Öko-Recherche
Büro für Umweltforschung und -beratung GmbH

Explanatory Note on modelling of climate benefits of charge size changes for air conditioning equipment in relation to the revision of the product standard IEC 60335-2-40

Prepared for the

Environmental Investigation Agency

by

Öko-Recherche

Büro für Umweltforschung und -beratung GmbH

Münchener Straße 23a

60329 Frankfurt/Main

GERMANY

June 2020

Contents

Abbreviations

AC	Air-conditioning
A2	Parties operating under Article 2 of the Montreal Protocol
A5	Parties operating under Article 5 of the Montreal Protocol
CO_2	Carbon dioxide
CO_2e	Carbon dioxide equivalent
F-gases	Fluorinated greenhouse gases
GWP	Global Warming Potential
HC	Hydrocarbon
HCFC	Hydrochlorofluorocarbon
HFC	Hydrofluorocarbon
H(C)FO	Hydro(chloro)fluorocarbon
Mt	Megatonne
RACHP	Refrigeration, air conditioning and heat pumps
R	Refrigerant

1 Introduction

For refrigeration, air conditioning and heat pumps (RACHP), hydrocarbons (HCs) such as propane (R290) are climate-friendly alternatives to fluorinated greenhouse gases (hereinafter: F-gases), especially hydrofluorocarbons (HFCs), which are widely used refrigerants. Regulation (EU) No 517/2014 (hereinafter "F-gas Regulation") requires a reduction in HFCs of more than two thirds by 2030, so that the market for hydrocarbon-based equipment is expected to see a strong growth in coming years. In order to facilitate the uptake of hydrocarbons in RACHP applications by removing barriers to their use, international standardisation plays an important role for the uptake of climate-friendly refrigerants. The on-going revision of product standard IEC 60335-2-40 relates to the charge size limitations of (mildly) flammable (A2L) and flammable (A3) refrigerants in air conditioning (AC) and heat pumps. A proposal to address the restrictions of charge sizes and to introduce mitigation measures for A2L refrigerants is currently at committee draft stage and a revised standard is expected in the period until 2022.

Expert interviews conducted in relation to this assessment indicated that potential emission reductions from RACHP sectors related to the revision of product standard IEC 60335-2-40 are likely to be considerable for room AC applications around the globe, in particular resulting from an increased use of propane (R290) in single-split AC equipment. In particular, the currently elaborated Edition 7 of IEC 60335-2-40 suggests allowing an increase in the size of releasable charge up to 988g per refrigeration circuit compared to the 6th edition of the standard. How much the charge can be increased depends on the specific application design, for example if the installation exhibits enhanced tightness (e.g. compressors outdoors) or circulation of airflow. However, the quantification of such climate benefits requires assessments that take current and future market trends into account. By using an existing stock model for projecting refrigerant demand related to the manufacturing and use of AC split systems, we quantify reduction potentials for the European Union and the rest of the world that could result from the standard revision, i.e. from an increase in charge size limits.

2 Methodology

The modelling tool

In order to project potential future refrigerant demand stemming from AC systems in buildings, we used an existing European stock model (AnaFgas) that was previously built for the design of the current F-gas Regulation and has since been updated.[1] This model was developed for the preparatory study for a review of Regulation (EC) No 842/2006 in 2009 to 2012. The refrigerant demand was calculated as the amount required during the manufacturing of new systems ('first fill') plus the amount for refilling of existing systems during servicing activities to compensate for leakage ('life time emissions'). We define single-split AC systems in accordance with the definition used in the current F-Gas Regulation as "systems for room air conditioning that consist of one outdoor unit and one indoor unit linked by refrigerant piping, needing installation at the site of usage" (Art. 2 (39)). In contrast to the above-mentioned preparatory study, single-split AC systems covered under this study also contain charges >3 kg and therewith also includes equipment with cooling capacities of greater than 12 kW.

