Electricity savings and greenhouse gas emission reductions from global phase-down of hydrofluorocarbons

Pallav Purohit[1], Lena Höglund-Isaksson[1], John Dulac[2], Nihar Shah[3], Max Wei[3], Peter Rafaj[1], and Wolfgang Schöpp[1]

[1]Air Quality and Greenhouse Gases (AIR) Program, International Institute for Applied Systems Analysis (IIASA), Schlossplatz 1, A-2361, Laxenburg, Austria
[2]International Energy Agency (IEA), 9, rue de la Federation, 75015 Paris, France
[3]Energy Technology Area, Lawrence Berkeley National Laboratory (LBNL), 1 Cyclotron Road, Berkeley, CA 94720, USA

Correspondence to: Pallav Purohit (purohit@iiasa.ac.at)

S1: Current legislation on HFC control in the Baselines

To estimate hydrofluorocarbon (HFC) emissions in the baseline scenarios, we take into account the effects on emissions from implementation of existing legislations to control HFC emissions at the regional or national level. The European Union (EU) first legislated to control emissions of HFCs in 2006 (Höglund-Isaksson et al., 2012; Höglund-Isaksson et al., 2013), adopting a regulation on emissions and a directive on mobile air-conditioning (EU, 2006). Regulation 842/2006 on certain fluorinated greenhouse gases (GHGs) aimed only at containment, through measures such as control of leaks, proper servicing of equipment and recovery of the gases at the end of the equipment's life. In May 2014, this was replaced by the much more ambitious Regulation 517/2014 on fluorinated GHGs (the F-Gas Regulation[1]), which entered into force on 1st January 2015. It is aimed at achieving a reduction in sales of HFCs on the EU market by 79 percent (GWP-weighted) from 2009–12 levels by 2030 (EU, 2014), with interim reduction steps starting in 2015 and applying roughly every three years. In addition, HFCs are banned outright in some categories of new equipment where alternatives are readily available.

Apart from the EU, Japan, the USA, Australia, Norway, and Switzerland have also implemented national regulations to limit the use of high-GWP HFCs. The USA has already implemented incentive credits for use of low-GWP refrigerants in support of greenhouse gas emission standards for light duty vehicles and removed certain high-GWP HFCs from the Significant New Alternatives Policy (SNAP) list of allowable technologies for specific sectors in 2015 (US EPA, 2015). Although recently legally challenged (Reilly, 2017), the changes to the SNAP list ban the use of many high-GWP HFCs in, for example, commercial refrigeration applications, such as supermarket systems and vending machines, beginning during the period 2016–2020 and in mobile air-conditioning from model year 2021. The implementation of the new SNAP list is estimated to reduce baseline USA HFC emissions by 0.18–0.24 Gt CO_2eq per year (about 43%) by 2050 (Velders et al., 2015). In Japan, the Fluorocarbons Recovery and Destruction Law was amended and became effective on 1st April 2015 as the *Act on Rational Use and Proper Management of Fluorocarbons* (Fluorocarbon Emission Control Law) (METI, 2015). Among other requirements, the Act requires entities manufacturing and importing air-conditioning and refrigeration units to transition to either fluorocarbon-free refrigerants or to low global warming fluorocarbons by certain target years.

For developing countries, several studies discuss the impact of the Clean Development Mechanism (CDM) projects on HFC-23 emissions from HCFC-22 production for emissive and feedstock applications (Wara, 2007; Miller et al., 2010; Montzka et al., 2010; Miller and Kuijpers, 2011; Schneider, 2011). HFC-23 emissions from HCFC-22 production are assumed to be controlled in most developing countries due to CDM (Fenhann, 2014), except China where 36% of HCFC-22 production is controlled (Feng et al., 2012). The Chinese production capacity of HCFC-22 accounts for 78% of the global HCFC production (UNEP, 2014). HCFC-22 is a major source of HFC-23 emissions, which is a strong greenhouse gas with GWP_{100} of 14,800 times that of CO_2 (IPCC, 2007).

