Emission projections for fluorinated greenhouse gases in Finland up to 2050

Update of projections published in 2009 (Alaja, 2009)

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Contents

1 Introduction

The emission projections of fluorinated greenhouse gases in Finland were previously estimated in the publication 'Emission abatement options and cost effects for fluorinated greenhouse gases' (Alaja, 2009). In 2010 the information and assumptions behind the projections published in 2009 (hereinafter 2009 projections) were analyzed and updated.

When preparing projections presented in the publication by Alaja (2009) the information collected for National Greenhouse Gas Inventory under the UNFCCC and the Kyoto Protocol was available until 2007. Since then, national 2008 and 2009 inventories of fluorinated greenhouse gases has become available. The emission estimates of 2008 and 2009 show that projections prepared in 2009 may be slightly underestimated. Therefore the projections were updated with new information available from inventories, statistics, literature and companies.

This document only describes the changes made to the 2009 projections and new emission estimates. Full background documentation with abatement costs and description of the use of fluorinated greenhouse gases in Finland is provided in Alaja 2009.

2 Projections for Refrigeration and air conditioning equipment

2.1 Main assumptions for HFC emission projections of refrigeration and air conditioning equipment

In the publication by Alaja (2009) three emission scenarios were established for the refrigeration and air conditioning sectors. The *with measures* (WM) scenario is a business as usual projection, which relates the ongoing trends in the sector without further changes in the operational environment. The other two scenarios are *with additional measures* (WAM) scenarios, where future regulatory changes are taken into account.

The effect of the EC Regulation on F-gases (842/2006) on the lifetimes and disposal emission factors was reconsidered as the inventory results for the years 2008 and 2009 were higher than the earlier scenario assumed. In the 2009 scenarios the EC F-gases Regulation was estimated to reduce the emission factors by 50% by 2011. The calculation model was updated with the assumption that the use-phase emission factors are linearly reduced by 40% and the disposal emission factors by 33% between 2006 and 2015. This new approach corresponds to the draft AnaGas model used in the Review of F-gas Regulation with the exception that the timeline for emission factor reduction in AnaGas is assumed to be 2010-2015.

In the previous scenarios the EC MAC Directive (2006/40/EC) was interpreted to relate to all transport vehicles. The WM scenario was updated with the assumption that the phase out of HFC-134a as a result of MAC Directive implementation has an effect only on passenger cars and the situation for other vehicles stays constant.

In addition, the effect of the economic recession in 2009 to the sales figures of fluorinated greenhouse gases and the different equipment was taken into account in the updated scenarios.

In the previous scenarios, two with additional measure scenarios were established. In the first WAM scenario (WAM 1) the use of HFC substances was assumed to be forbidden in new equipment from the beginning of year 2015 in all of the refrigeration subsectors, and in the second WAM scenario (WAM 2), the use of HFC substances of GWP higher than 150 was expected to be forbidden in new equipment from the beginning of year 2015. In the updated WAM 1 scenario it is assumed that the HFC share in the new equipment will be reduced by 50% compared to WM scenarios by the year 2020. The change is calculated linearly between the years 2011 and 2020.

In the WAM 2 scenario the HFC share in the new equipment will be reduced to 15% compared to HFC share in 2010 by the year 2030. The change is calculated linearly between the years 2011 and 2030.

In Table 1 the emission factors and the HFC share in the refrigeration and air conditioning sector in 2020 or 2030 are summarized for both WM and WAM scenarios. Also, for comparison, the parameters used in the 2009 scenarios are presented. Other parameters, such as sales data of different equipment for years 2008-2009, are not presented here but only in internal documentation of the calculation, as the parameters presented in Table 1 have the largest impact on the total emissions.

Table 1. Emission factors and HFC share in 2020 for refrigerants in the WM and WAM scenarios in the refrigeration and air conditioning sector.