[1] Preparatory study for a review of Regulation (EC) No 842/2006 on certain fluorinated greenhouse gases: https://ec.europa.eu/clima/sites/clima/files/f-gas/docs/2011_study_en.pdf

Geographical coverage

In order to further increase the geographical coverage of the model beyond the EU, we extended the EU modelling tool and included activity data covering the rest of the world. The refrigerant demand was calculated for three different groups of countries, i.e. i) the EU, ii) other developed countries (excluding the EU) and iii) developing countries. In order to update model activity data accordingly, estimates on world room AC demand compiled by the JRAIA's Air Conditioning Global Committee[2] were used. These data series have been extrapolated until 2050 by using country and region-specific growth rates derived from existing data series (this was the case for the EU dataset) or from growth rates estimated for residential AC in a recent forecast of future cooling demand.[3]

Scenarios

Within each country group, four different scenarios were built in order to reflect different levels of ambition in introducing new HC equipment to the market as a result of the standard revision in single split AC systems. For the period ranging from 2010 until 2021, all scenarios are identical with respect to the refrigerant replacement sequence, beginning with the ozone-depleting refrigerant HCFC-22 that was replaced by R407C, R410A and later R32.

The '**no ambition**' scenario data does not include hydrocarbons or other natural refrigerants as alternatives. For the EU, the 'no ambition' scenario builds upon the current F-gas regulatory framework and standards that are currently in place, i.e. the 4th edition of standard IEC 60335-2-40, and describes the situation that will most likely continue to occur in the future. For the EU data set, we built on assumptions for the single-split AC sector in the EU stock model that were updated in 2018 as part of a study conducted for the German Environment Agency, including comprehensive interviews on current and likely future technological developments and market trends. For the country groups in 'other developed countries (excluding the EU)' and 'developing countries', the scenario was constructed in accordance with the relevant HFC phase-down schedules as required by the Kigali Amendment to the Montreal Protocol.

In order to build three different market scenarios varying in the degree of **future uptake of hydrocarbons**, the relative market share of HCs was, based on the no ambition scenario, increased at the expense of available synthetic alternatives. In this regard, the above mentioned international HFC phase-down requirements have been reflected accordingly. Based on the interviews with experts on standardization in AC systems, a commercial launch of R290 units on the AC market can be assumed starting from 2021 onwards. This has been included as a common starting point of HCs in all respective scenarios. Depending on divergent levels of acceptance of flammability of refrigerants, the increase in market penetration differs among the three country groups. Within each country group, the scenario with '**low ambition**' reaches 50% market share of new equipment using HC in 2050, whereas this is 90 % for the scenario '**mid ambition**'. The scenario '**high ambition**' reflects a prohibition of AC split equipment containing HFCs and reaches 100 % market share of new equipment using HC from 2025 onward. A detailed overview over the market shares included in the projections is included in Annex 1.

In order to accommodate for divergent safety requirements for AC installations, the market penetration includes a minimum of 10 % of the market for refrigerants with lower flammability for all

[2] World Air Conditioner Demand by Region, Sales data broken down by equipment type. URL to 2019 publication: https://www.jraia.or.jp/english/World_AC_Demand.pdf

[3] Economist Intelligence Unit, The Cooling Imperative 2019, URL: http://www.eiu.com/graphics/marketing/pdf/TheCoolingImperative2019.pdf

scenarios. In the hypothetical scenario 'high ambition' (2025 HFC ban) all installations are assumed to operate using the refrigerant R290 as from 2025.

3 Results

Projected refrigerant demand

The refrigerant demand for single-split AC in the EU, expressed in CO_2 equivalents, increases over the period ranging from 2010 until 2016 and remains constant at 12.2 mega tonnes (Mt) CO_2 eq for 2017 and 2018 (Figure 1). This high plateau phase occurring after the EU HFC phase down, which entered into force in 2015, is a result of life-time emissions stemming from projected servicing and maintenance activities of the existing stock, which still comprises old equipment running on high GWP HFCs blends. As of 2021, the demand curves start to segregate as a result of the divergent HC uptake in the three HC scenarios. In 2030, the projected demand amounts to 3.1 Mt CO_2 eq for the no action scenario. In contrast, for the low, medium and high scenario the demand amounts to 2.6, 2.2 and 0.6 Mt CO_2 eq, respectively. In 2050, the projected demand amounts to 1.8, 1.0, 0.3 and 0.04 Mt CO_2 eq for the no, low, medium and high scenario, respectively.