In its Intended Nationally Determined Contribution (INDC) submitted in June 2015, China reiterated its commitment under the Montreal Protocol to achieve effective control on emissions of HFC-23 by 2020. In 2015, the Chinese National Development and Reform Commission (NDRC) announced that it plans to achieve abatement of all HFC-23 emissions by 2019 (NDRC, 2015). This would imply installing destruction technology in all plants currently not covered by CDM and ensuring that the destruction technology on plants covered under CDM is being operated and maintained. In line with this information, we assume in recent updates of the GAINS model that all HCFC-22 production facilities in China will be fully controlled from 2020 onwards. It is observed that except for China other developing countries do not make HFC specific emission reduction commitments in the INDCs. In the 28th Meeting of the Parties to the Montreal Protocol in October 2016 in Kigali, the Indian government presented a domestic legislation that mandates control of trifluoromethane (HFC-23) emissions. At present, all HCFC-22 production facilities in India are fully controlled under the Clean Development Mechanism (CDM) and we assume the control on all Indian facilities stays operational and will be maintained in the future.

S2: The Kigali Amendment to the Montreal Protocol

The Kigali Amendment to the Montreal Protocol on Substances that Deplete the Ozone Layer entered into force on 1st January 2019, following ratification by 65 countries[1]. KA sets targets for the phase-down of HFCs consumption for four different Party groups. The first group primarily includes 136 developing countries that make up all Article 5 countries as specified under the Montreal Protocol with the exception of Bahrain, India, Iran, Iraq, Kuwait, Oman, Pakistan, Qatar, Saudi Arabia, and the United Arab Emirates (UAE). These ten countries are characterized by high ambient air temperatures and make up a second and separate group of Article 5 countries. Countries specified as non-Article 5 countries under the Montreal Protocol are primarily developed countries and under the Kigali Amendment divided into two separate groups with 45 countries in a first group and with the five countries Belarus, the Russian Federation, Kazakhstan, Tajikistan and Uzbekistan forming a separate second group. Table 1 presents the baseline years and HFC phase-down schedule of Article 5 and non-Article 5 Parties. We will hereafter refer to these four Party groups as Article 5 Group I, Article 5 Group II, non-Article 5 Group I, and non-Article 5 Group II.

[1] The Parties to the Montreal Protocol agreed that the Kigali amendment to the Montreal Protocol would *enter into force* on 1 January 2019, provided that at least 20 Parties had ratified it.

Table S1: Baseline and HFC phase-down schedule of Article-5 and non- Article-5 Parties

	Article 5 (A5) Parties: Group I		**Article 5 (A5) Parties: Group II**	
Baseline Years	2020, 2021 & 2022		2024, 2025 & 2026	
Baseline calculation	Average production /consumption of **HFCs** in 2020, 2021, and 2022 *plus* **65%** of **HCFC** baseline production/consumption		Average production /consumption of **HFCs** in 2024, 2025, and 2026 *plus* **65%** of **HCFC** baseline production/consumption	
Reduction steps Freeze	2024		2028	
Step 1	2029	10%	2032	10%
Step 2	2035	30%	2037	20%
Step 3	2040	50%	2042	30%
Step 4	2045	80%	2047	85%
	Non-Article 5 (non-A5): Group I		**Non-Article 5 (non-A5): Group II**	
Baseline Years	2011, 2012 & 2013		2011, 2012 & 2013	
Baseline Calculation	Average production /consumption of **HFCs** in 2011, 2012 & 2013 *plus* **15%** of **HCFC** baseline production/consumption		Average production /consumption of **HFCs** in 2011, 2012 & 2013 *plus* **25%** of **HCFC** baseline production/consumption	
Reduction steps Step 1	2019	10%	2020	5%
Step 2	2024	40%	2025	35%
Step 3	2029	70%	2029	70%
Step 4	2034	80%	2034	80%
Step 5	2036	85%	2036	85%

Source: UNEP (2016)

Table S2: Technical and economic energy efficiency (EE) potential of cooling technologies in baseline and with low-GWP alternatives