Sector	2010 scenarios*	2009 scenarios**
Supermarket Refrigeration		
Lifetime EF	0.20 – 0.12	0.20 – 0.10
Disposal EF	0.15 – 0.1005	0.15 – 0.075
HFC share: 2020 WM/WAM1 and 2030 WAM2	70% / 35% / 14%	95% / 0%
Professional kitchens		
Lifetime EF	0.15 – 0.09	0.15 – 0.075
Disposal EF	0 15 – 0.1005	0.15 – 0.075
HFC share: 2020 WM/WAM1 and 2030 WAM2	100% / 50% / 15%	100% / 0%
Stand-alone commercial applications		
Lifetime EF	0.03 – 0.03	0.03 – 0.03
Disposal EF	0.20 – 0.10	0.20 – 0.10
HFC share: 2020 WM/WAM1 and 2030 WAM2	90% / 45% / 13.5%	90% / 0%
Processing industry		
Lifetime EF	0.15 – 0.09	0.15 – 0.075
Disposal EF	0 15 – 0.1005	0.15 – 0.075
HFC share: 2020 WM/WAM1 and 2030 WAM2	20% / 10% / 3%	20% / 0%
Transport refrigeration		
Lifetime EF	0.325 – 0.1625	0.325 – 0.1625
Disposal EF	0.25 – 0.125	0.25 – 0.125
HFC share: 2020 WM/WAM1 and 2030 WAM2	100% / 50% / 20%	100% / 0%
Mobile air conditioning		
Lifetime EF	0.20 – 0.06	0.20 – 0.05
Disposal EF	0.20 – 0.10	0.20 – 0.10
HFC share: 2020 WM/WAM1 and 2030 WAM2	80% / 80% (GWP-150)	80% / 0%

Sector	2010 scenarios*	2009 scenarios**
Stationary air conditioning		
Lifetime EF	0.10 – 0.06	0.10 – 0.05
Disposal EF	0.15 – 0.1005	0.15 – 0.075
HFC share: 2020 WM/WAM1 and 2030 WAM2	90% / 45% / 13%	90% / 0%
Heat pumps		
Lifetime EF	0.03 – 0.03	0.03 – 0.03
Disposal EF	0.20 – 0.10	0.20 – 0.10
HFC share: 2020 WM/WAM1 and 2030 WAM2	90% / 45% / 15%	90% / 0%
Domestic refrigeration		
Lifetime EF	0.003 – 0.003	0.003 – 0.003
Disposal EF	0.20 – 0.134	0.20 – 0.03
HFC share in 2020 WM/WAM	5% / 2.5%	5% / 0%
Ice rinks		
Lifetime EF	0.15 – 0.09	0.15 – 0.075
Disposal EF	0.15 – 0.1005	0.15 – 0.075
HFC share: 2020 WM/WAM1 and 2030 WAM2	20% / 10% / 3%	20% / 0%

*linear reduction of EFs between 2006-2015
**linear reduction of EFs between 2002-2011

2.2 Updated emission scenarios and comparison with the 2009 scenarios in the refrigeration and air conditioning equipment sector

The total HFC emission projections for refrigeration and air conditioning equipment are sums of the subsector scenarios presented in Table 1. The 3-year running mean of emissions is calculated in order to better fit the scenarios to the annual inventories. The total WM and WAM scenarios for refrigeration and air conditioning equipment are presented in Figure 1. The figure also includes 2009 scenarios and inventory results for comparison.

