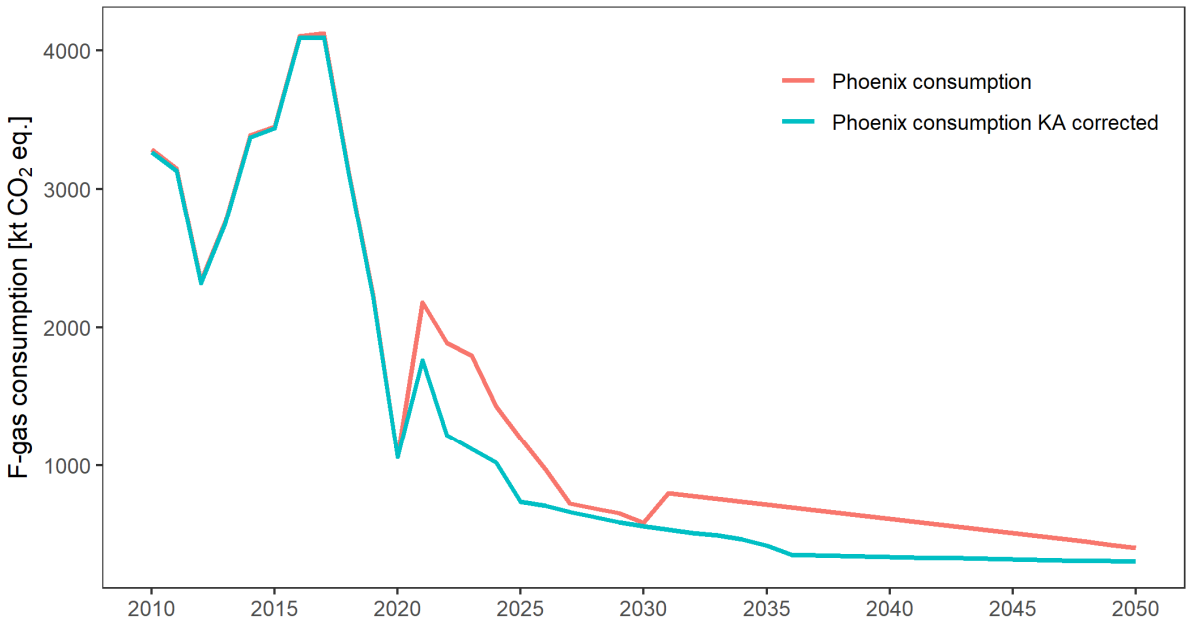

Figure 1. Consumption of F-gases inputted into the Phoenix model, both with and without KA correction.

Table 2. Total F-gas consumption in years 2010–2050, with and without the KA reduction (kt CO_2 eq.).

	Total Consumption	Total Consumption with the KA
2010	3289.67	
2011	3148.43	
2012	2335.22	
2013	2766.24	
2014	3390.28	3375.87
2015	3453.01	3439.83
2019	2233.03	2211.48
2020	1060.42	1060.42
2021	2177.49	1759.98
2022	1888.41	1220.71
2025	1195.52	736.58
2030	588.77	564.11
2035	719.31	422.77
2036	697.98	356.50
2040	615.67	341.77
2045	512.24	324.69
2050	408.74	308.36

The massive decline in F-gas consumption shown in Figure 1 above in the year 2020 was likely brought on by the CoV-SARS-2 pandemic, which had a negative impact on the economy and several manufacturing and industrial sectors. Lower F-gas usage in 2012 compared to 2011 and 2013 was caused by the economic downturn in that year. In general, it can be said that overall financial status of the state is reflected in the general prosperity of the country and is most obvious in the production of goods and F-gas consumption.

Regarding PAMs, the regulation of the European Parliament and of the Council No. 517/2014 plays an important role. Since January 2020, this regulation forbids the use of F-gases with GWP equal to or higher than 2500 in stationary air-conditioning with a charge of 40 t CO_2 eq. equivalent or higher. It also forbids the use of gases with a GWP of 150 or more in freezers and refrigeration equipment used for commercial applications [7]. This rule affects F-gas trading and impacts data that are currently available (activity data).