Countries	Year	EE due to systems improvements and low-GWP refrigerant (%)					
		HCFC-22/HFC-410A		HC-290		HFC-32/ HFOs	
		Economic	Technical	Economic	Technical	Economic	Technical
1. Mini-split air-conditioners (1.5 ton base-unit size)							
Brazil	2014	30%	70%	36%	73%	35%	72%
Chile	2014	30%	70%	36%	73%	35%	72%
China	2014	30%	70%	36%	73%	35%	72%
Colombia	2014	30%	70%	36%	73%	35%	72%
Egypt	2014	30%	70%	36%	73%	35%	72%
India	2014	30%	70%	36%	73%	35%	72%
Indonesia	2014	30%	70%	36%	73%	35%	72%
Mexico	2014	30%	70%	36%	73%	35%	72%
Pakistan	2014	30%	70%	36%	73%	35%	72%
Saudi Arabia	2014	30%	70%	36%	73%	35%	72%
Thailand	2014	30%	70%	36%	73%	35%	72%
UAE	2014	30%	70%	36%	73%	35%	72%
Vietnam	2014	30%	70%	36%	73%	35%	72%
2. Packaged air-conditioners (Rooftop units 10 ton AC)							
Asia	2015	31%	49%			37%	53%
North America	2015	31%	49%			37%	53%
Europe	2015	31%	49%			37%	53%
Rest of World	2015	31%	49%			37%	53%
3. VRF/ Ducted air-conditioners (10 ton HP)							
Asia	2015	15%	37%			21%	41%
North America	2015	15%	37%			21%	41%
Europe	2015	15%	37%			21%	41%
Rest of World	2015	15%	37%			21%	41%
4. Chillers, air cooled (Small, <300 tons - 500kW, 143 tons)[+]							
Asia	~2012-2017	29%	38%			32%	41%
North America	~2012-2017	22%	32%			25%	35%
Europe	~2012-2017	33%	42%			36%	44%
Rest of World	~2012-2017	12%	23%			15%	26%
5. Chillers, air cooled (Large, >= 300 tons - 1500kW, 429 ton)[+]							
Asia	~2012-2017	30%	38%			33%	41%
North America	~2012-2017	23%	32%			26%	35%
Europe	~2012-2017	35%	42%			37%	44%
Rest of World	~2012-2017	13%	23%			17%	26%

Countries	Year	EE due to systems improvements and low-GWP refrigerant (%)					
		HCFC-22/HFC-410A		HC-290		HFC-32/ HFOs	
		Economic	Technical	Economic	Technical	Economic	Technical
1. Chillers, water cooled (Small, <300 tons - 500kW, 143 tons) +							
Asia	~2012-2017	31%	51%			34%	53%
North America	~2012-2017	18%	41%			21%	44%
Europe	~2012-2017	50%	64%			52%	66%
Rest of World	~2012-2017	25%	46%			28%	49%
2. Chillers, water cooled (Large, >= 300 tons - 1500kW, 429 ton) +							
Asia	~2012-2017	36%	57%			39%	59%
North America	~2012-2017	13%	41%			17%	44%
Europe	~2012-2017	45%	63%			48%	65%
Rest of World	~2012-2017	26%	50%			29%	52%
3. Remote display cabinet - Chilled, multi-deck (RVC2)++							
Asia	2014	69%	75%	68%	74%		
North America	2014	53%	63%	51%	61%		
Europe	2014	13%	30%	8%	26%		
Rest of World	2014	35%	48%	32%	45%		
4. Remote display cabinet - Frozen, open, island (RHF4) ++							
Asia	2014	23%	23%	19%	19%		
North America	2014	31%	31%	27%	27%		
Europe	2014	17%	17%	13%	13%		
Rest of World	2014	42%	42%	39%	39%		
Integral display cabinet - Chilled, multi-deck (IVC2) ++							
Asia	2014	66%	77%	64%	76%		
North America	2014	48%	65%	45%	64%		
Europe	2014	30%	53%	26%	51%		
Rest of World	2014	30%	54%	27%	51%		
Integral display cabinet - Chilled, glass door (IVC4) ++							
Asia	2014	15%	30%	11%	26%		
North America	2014	15%	30%	11%	26%		
Europe	2014	15%	30%	11%	26%		
Rest of World	2014	15%	30%	11%	26%		
Integral display cabinet - Frozen, open, island (IHF4) ++							
Asia	2014	41%	41%	37%	38%		
North America	2014	47%	47%	44%	45%		
Europe	2014	24%	25%	20%	21%		
Rest of World	2014	56%	56%	53%	54%		