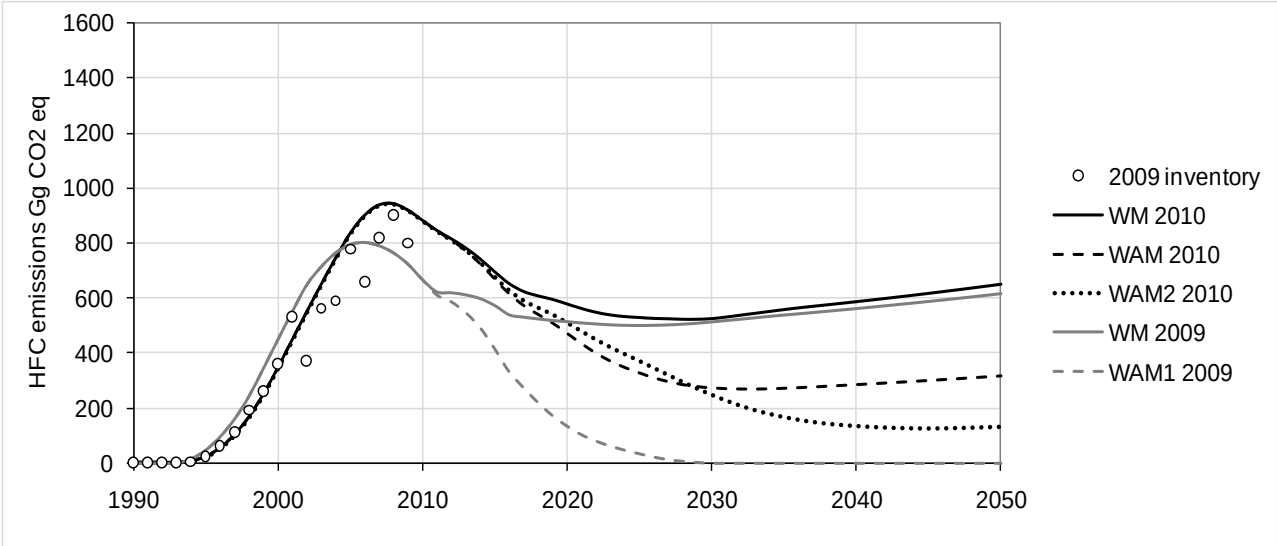

Figure 1. Total WM and WAM projections for HFC emissions from refrigeration and air conditioning equipment in Gg CO_2 eq with the reported actual emission estimates of F-gas inventories and 2009 scenarios.

The projection follows the highest peak of the annual F-gas inventory emission estimates but does not take into account the yearly fluctuation of emissions. The highest peak of the calculated scenario is 940 Gg CO_2 eq in 2008, the highest F-gas inventory estimate so far being 902 Gg CO_2 eq in 2008. This is approximately 17% higher than in the 2009 WM scenario. The lowest point of the WM projection is reached in 2028 with emissions of 520 Gg CO_2 eq, which is roughly in the level of 2002. In the 2009 WM scenario the lowest point is reached already in 2025. From 2028 onwards the WM projection emissions increase slowly, reaching 647 Gg CO_2 eq by 2050. The total WAM 1 projection of HFC refrigerant reduces the emissions by 48% to 2030 after which the emission reduction stays approximately constant. The WAM 2 scenario continues to decline also after 2030. The 2009 WAM1 scenario reaches zero level by 2035.

The projected HFC emission reductions for refrigeration and air conditioning equipment are compiled in Table 2. The inventory results for 2006, 2008 and 2009 are presented in the table and the WAM projection is compared with the WM projection of the years 2010, 2020, 2030 and 2050. The achieved emission reductions are given in Gg CO_2 eq and in addition as the percentage change from the WM projection. The 2009 projections are presented for comparison.

Table 2. Projected HFC emission reductions for refrigeration and air conditioning equipment and comparison with the 2009 projections.

Year	WM	WAM 1	Emission reduction from WM	Diff. from WM	WAM 2	Emission reduction from WM	Diff. from WM	2009 WM	2009 WAM1	Emission reduction from WM	Diff. from WM
	Gg CO_2 eq			%	Gg CO_2 eq		%	Gg CO_2 eq			%
2006	659	659			659			800	801		
2008	902	902			902			763	763		
2009	799	799			799			-	-		
2010	880	879			879			666	666		
2020	576	469	107	19	510	66	11	514	135	379	74
2030	522	271	251	48	248	274	52	-	-	-	-
2050	648	314	334	52	132	516	80	615	0	615	100

3 Projections for Foam blowing and foam products

Emission scenarios for the foam blowing sector were updated to correspond to F-gas inventories for the years 2008 and 2009. The WM and WAM HFC emission projections for foams are presented in Figure 2 together with the reported actual emissions of F-gas inventories and 2009 scenarios.

