



INTERNATIONAL INSTITUTE OF REFRIGERATION

Annexes to the 35th Informatory Note on Refrigeration Technologies
“The impact of the refrigeration sector on climate change”

ANNEX A

Emissions, emission trends, GWP and percentages of various refrigerants used in the refrigeration sector.

The table below presents information about the gases that have an impact on climate change and which are used as refrigerants in the refrigeration sector. Total emissions (from all sectors, including refrigeration sector), trends of these emissions and GWP values come from the WMO report ^[1]. The percentage from within the refrigeration sector has been calculated using information from the IPCC/TEAP special report ^[2].

	Substances	Total emissions (Gg) in 2012 ^[1]	Trends ^[1]	GWP ₁₀₀ ^[1]	Percentage from within the refrigeration sector (IPCC/TEAP ^[2])
CFC	CFC-11	57	Slow decline over the last decades	4,660	15.79 %
	CFC-12	40	- 7 Gg.yr ⁻¹	10,200	86.36 %
	CFC-115	Non disponible		7,670	100 %
HCFC	HCFC-22	366	Spike in 2010 at 381 (331-431) Gg, then decrease by 1.99%.yr ⁻¹	1,760	98.78 %
	HCFC-123	Non disponible		79	100 %
	HCFC-124	Non disponible		527	100 %
HFC	HFC-32	19	Emissions have approximately doubled (2009-2012)	677	100 %
	HFC-125	40	Emissions have approximately doubled (2009-2012)	3,170	100 %
	HFC-134a	176	Increase of 4% yr ⁻¹ vs 2008	1,300	93.26 %
	HFC-143a	24	50% increase (2009-2012)	4,800	100 %
	HFC-152a	50	Stabilisation at 50 Gg since 2010	138	10 %



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ANNEX B

Radiative forcing

Radiative forcing from refrigeration sector ^[1, 3, 4] has been calculated using the percentage of different gases within the refrigeration sector ^[2] (see Annex A). The radiative forcing values mentioned in the Informatory Note concern 2015.

W.m ⁻²	CFC ^[1, 2, 3, 4]	HCFC ^[1, 2, 3, 4]	HFC ^[1, 2, 3, 4]	CO ₂ ^[1, 2, 3, 4]	CH ₄ ^[1, 2, 3, 4]	N ₂ O ^[1, 2, 3, 4]	Total
	Direct emissions			Indirect emissions			
2005	0.1626	0.0352	0.0073	0.1085	0.0107	0.0014	0.3258
2006	0.1619	0.0368	0.0082	0.1100	0.0107	0.0015	0.3291
2007	0.1612	0.0384	0.0092	0.1116	0.0108	0.0015	0.3327
2008	0.1605	0.0400	0.0103	0.1133	0.0108	0.0015	0.3364
2009	0.1598	0.0418	0.0116	0.1149	0.0108	0.0016	0.3405
2010	0.1591	0.0436	0.0130	0.1166	0.0109	0.0016	0.3448
2011	0.1583	0.0447	0.0141	0.1183	0.0109	0.0016	0.3479
2012	0.1574	0.0459	0.0155	0.1202	0.0110	0.0017	0.3516
2013	0.1566	0.0471	0.0168	0.1228	0.0110	0.0017	0.3560
2014	0.1558	0.0483	0.0182	0.1242	0.0111	0.0017	0.3594
2015	0.1550	0.0495	0.0198	0.1262	0.0112	0.0018	0.3635

Total radiative forcing value (2.9642 W.m⁻²) has been extrapolated from latest IPCC report ^[3].

ANNEX C

Direct emissions (in CO₂eq) of the various refrigerants

The figures below have been obtained from data provided in Annex A.

It should be noted that there are significant uncertainties for the figures in the years following 2014. So, we used the 2014 values in the Informatory Note.

Table 1: CFC emissions in Mt CO₂ eq

	CFC-11	CFC-12	CFC-115 ⁽¹⁾	Total
2012	42	352	50	444
2013	42	291	44	377
2014	41	229	39	309
2015	41	167	33	242
2016	40	106	28	174

Table 2: HCFC emissions in Mt CO₂ eq

	HCFC-22
2012	643
2013	630
2014	617
2015	605
2016	593

HCFC-123 and HCFC-124 emissions are negligible compared to those produced by other refrigerants.

Table 3: HFC emissions in Mt CO₂ eq

	HFC-32	HFC-125	HFC-134a	HFC-143a	HFC-152a	Total
2012	13	127	213	115	1	469
2013	16	160	222	132	1	530
2014	20	201	231	151	1	604
2015	26	254	240	173	1	693
2016	32	320	250	198	1	800

Table 4: Cumulative emissions for the refrigeration sector in Mt CO₂ eq

	CFC	HCFC	HFC	Refrigeration sector
2012	444	643	469	1556
2013	377	630	530	1537
2014	309	617	604	1531
2015	242	605	693	1540
2016	174	593	800	1567

⁽¹⁾ IIR estimates



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ANNEX D

Indirect emissions: methodology and calculation of CO₂ emissions related to electricity consumption in the refrigeration sector.

CO₂ / kWh of electricity ^[5]	519 gCO ₂ /kWh
Global electricity production ^[6]	23,815 TWh
CO₂ emissions related to electricity production	12.36 Gt CO ₂
Percentage of electricity consumed by the refrigeration sector ^[7]	17 %
Emissions related to electricity consumption in the refrigeration sector	2.10 Gt CO ₂

Here, multiplying the CO₂/kWh ^[5] emission factor by global electricity ^[6] gives the global emissions of CO₂ linked to electricity production.

According to an IIR estimate ^[7], the refrigeration sector consumes 17% of the overall electricity used worldwide.