Countries	Year	EE due to systems improvements and low-GWP refrigerant (%)					
		HCFC-22/HFC-410A		HC-290		HFC-32/ HFOs	
		Economic	Technical	Economic	Technical	Economic	Technical
Integral display cabinet - Frozen, glass lid, island (IHF6) ++							
Asia	2014	32%	34%	29%	31%		
North America	2014	39%	41%	36%	38%		
Europe	2014	13%	16%	9%	12%		
Rest of World	2014	41%	43%	38%	40%		
Domestic refrigerators/freezers (Average size)+++							
Asia	2015	16%	60%	22%	63%		
North America	2015	22%	47%	28%	51%		
Europe	2015	13%	53%	19%	56%		
Rest of World	2015	15%	57%	21%	60%		
Beverage vending machines (500 bottle/unit capacity) +++							
Asia	2015	44%	58%	48%	61%		
North America	2015	34%	55%	39%	58%		
Europe	2015	44%	58%	48%	61%		
Rest of World	2015	19%	59%	25%	62%		

RID: Remote and integral displays

+HFO as an alternative low-GWP refrigerant

++CO_2 as an alternative low-GWP refrigerant

+++HC-600a as an alternative low-GWP refrigerant

Source: (DOE, 2011; IEA-4E, 2012a; IEA-4E, 2012b; CLASP, 2013; CLASP, 2014; IEA-4E, 2014; IEA-4E, 2015; Shah et al., 2015; Rosenquist, 2016; UNEP, 2017; DOE, 2018; DOE-FEMP, 2018)

Table S3: Annual technical/economic electricity saving potentials in HFC reduction scenarios relative respective pre-KA baseline scenarios

Year	KA Groups	Technical electricity savings (TWh)				Economic electricity savings (TWh)			
		SSP3 - KA	Cooling for All - KA	SSP3 - MTFR	Cooling for All – MTFR	SSP3 – KA	Cooling for All - KA	(SSP3 - MTFR)	(Cooling for All - MTFR)
2030	Non-A5 (Group-I)	806	806	767	767	491	491	455	455
	Non-A5 (Group-II)	25	25	25	25	16	16	16	16
	A5 (Group-I)	1452	1464	1708	1717	861	865	993	996
	A5 (Group-II)	449	453	518	521	260	262	290	291
	Global	2732	2748	3018	3030	1628	1634	1754	1759
2050	Non-A5 (Group-I)	1304	1304	1238	1238	795	795	734	734
	Non-A5 (Group-II)	58	59	56	57	37	38	35	35
	A5 (Group-I)	4017	4272	3868	4114	2474	2601	2239	2343
	A5 (Group-II)	2503	2535	2410	2440	1515	1530	1351	1364
	Global	7882	8169	7572	7849	4821	4964	4359	4477
2100	Non-A5 (Group-I)	1772	1772	1683	1683	1109	1109	1032	1032
	Non-A5 (Group-II)	109	117	106	113	70	73	65	68
	A5 (Group-I)	7341	9947	7064	9572	4345	5647	3867	4942
	A5 (Group-II)	3581	3760	3447	3619	2100	2189	1853	1927
	Global	12803	15595	12299	14987	7624	9019	6817	7969