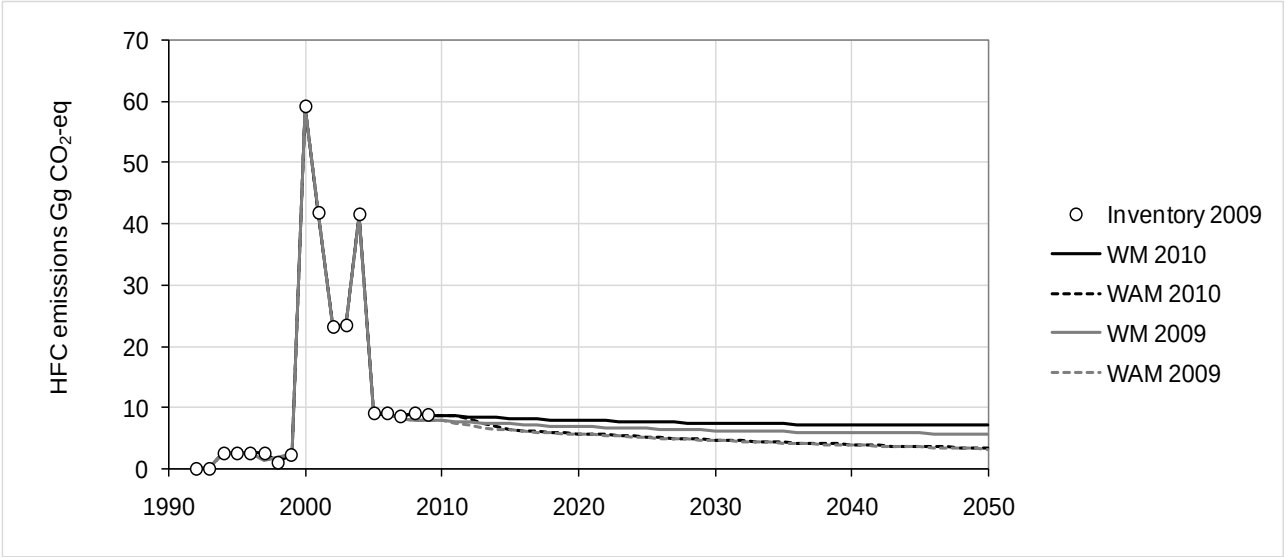

Figure 2. WM and WAM projections for HFC emissions from foam blowing and foam products in Gg CO_2 eq with the reported actual emission estimates of F-gas inventories and 2009 scenarios.

The year-to-year fluctuation of emission estimates are due to changes in the volume of HFC blowing agents consumed in the manufacturing. In the WM projection the emissions decline slowly from 2009 onwards as the amount of gas banked in foam products decreases. From the peak of 59 Gg CO_2 eq in 2000 the emissions decrease to the level of 7.0 Gg CO_2 eq by 2050. In the WAM projection the downward trend is slightly stronger, since the emissions from manufacturing decrease totally by 2015 due to the assumed restrictions of HFC blowing agent consumption. However, HFC emissions from the blowing agent banked in the foam products continues.

The projected HFC emission reductions for the foam blowing sector are compiled in Table 3. The WAM projection is compared with the WM projection for the years 2010, 2020, 2030 and 2050. The achieved emission reductions are given in Gg CO_2 eq and, in addition, as percentage change from the WM projection. The 2009 projections are presented for comparison.

Table 3. Projected HFC emission reductions for foam blowing and comparison with the 2009 projections.

Year	WM Gg CO_2 eq	WAM Gg CO_2 eq	Emission reduction from WM Gg CO_2 eq	Diff. from WM %	2009 WM Gg CO_2 eq	2009 WAM1 Gg CO_2 eq	Emission reduction from WM Gg CO_2 eq	Diff. from WM %
2006	9.0	9.0			9.0	9.0		
2008	9.0	9.0			8.0	8.0		
2009	8.7	8.7			-	-		
2010	8.6	8.6			7.7	7.7		
2020	7.8	5.7	2.2	28	6.8	5.6	1.2	18
2030	7.4	4.7	2.7	36	-	-	-	-
2050	7.0	3.3	3.8	54	5.6	3.2	2.5	45

4 Projections for Aerosols and one-component foams

Emission scenarios for aerosols and one-component foams were updated to correspond to F-gas inventories for the years 2008 and 2009. The updated with measures HFC emission projection for this sector is presented in Figure 3 together with the reported actual emissions of F-gas inventories and 2009 scenario.