EFs are another part of the input. EFs used for emission estimation for whole timeline (2010–2050) are listed below in Table 3 and are in line with IPCC methodology [11].

Table 3. EFs used for emission estimation for the years 2010–2050.

Factor in Equations	Lifetime (Years)	Emission Factors (% of Initial Charge/Year)		End-of-Life Emissions (%)	
	(d)	(k)	(x)	($\eta_{rec,d}$)	(p)
		Initial Emissions	Operation Emissions	Recovery Efficiency	Initial Charge Remaining
Commercial refrigeration	10.5	3.0	13.0	55.0	70.0
Domestic refrigeration	13.5	0.5	3.5	55.0	70.0
Industrial refrigeration	17.0	3.0	13.0	55.0	70.0
Transport refrigeration	8.5	0.5	20.0	55.0	30.0
SAC	13.5	0.5	6.5	55.0	70.0

Emission estimates consist of three main equations: emission from the initial charge when filling new equipment $E_{1at\ fill}$, emissions from use during the lifetime of the product $E_{lifetime}$ and product-decommissioning emissions $E_{decommissioning}$. The emissions are calculated

for each gas and area of application separately based on emission calculations described in the IPCC Guidelines 2006 [11].

Emission from filling new equipment in any year t is estimated according to following equation:

$$E_{1st\ fill,t} = M_t \cdot \frac{k}{100} \quad (1)$$

where M_t is amount of F-gas filled in new charges and k is the emission factor for initial losses.

Lifetime emissions are calculated with a similar equation to the first fill emissions:

$$E_{lifetime,t} = B_t \cdot \frac{x}{100} \quad (2)$$

where x is annual emission rate factor and B_t is the amount of chemical stored in the system calculated as:

$$B_t = S_t - E_{lifetime,t} - E_{decommissioning,t} + B_{t-1} - E_{decommissioning,t-1} \quad (3)$$

where S_t is the amount of gas in the equipment first fill and while servicing.

Emissions from the system at the end of life are calculated as:

$$E_{decommissioning,t} = \left(1 - \frac{\eta_{rec,d}}{100}\right) \cdot H_t \quad (4)$$

where $\eta_{rec,d}$ is the factor for recovery efficiency at disposal and H_t is the amount of chemical remaining in the system.

The final stage of the Phoenix model is the output of overall emissions from each gas for all application areas separately.

2.2. MAC Emissions

Emissions and predictions from MAC are calculated separately. The MAC emission estimations take into account the type of vehicle: whether it is a passenger car, bus or truck. Trucks are further categorized into light and heavy-duty vehicles. Activity data for the standard GHG inventory were described above in this chapter. For the MAC forecast, the predicted number of newly manufactured vehicles in the Czech Republic provided by the Ministry of Industry and Trade plays an important role. However, these data contain aggregated information, and the value for each car producer is then recalculated in line with the average annual share of each producer. The same procedure is applied to estimate the average initial charge. Czech car producers' percentage shares and their average MAC charge are shown in the Table 4.

Table 4. Annual percentage of the total production and average initial charge of Czech passenger car producers.

Car Producer	%-Share	Average Initial MAC Fluid Charge [g]
A	61.0	478
B	14.5	390
C	24.5	570

Actual F-gas consumption in MAC is affected by Directive 2006/40/EC (also called the MAC Directive), which regulates F-gases for air-conditioning devices in passenger cars and light commercial vehicles. Since 2007, the MAC directive prohibits the use of F-gases with GWP higher than 150 in MAC, with exceptions for system with annual leak rates not exceeding 40 g or 60 g, according to the type of evaporator system [15]. The KA, as for the Phoenix model, is used in MAC to adjust projected consumption, which can be seen in Figure 2 and Table 5 below.