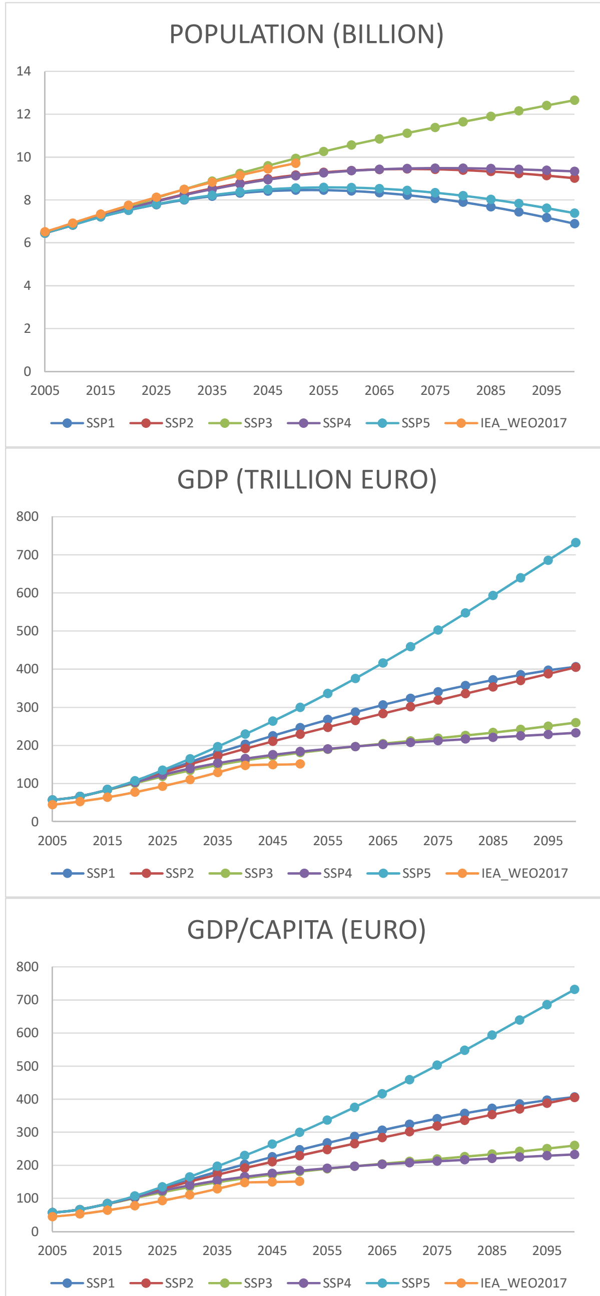

Figure S1: Comparison of future developments in global population and GDP between the IEA-WEO 2017 and the five Shared Socioeconomic Pathways (SSPs) scenarios.

Source: IIASA (2017)

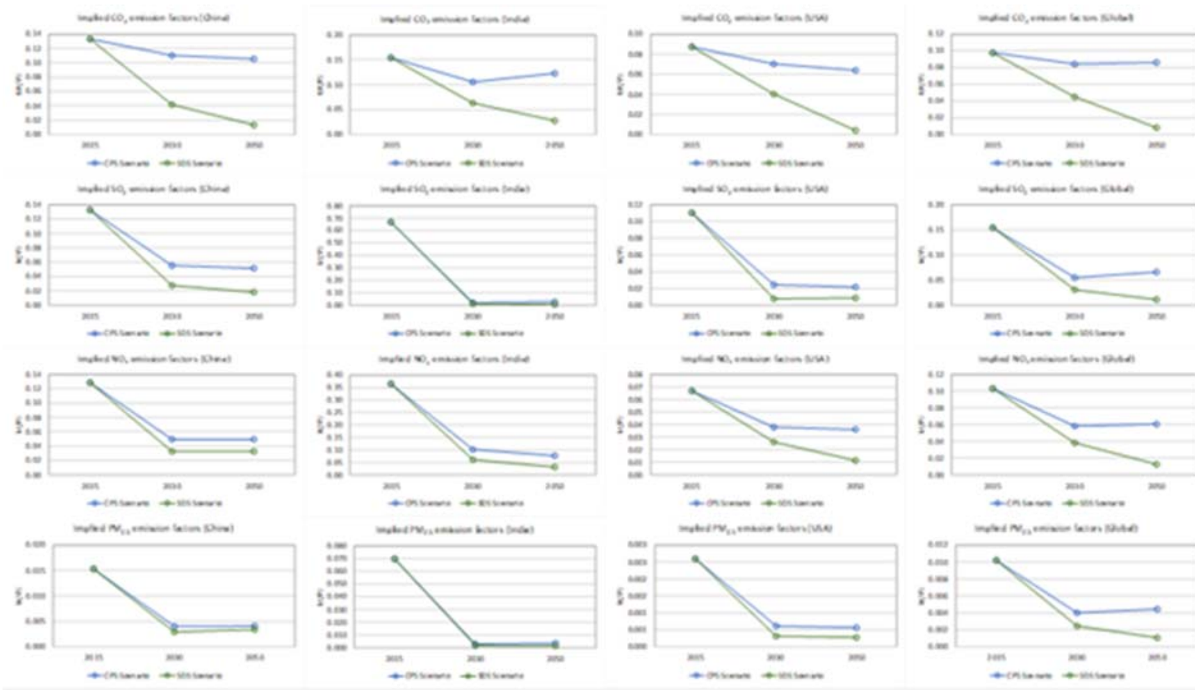

Figure S2: Implied emission factors for electricity production in the power plant sector for CO_2 and the air pollutants (SO_2, NO_x and $PM_{2.5}$) at global and select country level