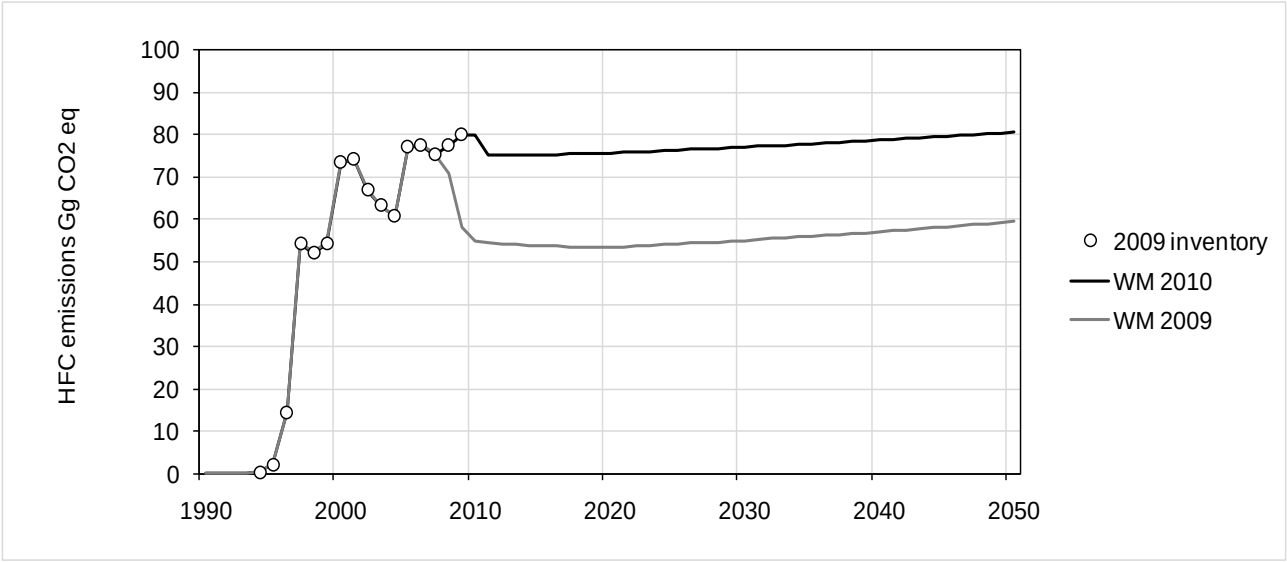

Figure 3. WM projection for HFC emissions from aerosols and OCFs in Gg CO_2 eq with the reported actual emission estimates of F-gas inventories and 2009 scenario.

The emission trend increases sharply from the middle of the 1990's due to the substitution of ozone depleting substances. After 2009 the emissions are expected to stay approximately at the same level as the emission decrease due to the restrictions of the EC F-gases Regulation is compensated with the growth of MDI sales. The difference between the 2009 scenario and the updated scenario is due to the F-gas inventory results for the years 2008 and 2009. The projected emissions reach 80 Gg CO_2 eq by 2050 which is also the highest F-gas inventory estimate reached in 2009. The projected emissions for the years 2010, 2020, 2030 and 2050 as well as the 2009 projection are displayed in Table 4.

Table 4. Projected HFC emissions for aerosols and OCFs.

Year	WM 2010 Gg CO_2 eq	WM 2009 Gg CO_2 eq
2006	77	77
2008	77	71
2009	80	-
2010	80	55
2020	75	53
2030	77	-
2050	81	59

5 Projections for Electrical equipment

The WM emission projection for electrical equipment was updated to correspond to emission estimates in the F-gas inventories for the years 2008 and 2009. SF_6 emissions have decreased sharply from the level of 1990 due to voluntary actions by the industry. From 2009 onwards the emission trend is expected to stay constant. The projected SF_6 emissions for the years 2010, 2020, 2030 and 2050 as well as the 2009 projection are displayed in Table 5.