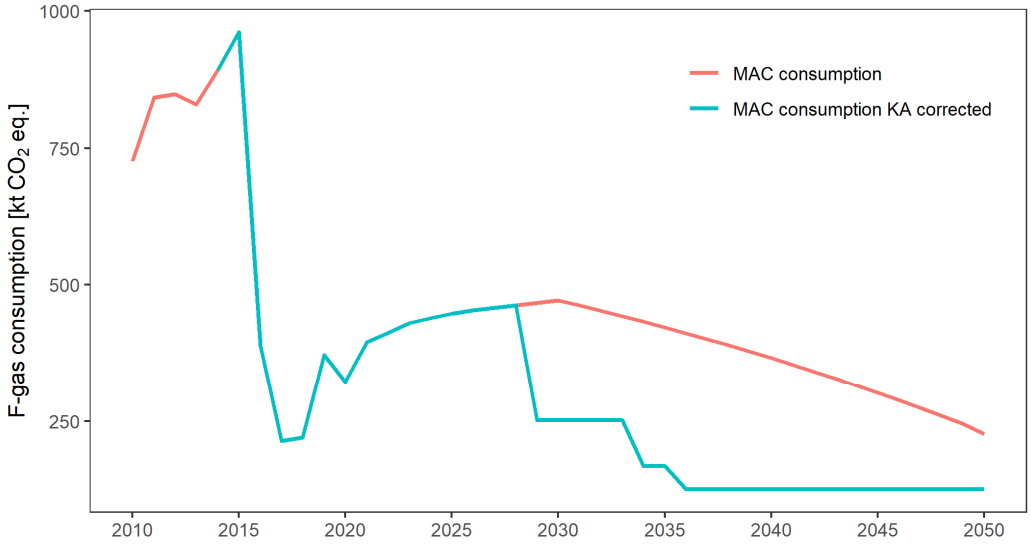

Figure 2. MAC F-gas consumption in the years 2010–2050 with and without the KA correction.

Table 5. MAC F-gas consumption in the years 2010–2050 with and without the KA correction (kt CO_2 eq.).

	MAC Consumption	MAC Consumption the KA Corrected
2010	726.97	
2011	841.85	
2012	848.25	
2013	829.76	
2014	892.55	892.55
2015	961.57	961.57
2019	371.37	371.37
2020	322.28	322.28
2021	394.62	394.62
2022	412.46	412.46
2025	447.13	447.13
2030	471.33	251.99
2035	422.02	167.99
2036	411.43	125.99
2040	366.11	125.99
2045	301.84	125.99
2050	226.43	125.99

Emission estimations from MAC are based on same Equations (1)–(4) as the Phoenix model, though with different factor values listed in Table 6 below.

Table 6. EFs used for calculation of MAC emissions [12].

Factor in Equations	Lifetime (Years)	Emission Factors (% of Initial Charge/Year)		End-of-Life Emissions (%)	
	(d)	(k)	(x)	($\eta_{rec,d}$)	(p)
		Initial Emissions	Operation Emissions	Recovery Efficiency	Initial Charge Remaining
Passenger cars	15.0	0.5	20.0	10.0	30.0
Light duty vehicles	13.0				
Heavy duty trucks	16.0				
Buses	14.0				

2.3. Other F-Gas Emissions

Lastly, F-gas emissions from solvents, aerosols and metered-dose inhalers; fire protection; and FBA are estimated separately from the F-gas applications mentioned above. Similar to the previous categories, the calculation here is divided into: input, emission estimates and output. Activity data for the standard inventory for these sectors are obtained from the same sources as for the categories listed in the Phoenix model (e.g., ISPOP, F-gas register and custom data). However, there is one additional data source for metered-dose inhalers. The State Institute for Drug Control (SIDC) provides data on the annual sales of drugs in the Czech Republic. SIDC publishes data for each pharmaceutical company on the amount sold of a specific type of a drug. Parameters for each drug are then obtained from the product specification list provided by the manufacturing company. Input activity data for the projection model are based on the trend of the current situation of the past 5 to 10 years and currently active PAMs. In regard to PAMs, regulation No. 517/2014 prohibits use of F-gases with a GWP of 150 or higher as technical aerosols since 2018 and as FBA for XPS since 1 January 2020 and additionally for other foams since 2023 [7]. The KA influences F-gas consumption in fire protecting agents are shown below in Table 7 [14]. All the PAMs mentioned above affect consumption, and this is being reflected in overall emissions per year.