Source: IIASA/GAINS Model available at: gains.iiasa.ac.at

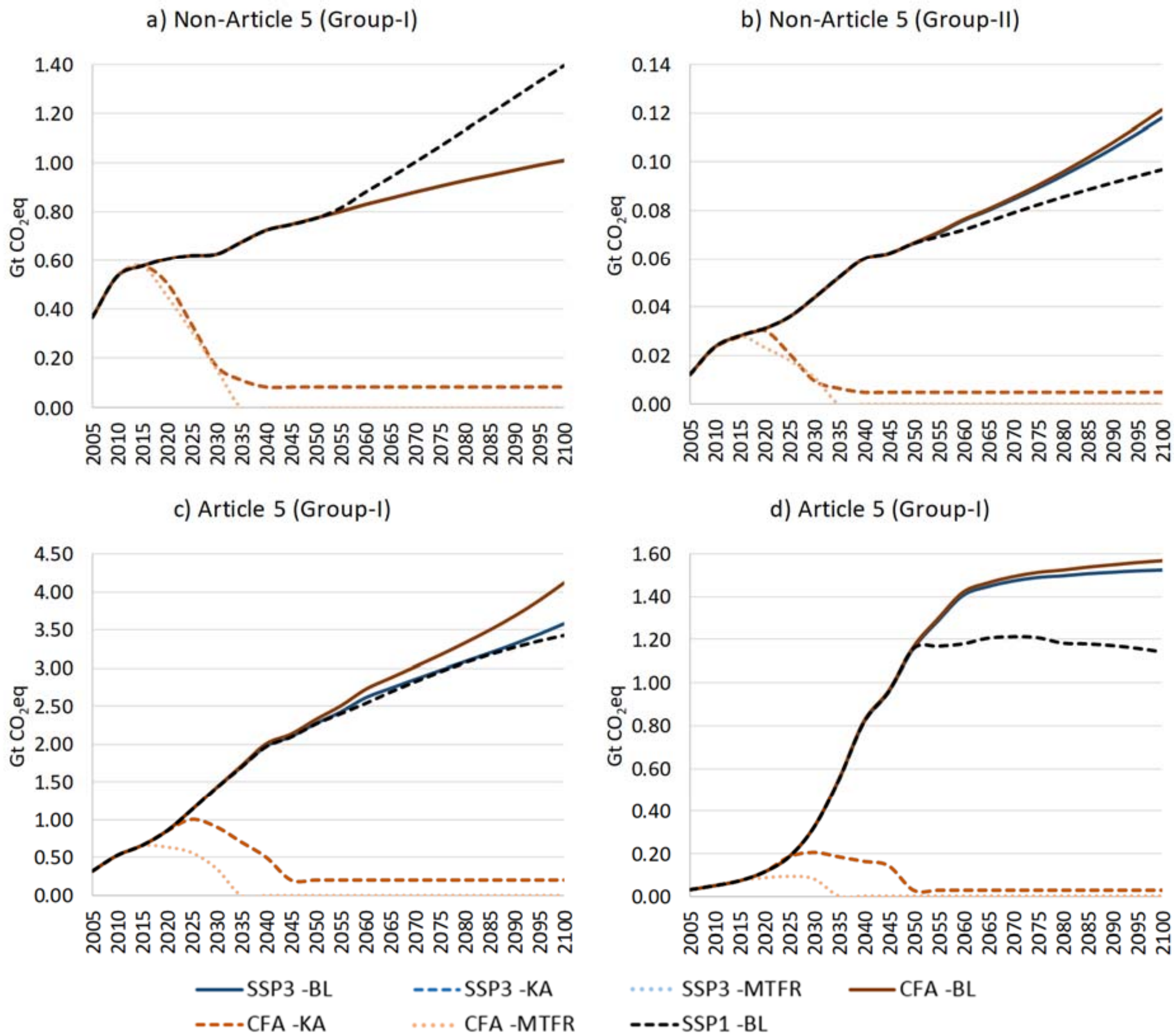

Figure S3: Baseline HFC/HCFC (Gt CO2eq) by different party groups