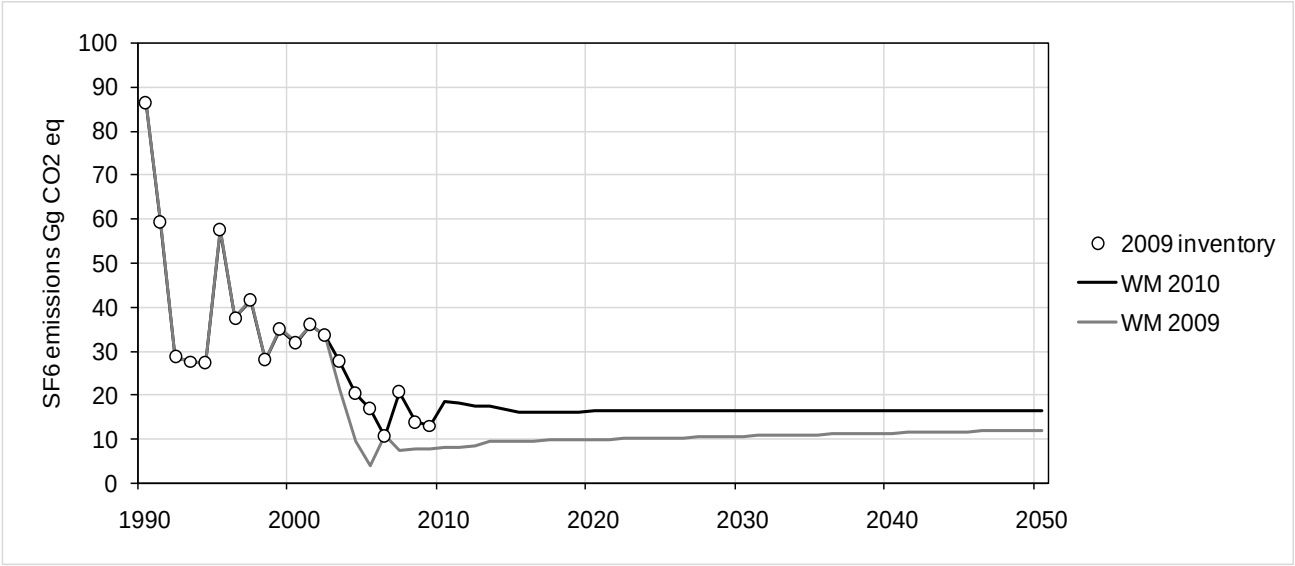

Figure 4. WM projection for SF_6 emissions from electrical equipment in Gg CO_2 eq with the reported actual emission estimates of F-gas inventories.

Table 5. Projected SF_6 emissions for electrical equipment.

Year	WM 2010 Gg CO_2 eq	WM 2009 Gg CO_2 eq
2006	11	11
2008	14	7.5
2009	13	-
2010	18	7.9
2020	16	9.6
2030	16	-
2050	16	12

6 Emission projection for grouped emission sources

In the Finnish F-gas inventory, semiconductor manufacturing, fire suppression systems, magnesium die casting and other minor emission sources like training shoes and use in research have been grouped due to confidentiality reasons. The grouped emissions also include emissions of HFC-23 from refrigeration and air conditioning equipment.

The WM projection for the grouped emission sources is based on the F-gas inventory information up to 2009. Emission estimates and activity data for different sources in 2009 are used as a starting point, where developments of emissions from separate sources are forecasted. The projection of grouped emission sources includes emissions of HFC substances, HFC-23, HFC-125, HFC-134a and HFC-227ea, and PFCs, CF_4 and c-C_4F_8, as well as SF_6.

The F-gas emission projection for grouped emission sources is represented in Figure 5. The increase of emissions from 2009 onwards is mainly driven by the growth of semiconductor manufacturing. The growth evens out and emissions stay constant at the level of 47 Gg CO_2 eq from 2023 onwards. The projected F-gas emissions for the years 2010, 2020, 2030 and 2050 as well as the 2009 projections are displayed in Table 6.