Table 7. F-gas consumption in fire protecting agents with and without the KA correction (kt CO_2 eq.).

	Fire Protection	Fire Protection with the KA
2010	103.65	
2011	63.33	
2012	81.72	
2013	96.73	
2014	111.51	
2015	107.81	
2019	128.38	29.90
2020	53.0	55.95
2021	43.09	43.09
2022	39.77	39.77
2025	29.83	29.83
2030	15.47	15.47
2035	9.67	9.67
2036	8.29	8.29
2040	2.76	2.76
2045	2.76	2.76
2050	2.76	2.76

Emission estimation from these applications follows IPCC 2006 Guidelines [11] using Tier 1 methodology and recommended EFs. EFs used are summarized in Table 8 below.

Table 8. EFs used for emission estimation for FBA, fire protection, aerosols/metered-dose inhalers and solvents.

	Lifetime (Years)	First Year Losses (%)	Annual Losses (%)	Disposal Losses (%)
FBA	20.0	10.0	4.5	100.0
Fire Protection	15.0–20.0	2.0	2.0	15.0
Aerosols/Metered-dose Inhalers	2.0	50.0	50.0	NO [1]
Solvents	2.0	50.0	50.0	NO [1]

[1] NO—not occurring.

Expert judgement and the IPCC 2006 Guidelines were used to base the uncertainty estimations (for more see IPCC 2006 Gl., Volume 1, Chapter 3 Uncertainties) [11]. The level of uncertainty for all activity data was calculated to be 37%, whereas the uncertainty for the EFs was 23%.

3. Results and Discussion

In the year 2020, F-gas emissions were 3641 kt CO_2 eq. for HFCs and 0.6 kt CO_2 eq. for PFCs in the Czech Republic. According to the predictions, HFCs emissions are expected to decrease by 80% to 716 kt CO_2 eq., and PFCs emissions will sink by nearly 97% to 0.02 kt CO_2 eq. by the year 2050. Projected emissions of HFCs and PFCs for the years 2010–2050 are shown below in Table 9.

Table 9. HFC and PFC emissions overview (kt CO_2 eq.).

	HFCs				PFCs			
	Refrigeration and SAC	**MAC**	**Other Use**	**Total HFCs**	**Refrigeration and SAC**	**MAC**	**Other Use**	**Total PFCs**
2010	1634	739	51	2423	7.8	NO	0.02	7.8
2011	1839	799	49	2686	5.8	NO	0.03	5.9
2012	1923	835	40	2798	4.9	NO	0.03	4.9
2013	2040	847	39	2926	3.9	NO	0.03	4.0
2014	2209	840	36	3085	2.7	NO	0.03	2.7
2015	2370	901	35	3305	1.7	NO	0.03	1.7
2019	2840	884	36	3760	1.1	NO	0.03	1.1
2020	2722	885	38	3645	0.57	NO	0.03	0.60
2021	2678	878	38	3590	0.28	NO	0.03	0.31
2022	2496	875	42	3410	0.13	NO	0.03	0.16
2025	2003	857	48	2904	0.01	NO	0.03	0.04
2030	1226	791	53	2066	<0.01	NO	0.02	0.02
2035	823	650	55	1527	<0.01	NO	0.02	0.02
2040	544	526	54	1122	<0.01	NO	0.02	0.02
2045	435	402	52	887	<0.01	NO	0.02	0.02
2050	376	293	48	716	<0.01	NO	0.02	0.02

In comparison with the actual numbers from 2020, projected F-gas emission shares will be quite different in the year 2050. In 2020, refrigeration represents 53% with 1915 kt CO_2 eq., air-conditioning represents 46% with 1693 kt CO_2 eq. and other use represents 1% with 38 kt CO_2 eq., while in 2050, the equivalent numbers are 29% for refrigeration (210 kt CO_2 eq.), 64% for MAC and SAC (459 kt CO_2 eq.) and 7% for other use (48 kt CO_2 eq.). Overall emissions will sink by slightly more than 80% by 2050, according to these predictions. For interest, comparison of more detailed distribution of emissions for the years 2020 and 2050 is shown in Figure 3.