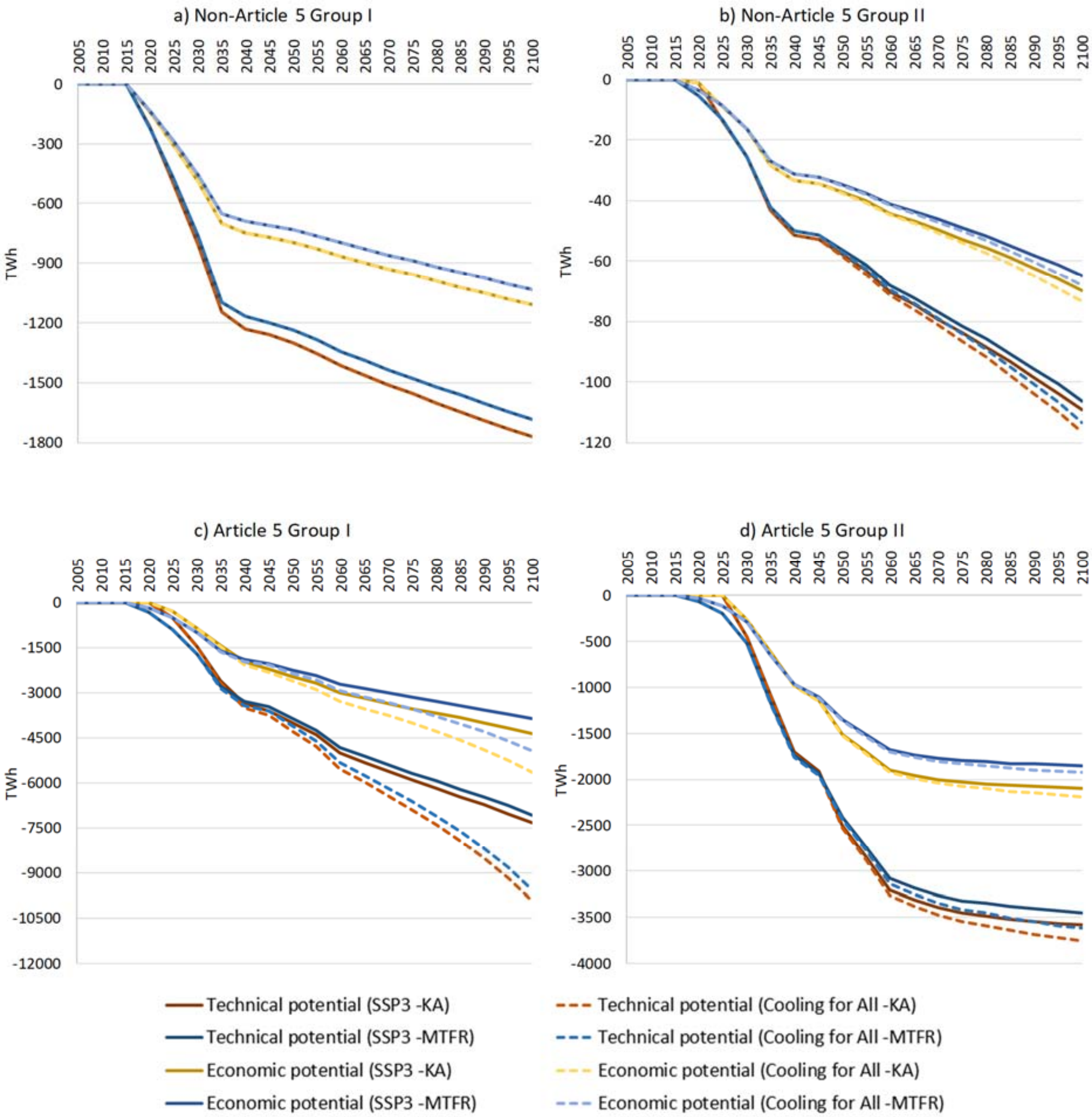

Figure S4: Technical and economic electricity saving (TWh) potential by different party groups