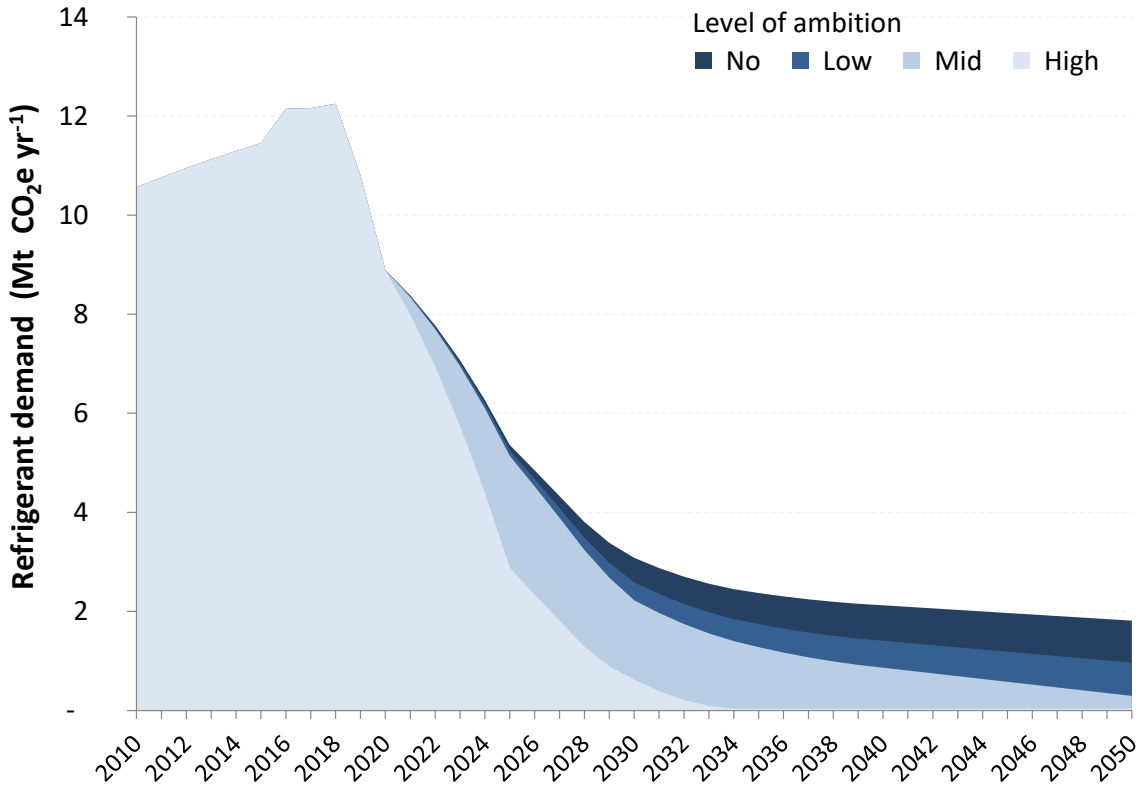

Figure 1: Refrigerant demand (in Mt CO_2 eq yr^{-1}) in split air conditioning in the EU

For other developing countries (excluding the EU), the demand increases steadily from 2010 until 2014 with the highest level of 55.9 Mt CO_2 e in 2015 and 2016 (Figure 2). Due to the later start of the international HFC phase down requirements under the Montreal Protocol, the decrease in demand for the high ambition scenario is more pronounced for this country group compared to the EU.