Table 10 below provides a summary of the total F-gas emissions broken down by their use for the years 2010 to 2050, in units of kt CO_2 eq. The data are discussed in more detail below in the text and served as input data for the following graphs.

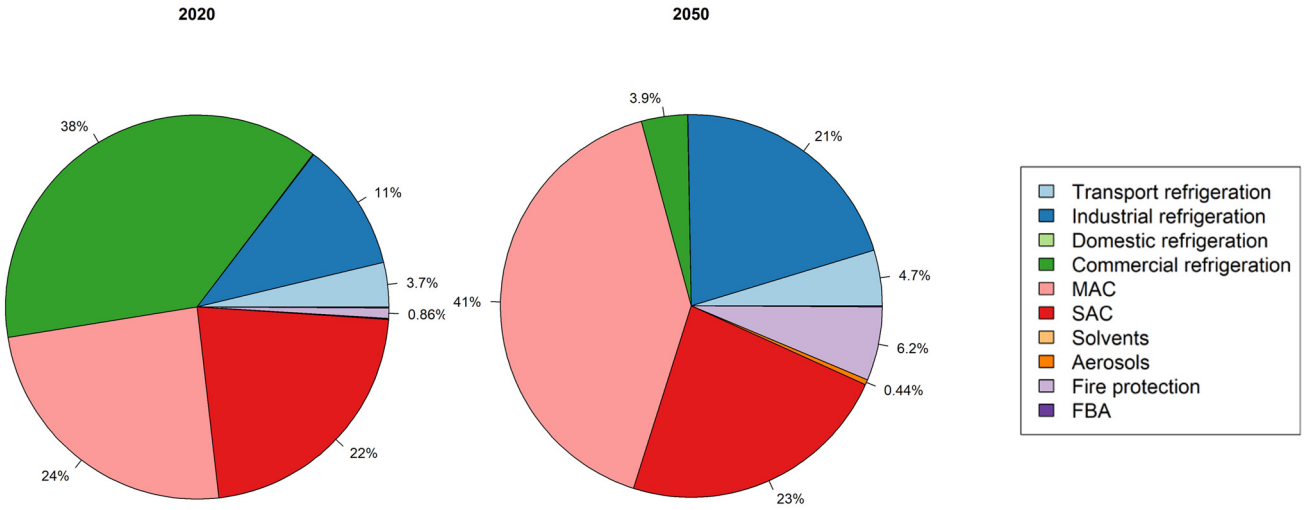

Figure 3. F-gas emission shares for years 2020 and 2050 based on kt CO_2 eq. Categories with share 0.1% and less are not shown.

Table 10. F-gas emission distribution for different use categories from 2010 to 2050 (kt CO_2 eq.).

	Commercial Refrigeration	Domestic Refrigeration	Industrial Refrigeration	Transport Refrigeration	SAC	MAC	FBA	Fire Protection	Aerosols	Solvents
2010	903	2.0	262	108	367	742	3.2	15	32	0.93
2011	1005	2.0	293	119	426	802	3.0	16	29	0.93
2012	1043	2.1	302	118	463	839	2.9	17	18	2.0
2013	1079	2.4	322	122	519	851	2.8	19	13	4.3
2014	1142	2.8	357	134	575	844	2.6	21	9.7	2.7
2015	1223	2.6	389	144	612	922	2.6	23	8.5	0.78
2019	1477	2.2	439	157	767	887	4.0	29	2.4	0.00
2020	1379	2.2	396	136	808	885	3.5	31	2.5	0.51
2021	1304	2.0	399	138	836	878	1.1	33	3.4	0.68
2022	1138	1.6	384	138	835	875	2.5	36	4.0	0.29
2025	716	1.2	395	134	758	857	2.9	42	3.0	0.08
2030	175	0.87	351	104	596	791	0.83	49	3.2	NO
2035	50	0.71	293	69	410	650	0.78	51	3.2	NO
2040	31	0.44	201	45	266	526	0.62	50	3.2	NO
2045	31	0.29	159	37	208	402	0.92	48	3.2	NO
2050	28	0.22	148	34	166	293	0.66	45	3.2	NO