ANNEX E

Indirect emissions: methodology and calculation of CO₂ emissions related to fuel consumption due to mobile air conditioning

Table 1: Number of air-conditioned vehicles in circulation worldwide

Private vehicles (2014) ^[8]	907,051,000
Utility vehicles (2014) ^[8]	329,253,000
Total	1,236,304,000
Air-conditioned vehicles ^[7] ($N_{air-conditioned}$)	700,000,000

Table 2: CO₂ emissions related to mobile air-conditioning, in gigatons

Transport ^[5]	7.45
Road transport (E_{total}) ^[5]	5.59
Air-conditioned vehicles ⁽¹⁾	3.27
Air-conditioning⁽¹⁾	0.24

Model used:

$$E_{total} = S * N_{air-conditioned} * X + N_{non-air-conditioned} * X$$

Where:

- E_{total} : total of CO₂ emissions from road transport (Gt CO₂) ;
- S: factor representing fuel consumption due to the use of mobile air conditioning ;
- $N_{air-conditioned}$ et $N_{non-air-conditioned}$: the number of air-conditioned vehicles and the number of non-air-conditioned vehicles, respectively ;
- X: average CO₂ emissions of a vehicle (Gt CO₂).

Emissions due to the use of mobile air conditioning are therefore equal to:

$$E_{air-conditioning} = N_{air-conditioned} * X * (S-1)$$

The same reasoning is applied for refrigerated transport. According to the IIR, there are 4 million “refrigerated vehicles”^[7]. This represents only 1.21% of the commercial vehicle fleet. Emissions from refrigerated transport can thus be considered as negligible (order of magnitude: 2 Mt).

⁽¹⁾ IIR estimates



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ANNEX F

Indirect emissions: methane emissions related to the refrigeration sector

Emissions related to coal extraction (2012) ^[9]	46.2 Mt CH ₄
Share related to electricity production (coal) ^[10, 11]	25.60 Mt CH ₄
Share related to refrigeration (coal)	4.35 Mt CH ₄ 121.86 Mt CO ₂ eq
Emissions related to natural gas extraction (2012) ^[9, 12]	67.84 Mt CH ₄
Share related to electricity production (natural gas) ^[10, 11]	20.62 Mt CH ₄
Share related to refrigeration (natural gas)	3.51 Mt CH ₄ 98.17 Mt CO ₂ eq
Emissions related to petroleum extraction ^[9, 12]	20.26 Mt CH ₄
Share from electricity (gasoline) ^[10, 11]	0.19 Mt CH ₄
Share from refrigeration (gasoline)	0.03 Mt CH ₄ 0.90 Mt CO ₂ eq
Total methane emissions related to the refrigeration sector (2012)	7.89 Mt CH ₄ 220.92 Mt CO ₂ eq
Total methane emissions related to the refrigeration sector (2013) <i>(IIR estimates)</i>	7.97 Mt CH ₄ 223.12 Mt CO ₂ eq
Total methane emissions related to the refrigeration sector (2014) <i>(IIR estimates)</i>	8.05 Mt CH ₄ 243.74 Mt CO ₂ eq

⁽¹⁾ IIR estimates



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ANNEX G

Regional emissions

We provide here estimates of regional and national greenhouse gases emissions generated by refrigeration use. We based these estimates on data from the regional and national reports to the UNFCCC ^[13] within the framework of the Kyoto Protocol and from specific studies on certain countries.

	Direct emissions		Indirect emissions	
EU-28 ^[14, 15]	109.59 Mt CO ₂ eq	215.65 kgCO ₂ /capita	174.68 Mt CO ₂ eq	343.73 kgCO ₂ /capita
Germany ^[14]	12.64 Mt CO ₂ eq	155.26 kgCO ₂ /capita	38.85 Mt CO ₂ eq	477.27 kgCO ₂ /capita
France ^[14]	18.14 Mt CO ₂ eq	271.49 kgCO ₂ /capita	11.66 Mt CO ₂ eq	174.57 kgCO ₂ /capita
Iceland ^[14]	0.16 Mt CO ₂ eq	477.86 kgCO ₂ /capita	0.011 Mt CO ₂ eq	32.85 kgCO ₂ /capita
Japan ^[13]	39.78 Mt CO ₂ eq	313.21 kgCO ₂ /capita	91.61 Mt CO ₂ eq	723.73 kgCO ₂ /capita
Russia ^[13]	35.31 Mt CO ₂ eq	240.97 kgCO ₂ /capita	49.54 Mt CO ₂ eq	338.09 kgCO ₂ /capita
USA ^[16, 17, 18]	211.36 Mt CO ₂ eq	657.62 kgCO ₂ /capita	528.08 Mt CO ₂ eq	1,643.06 kgCO ₂ /capita
China ^[16, 19, 20, 21]	315.92 Mt CO ₂ eq	230.43 kgCO ₂ /capita	710.83 Mt CO ₂ eq	518.48 kgCO ₂ /capita
India ^[16, 17]	37.66 Mt CO ₂ eq	28.73 kgCO ₂ /capita	144.95 Mt CO ₂ eq	114.88 kgCO ₂ /capita
Qatar ^[13]	3.18 Mt CO ₂ eq	1,422.37 kgCO ₂ /capita	7.12 Mt CO ₂ eq	3,183.98 kgCO ₂ /capita



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ANNEX H

Emissions forecast

G. Velders' work ^[22] was used to create these projections. Velders made forecasts before the signature of the Kigali Amendment. He did so by simulating the implementation of four proposals made during preparatory talks at the Kigali Amendment (North America, Pacific Island States, European Union and India).

The final text of the Kigali Amendment is more ambitious than the Indian proposal, but less limiting than the other three. The IIR projection was drawn from Velders' four forecasts.



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