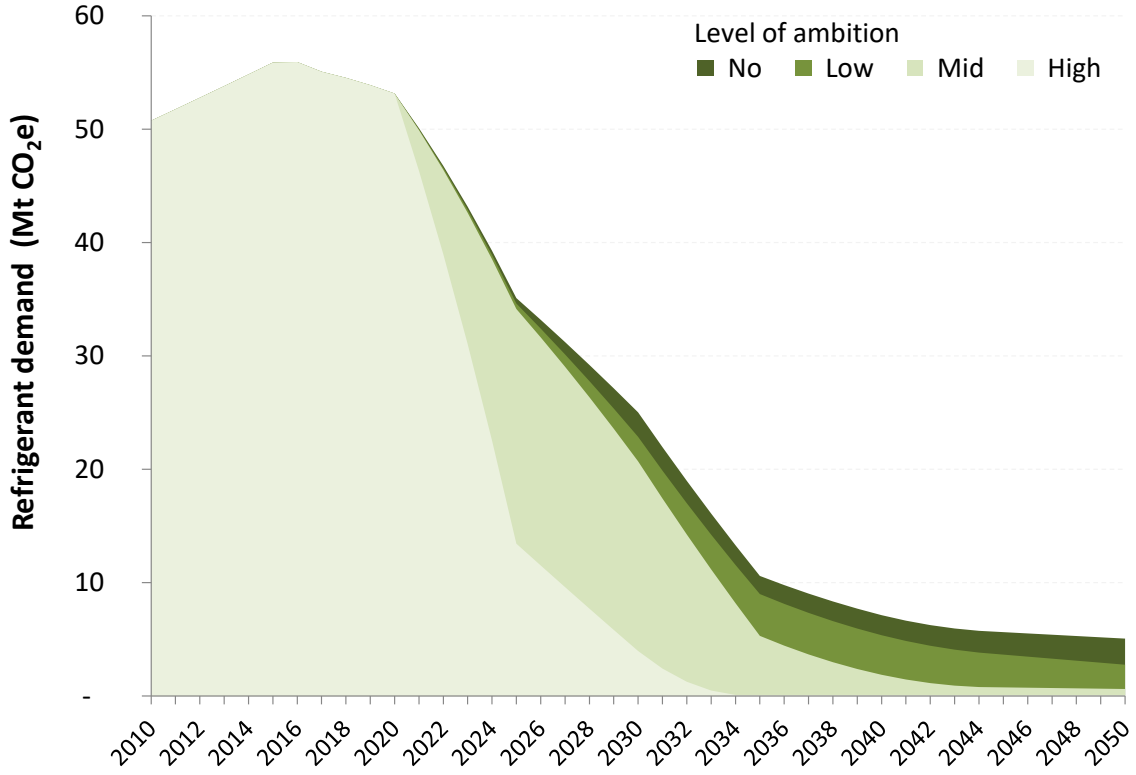

Figure 2: Refrigerant demand (in Mt CO_2 eq yr-1) in split air conditioning in other developed countries (excluding the EU)

For most developing countries, the first HFC reduction step under the Montreal Protocol in 2029 still allows the considerable use of high GWP refrigerants such as R410A and R32 in the no ambition scenario. This probably lends an explanation for the large demand of 310 Mt CO_2e that can be observed in the no ambition scenario in 2030.

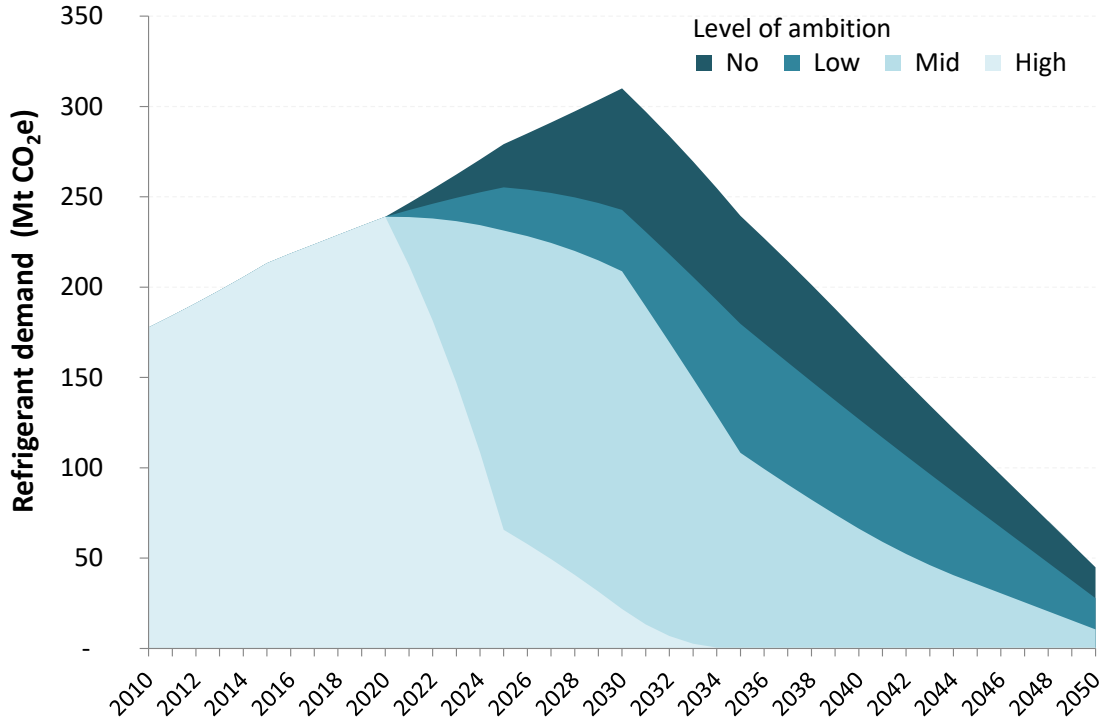

Figure 3: Refrigerant demand (in Mt CO_2 eq yr-1) in split air conditioning in developing countries