If we focus on each category individually, emissions from air-conditioning and refrigeration must decrease as a result of tight legislation. Overall F-gas emission predictions from refrigeration copy the curve of the predicted F-gas market trend within the EU by Mota-Babiloni and Makhnatch (2021) [16]. The drop in emissions from refrigeration is expected to be around 89% from 2020 to 2050; the predicted trend is shown in Figure 4. In the case of F-gases, regardless of whether they are HFCs or PFCs, because of the thorough understanding of their GWPs; it is known that some of them will not be on the market in the future [17]. It is assumed that HFCs and PFCs will be replaced by carbon dioxide [18,19], ammonia and short-chain hydrocarbons, which were used earlier [20,21], as well as newly introduced low GWP HFOs [22,23].

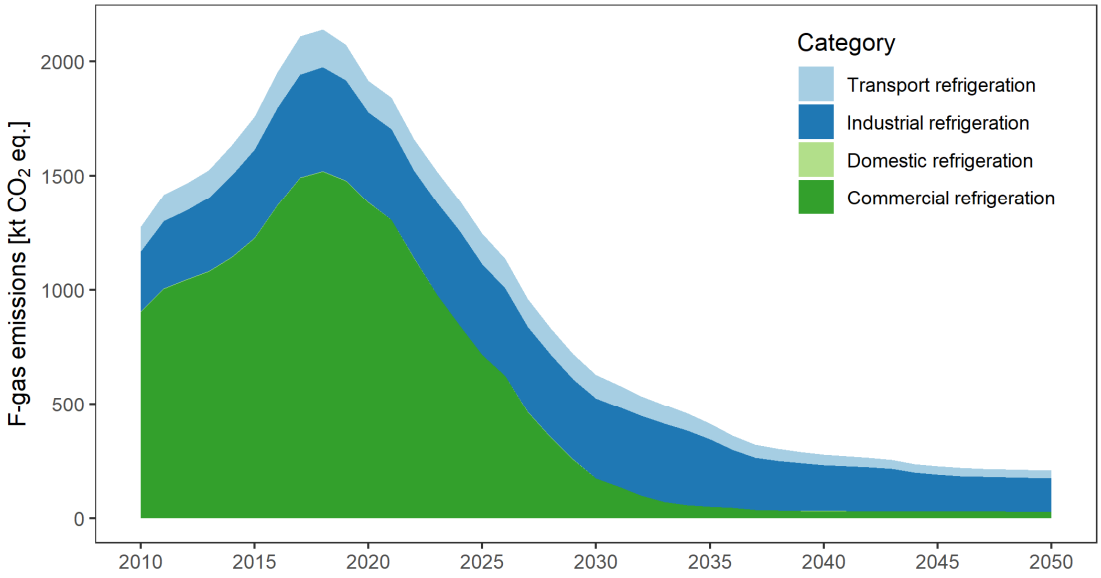

Figure 4. Forecast of F-gas emissions from refrigeration.

Air-conditioning (AC), as another application field, is estimated separately for SAC and MAC. In the Czech Republic, there are two particular F-gases, hydrofluoroolefins (HFOs): HFO-1234yf and HFO-1234zeE. These HFOs have been in passenger cars' MAC since 2016 and in SAC since 2017. However, thanks to their low GWP, these substances do not fall under the reporting obligation. Moreover, their impact on total emissions is negligible [24].