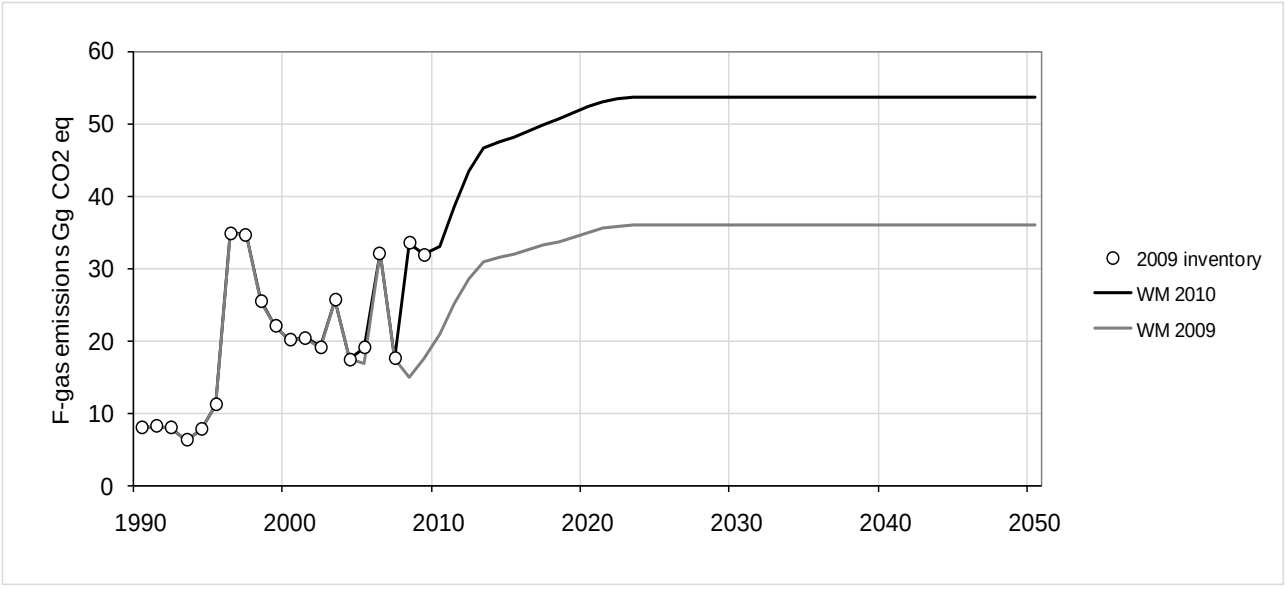

Figure 5. WM projection for F-gas emissions from grouped emission sources in Gg CO_2 eq with the reported actual emission estimates of F-gas inventories.

Table 6. Projected F-gas emissions from grouped emission sources.

Year	WM 2010 Gg CO_2 eq	WM 2009 Gg CO_2 eq
2006	32	32
2008	34	15
2009	32	-
2010	33	21
2020	52	35
2030	54	-
2050	54	36

7 Summarized emission projections for F-gases

Total F-gas emissions in Finland are projected by adding up the WM emission projections of the different source categories. PFC emissions from refrigeration and air conditioning equipment are included in the projection. The total WM emission projection for F-gases is presented in Figure 6. The projection is dominated by the emission trend of refrigeration and air conditioning equipment, because emissions from this source presently account for close to 90% of F-gas emissions in Finland. The emissions are projected to decrease after the peak of 2008 as a joint effect of the EC F-gases Regulation (842/2006/EC), the EC MAC Directive (2006/40/EC) and the technical tendency towards indirect refrigeration systems resulting in smaller refrigerant charges. The trend is reversed just before 2030 by the increasing amount of refrigeration and air conditioning equipment installations.

The total WAM emission projections for F-gases are calculated from the WAM projections of refrigeration and air conditioning equipment and foam blowing and foam products and the WM projections of other emission sources, which WAM scenarios were not established for. The WAM 1 projection reduces the emission by 109 Gg CO_2 eq in 2020 and 337 Gg CO_2 eq in 2050 and the WAM 2 projection by 68 Gg CO_2 eq in 2020 and 520 Gg CO_2 eq in 2050 compared to the WM projection estimates as presented in Table 7.