Climate benefits achieved by the revision of the product standard

In general, the total refrigerant demand projected for developing countries until 2030 (no ambition scenario) amounts to 2800 Mt CO2eq (Table 1) and accounts for 87 % of the global total demand (3215 Mt CO2eq) for the period from 2021 until 2030. In comparison, the European Union and other developed countries (excluding the EU) account for 2 % and 11 %, respectively. This predominant share of developing countries of the global refrigerant demand expressed in CO_2eq can be attributed to a multitude of factors. In fact, the above mentioned late start of HFC reduction schedules in developing countries and many other factors come into play, including e.g. number of inhabitants per country, population growth rates, and relative increase per capita income. Due to the early political action on F-gas emission reduction in the EU compared to the rest of the world, the savings in demand (the sum of life time emissions and first fill in manufacturing) obtained in the EU appear minor in comparison to those achieved in other developed countries or even in developing countries. The table shown in Annex I contains additional corresponding data, i.e. demand disaggregated into life time emissions and first fill as well as disposal emissions.

For the **EU**, the demand saved (i.e. climate benefit) by the high ambition scenario amounts to 19 and 62 Mt CO_2eq for the time period from 2021-2030 and 2021-2050, respectively (Table 1). When looking at the shorter time period 2021-2030, the low and mid ambition scenario lead to only 10 % and 18 % of the climate benefit under the HFC prohibition scenario (high ambition), respectively. However, when looking at larger time scales, the low and mid HC scenarios account for 26 % and 46 % of the climate benefits achieved under the HFC prohibition scenario.

For the **developed countries** (excluding the EU), the demand saved by the high ambition scenario amounts to 169 and 343 Mt CO_2eq for the time period from 2021-2030 and 2021-2050, respectively.

For the period from 2021-2030, the low and mid scenario result in 5 % and 10 % of the climate benefit under the HFC prohibition scenario, respectively (Table 1). Again, when looking at larger time scales, the low and mid HC scenarios account for 14 % and 34 % of the climate benefits achieved under the HFC prohibition scenario.

For the **developing countries**, the demand saved by the high ambition scenario amounts to 1884 and 5228 Mt CO_2eq for the time period from 2021-2030 and 2021-2050, respectively. When looking at the shorter time period 2021-2030, the low and mid ambition scenario lead to only 16 % and 28 % of the climate benefit under the HFC prohibition scenario, respectively. However, when looking at larger time scales, the low and mid HC scenarios account for 23 % and 46 % of the climate benefits achieved under the HFC prohibition scenario.

Table 1: Refrigerant demand calculated for the EU, other developed countries and developing countries from 2021 until 2030 and 2050, respectively. The column 'Demand saved' shows the amount saved in comparison to scenario 'no ambition'.

Country group	Scenario	Time frame 2021 until 2030			Time frame 2021 until 2050		
		Total demand [Mt CO_2eq]	Demand saved [Mt CO_2eq]	Demand saved relative to scenario high (%)	Total demand [Mt CO_2eq]	Demand saved [Mt CO_2eq]	Demand saved relative to scenario high (%)
EU	No	54	0	0%	98	0	0%
EU	Low	52	2	10%	82	16	26%
EU	Mid	51	4	18%	69	29	46%
EU	High	35	19	100%	36	62	100%
Developed	No	360	0	0%	540	0	0%
Developed	Low	352	9	5%	493	47	14%
Developed	Mid	343	17	10%	423	117	34%
Developed	High	191	169	100%	197	343	100%
Developing	No	2 800	0	0%	6 177	0	0%
Developing	Low	2 491	309	16%	4 978	1 199	23%
Developing	Mid	2 275	525	28%	3 770	2 406	46%
Developing	High	917	1 884	100%	948	5 228	100%
Global total	No	3 215	0	0%	6 814	0	0%
Global total	Low	2 895	319	15%	5 553	1 262	22%
Global total	Mid	2 669	545	26%	4 263	2 552	45%
Global total	High	1 142	2 072	100%	1 181	5 633	100%

Annex 1: Summary table on market shares for single-split air-conditioning equipment based on halogenated and hydrocarbon refrigerants.