Emissions from AC are predicted to follow the same trajectory as those from refrigeration, as can be seen in Figure 5. The estimated decrease for SAC and MAC emissions from 2020 to 2050 is 79% and 67%, respectively. In SAC, there are F-gases, such as HFC-134a, HFC-32 and R407C, while in MAC, there are HFC-134a and HFO-1234yf [12]. This is despite the fact most of MAC emissions are affected by HFC-134a.

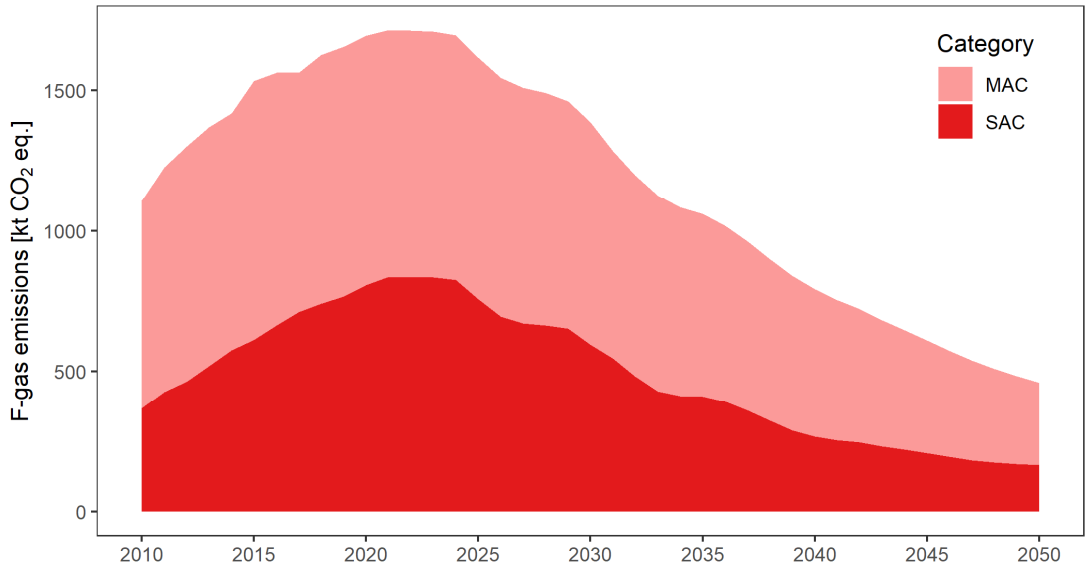

Figure 5. Trend of F-gas emission projections from air-conditioning.

However, the trend of projected emissions decreases due to gradual replacement of HFC-134a by HFO-1234yf. This replacement started in the 2017 due to the directive by the European parliament and of the council No. 2006/40/EC, which allows producers to use only the F-gases with a GWP of 150 or lower in MAC systems [15]. HFO-1234yf,

its structural isomers and other low-GWP substances also have potential to be used in refrigeration systems [25].

In the Czech Republic, other F-gas applications are as FBA, fire protection agents, aerosols and metered-dose inhalers and solvents. This category releases minimal emissions. It is assumed that neither applications nor emissions will change drastically for a number of years, as shown in Figure 6.