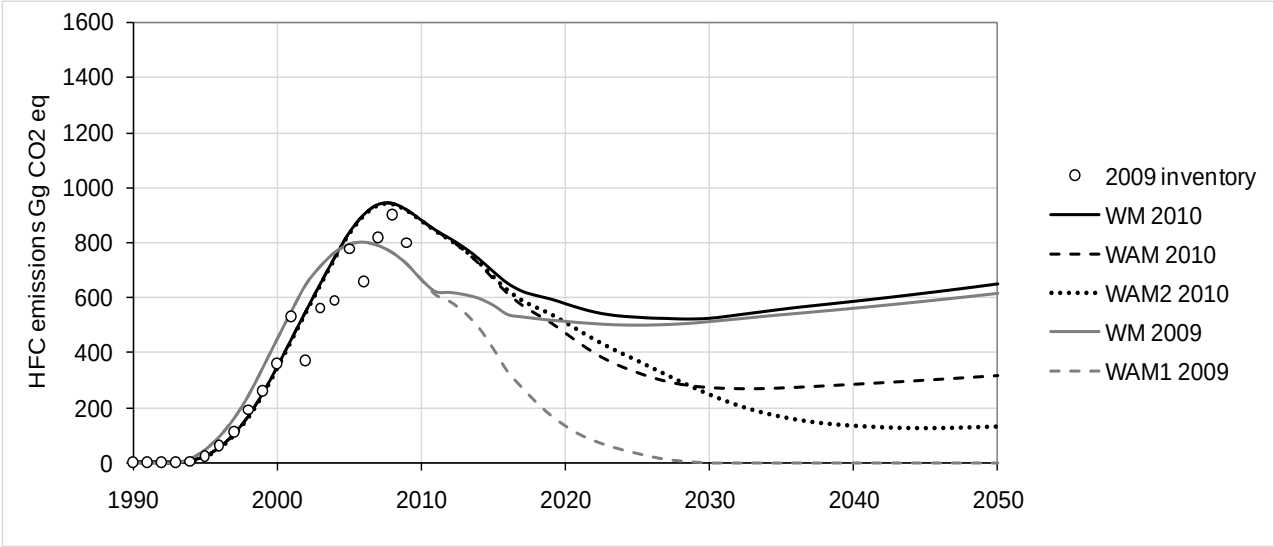

Figure 6. The total WM and WAM emission projections for F-gases (Gg CO_2 eq) with the reported actual emission estimates of F-gas inventories.

Table 7. Projected F-gas emission reductions.

Year	WM	WAM 1	Emission reduction from WM	Diff. from WM	WAM 2	Emission reduction from WM	Diff. from WM	2009 WM	2009 WAM1	Emission reduction from WM	Diff. from WM
	Gg CO_2 eq			%	Gg CO_2 eq		%	Gg CO_2 eq			%
2006	803	803			803			804	804		
2008	1045	1045			1045			872	872		
2009	939	939			939			-	-		
2010	1028	1028			1028			765	765		
2020	730	549	109	15	662	68	9	626	246	380	61
2030	677	422	255	38	400	277	41	-	-	-	-
2050	805	468	337	42	285	520	65	736	118	618	84

8 Concluding remarks

In light of the projections the growing trend of F-gas emissions is expected to be intercepted by the implemented measures and ongoing technical development. In addition, there is substantial potential for further emission reductions with additional measures. The technical development and change in the F-gas emission source sectors is fast, especially in the field of refrigeration and air conditioning equipment. The progress of the industries in question, new low GWP substances and equipment designs, should be closely followed in the future as well.

9 References

Alaja, T. 2009. Emission abatement options and cost effects for fluorinated greenhouse gases – Emission projections for fluorinated greenhouse gases up to 2050. Finnish Environment Institute (SYKE).

Regulations and Directives

Regulation (EC) No 842/2006 of the European Parliament and of the Council of 17 May 2006 on certain fluorinated greenhouse gases (Text with EEA relevance)

Directive 2006/40/EC of the European Parliament and of the Council of 17 May 2006 relating to emissions from air-conditioning systems in motor vehicles and amending Council Directive 70/156/EEC (Text with EEA relevance)

Statistical information

F-gas inventories 2000–2009. Finnish Environment Institute (SYKE).

10 List of abbreviations

EC F-gases Regulation	Regulation (EC) No 842/2006 of the European Parliament and of the Council on certain fluorinated greenhouse gases
EC MAC Directive	Directive 2006/40/EC of the European Parliament and of the Council relating to emissions from air-conditioning systems in motor vehicles and amending Council Directive 70/156/EEC
HFC	Hydrofluorocarbon
MDI	Metered dose inhaler
OCF	One-component foam
ODS	Ozone depleting substance
PFC	Perfluorocarbon
SYKE	Finnish Environment Institute
WAM	With additional measures
WM	With measures