Country group	Scenario	Refrigerant type	2020	2025	2030	2035	2040	2045	2050
EU	No ambition	Halogenated	100%	100%	100%	100%	100%	100%	100%
		Hydrocarbons	0%	0%	0%	0%	0%	0%	0%
	Low ambition	Halogenated	100%	90%	65%	61%	58%	54%	50%
		Hydrocarbons	0%	10%	35%	39%	43%	46%	50%
	Mid ambition	Halogenated	100%	80%	40%	33%	25%	18%	10%
		Hydrocarbons	0%	20%	60%	68%	75%	83%	90%
	High ambition	Halogenated	100%	0%	0%	0%	0%	0%	0%
		Hydrocarbons	0%	100%	100%	100%	100%	100%	100%
Developed	No ambition	Halogenated	100%	100%	100%	100%	100%	100%	100%
		Hydrocarbons	0%	0%	0%	0%	0%	0%	0%
	Low ambition	Halogenated	100%	95%	80%	70%	63%	57%	50%
		Hydrocarbons	0%	5%	20%	30%	37%	43%	50%
	Mid ambition	Halogenated	100%	90%	60%	10%	10%	10%	10%
		Hydrocarbons	0%	10%	40%	90%	90%	90%	90%
	High ambition	Halogenated	100%	0%	0%	0%	0%	0%	0%
		Hydrocarbons	0%	100%	100%	100%	100%	100%	100%
Developing	No ambition	Halogenated	100%	100%	100%	100%	100%	100%	100%
		Hydrocarbons	0%	0%	0%	0%	0%	0%	0%
	Low ambition	Halogenated	100%	90%	70%	60%	57%	53%	50%
		Hydrocarbons	0%	10%	30%	40%	43%	47%	50%
	Mid ambition	Halogenated	100%	80%	60%	30%	23%	17%	10%
		Hydrocarbons	0%	20%	40%	70%	77%	83%	90%
	High ambition	Halogenated	100%	0%	0%	0%	0%	0%	0%
		Hydrocarbons	0%	100%	100%	100%	100%	100%	100%

Annex 2: Life time emissions, first fill and disposal emissions for the EU, other developed countries and developing countries.

Country group	Scenario	Time frame 2021 until 2030		Time frame 2021 until 2050	
		Total demand [Mt CO_2eq]	Demand saved [Mt CO_2eq]*	Total demand [Mt CO_2eq]	Demand saved [Mt CO_2eq]*
Life time emissions					
EU	No	30	0	46	0
EU	Low	30	0	41	5
EU	Mid	29	1	38	8
EU	High	26	4	27	19
Developed	No	154	0	236	0
Developed	Low	153	1	223	13
Developed	Mid	152	3	201	35
Developed	High	120	34	125	111
Developing	No	947	0	2 328	0
Developing	Low	896	4 799	1 944	385
Developing	Mid	854	4 841	1 560	769
Developing	High	580	5 115	605	1 724
Global total	No	1 132	0	2 610	0
Global total	Low	1 079	5 994	2 208	403
Global total	Mid	1 036	6 038	1 799	812
Global total	High	726	6 347	756	1 854
First fill					
EU	No	24	0	52	0
EU	Low	23	2	40	12
EU	Mid	21	3	31	21
EU	High	9	15	9	42
Developed	No	206	0	304	0
Developed	Low	198	7	271	33
Developed	Mid	191	15	222	82
Developed	High	70	135	72	232
Developing	No	1 853	0	3 849	0
Developing	Low	1 595	257	3 034	814
Developing	Mid	1 421	432	2 211	1 638
Developing	High	337	1 516	344	3 505
Global total	No	2 083	0	4 205	0
Global total	Low	1 816	266	3 346	859
Global total	Mid	1 634	449	2 464	1 741
Global total	High	416	1 667	425	3 780
Disposal emissions					
EU	No	25	0	38	0
EU	Low	25	0	36	2
EU	Mid	25	0	34	4
EU	High	25	0	28	10

Developed	No	126	0	219	0
Developed	Low	126	0	213	7
Developed	Mid	126	0	202	18
Developed	High	126	0	151	69
Developing	No	499	0	1 651	0
Developing	Low	499	0	1 427	224
Developing	Mid	499	0	1 213	438
Developing	High	499	0	618	1 034
Global total	No	649	0	1 909	0
Global total	Low	649	0	1 676	233
Global total	Mid	649	0	1 449	460
Global total	High	649	0	796	1 113

Note: * For each country group, the demand of saved Mt CO_2 eq is shown calculated as the difference to scenario 'No ambition'.