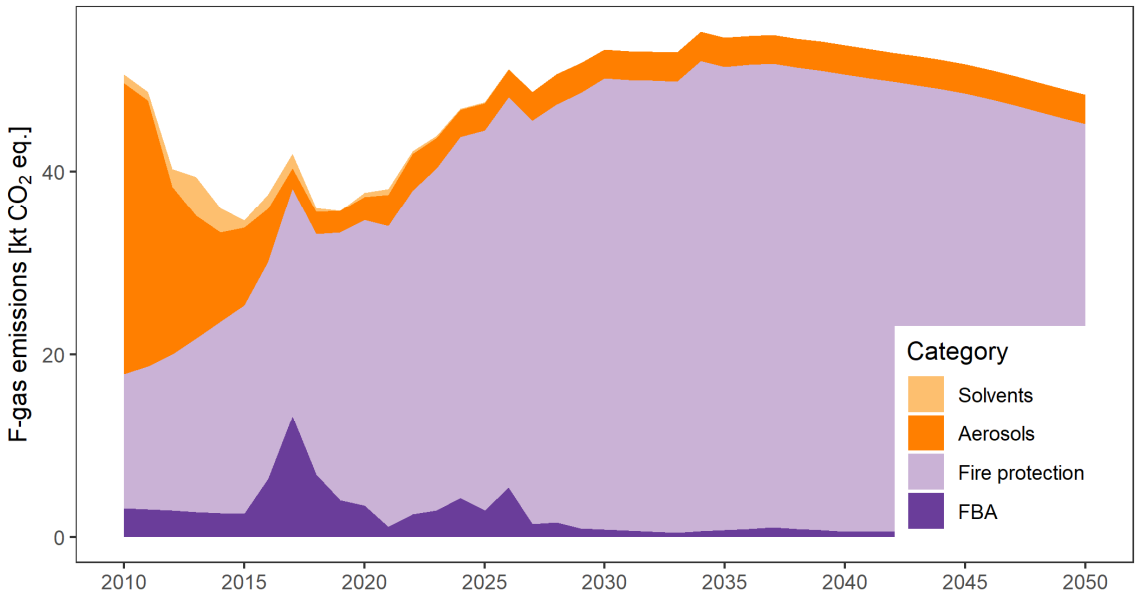

Figure 6. Other F-gas use emission projections.

Regarding other uses, some prohibitions have been active since 2007 thanks to EU regulation No. 517/2014, which has affected the current state of F-gas market and emissions [7]. Total F-gas emissions from other use is 37.7 kt CO_2 eq. for the year 2020. According to projections, it is assumed that these emissions will slightly rise to 48.4 kt CO_2 eq. by 2050. This is mostly caused by F-gases used as fire protection agents, which cover from 83% to 93% of F-gas emissions from other use. Fire retardants represent only 0.9% of overall HFC and PFC emissions in 2020 and 6% in 2050 in the Czech Republic. The value 0.9% is close to the historical world average [26]. Moreover, the US EPA predicted 0.4% emissions from fire extinguishers worldwide in the year 2030 with a value three times higher than the base year 2010. The US EPA also projected that emissions from this sector would sink if an appropriate abatement price is used per ton of CO_2 equivalent [27]. On the other hand, global emission projections cannot be compared with the situation in the EU member states, as regional legislation applies here. According to the US EPA report, the EU does not belong in the top emitting countries or regions [28].

4. Conclusions

HFCs and PFCs have been used in some cases as a replacement for ODS until now. Although they do not affect the stratospheric ozone layer, they do contribute significantly to global warming, as most of these substances have a high GWP.

In the Czech Republic, F-gas trade is regulated mostly by the EU regulation No. 517/2014, which seems to be the most effective, and the effects of this regulation are already visible in current F-gas first fill emissions. The Kigali Amendment to the Montreal Protocol is another promising policy whose requirements could be reflected in the future development of these substances emissions. Like this EU regulation, the Kigali Amendment affects most visible emissions from the initial charge and first year losses. However, these restrictions' effectiveness will slowly become more visible in the following decades.

According to these regulations, a decrease in F-gas trade and consumption is expected, which will consequently result in a decline in their emissions, according to current projections.

If we focus on the largest sources of F-gas emissions, without hesitation those are all types of refrigeration, MAC and SAC, sorted in a descending order. These categories are responsible for 99% of the total F-gas emission in the Czech Republic in the year 2020. Their emissions will drop by 78% on average by 2050, according to projections. Emissions from fire protectors and aerosols are expected to increase by 2050, as there are still no significant measures to limit their use. However, emissions from these areas are at a very low level in the Czech Republic, so they do not appear to be a significant issue.

Turning to FBA, there is also expected to be a sinking trend of emissions. It is assumed that it will take longer time to completely phase these out because of the huge amount banked into insulating foams, which are still in use or stored in waste.

Overall, the fact that previously restricted F-gases are present in items that are still in use, as well as legal exceptions that allow for their recycling and reuse in products, are the primary reason for these emissions to take longer before showing a decline.

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