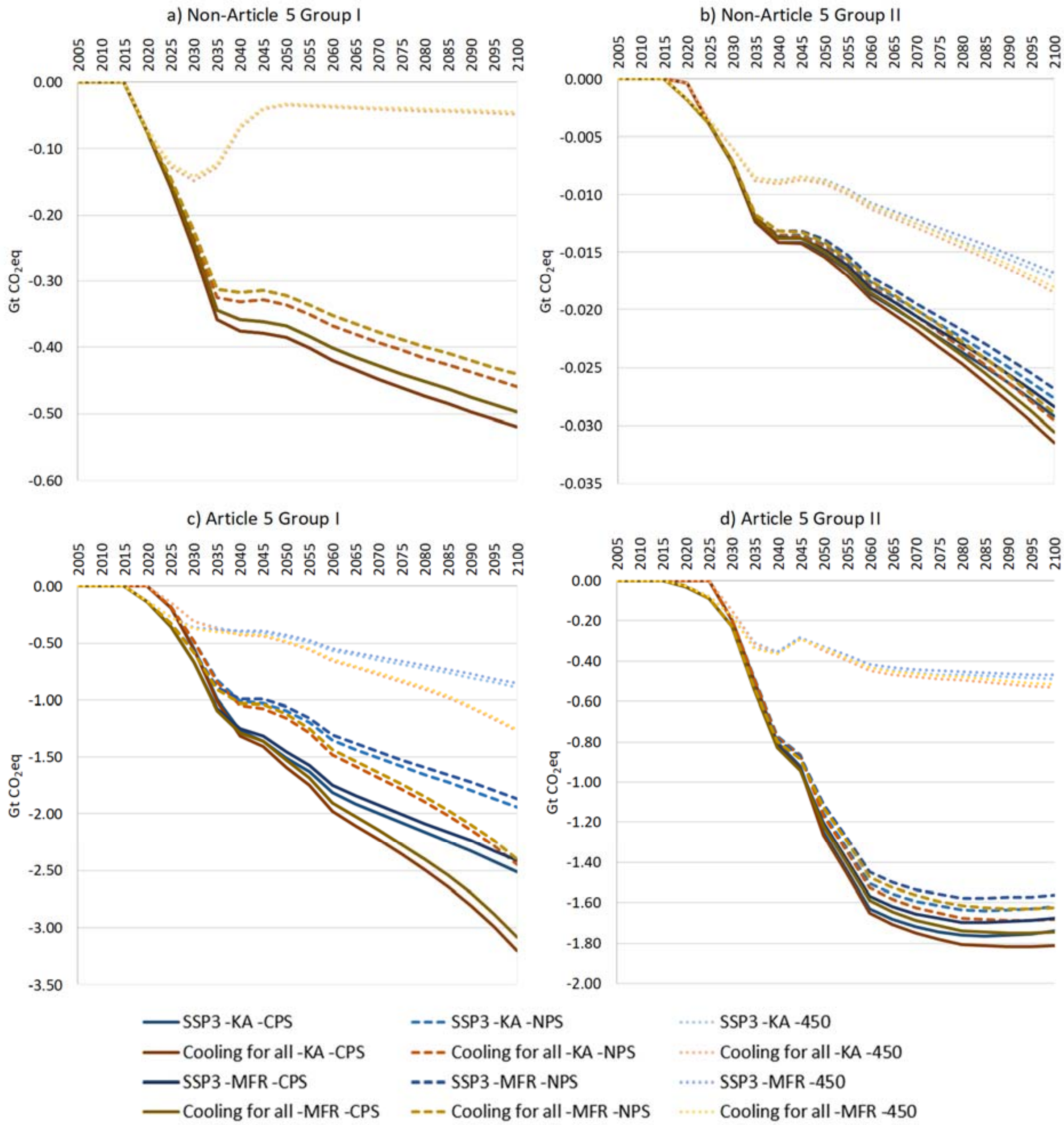

Figure S5: GHG emissions reductions in the baseline (SSP3 and Cooling for All) and alternative (KA and MTFR) scenarios due to technical electricity savings potential by different party groups

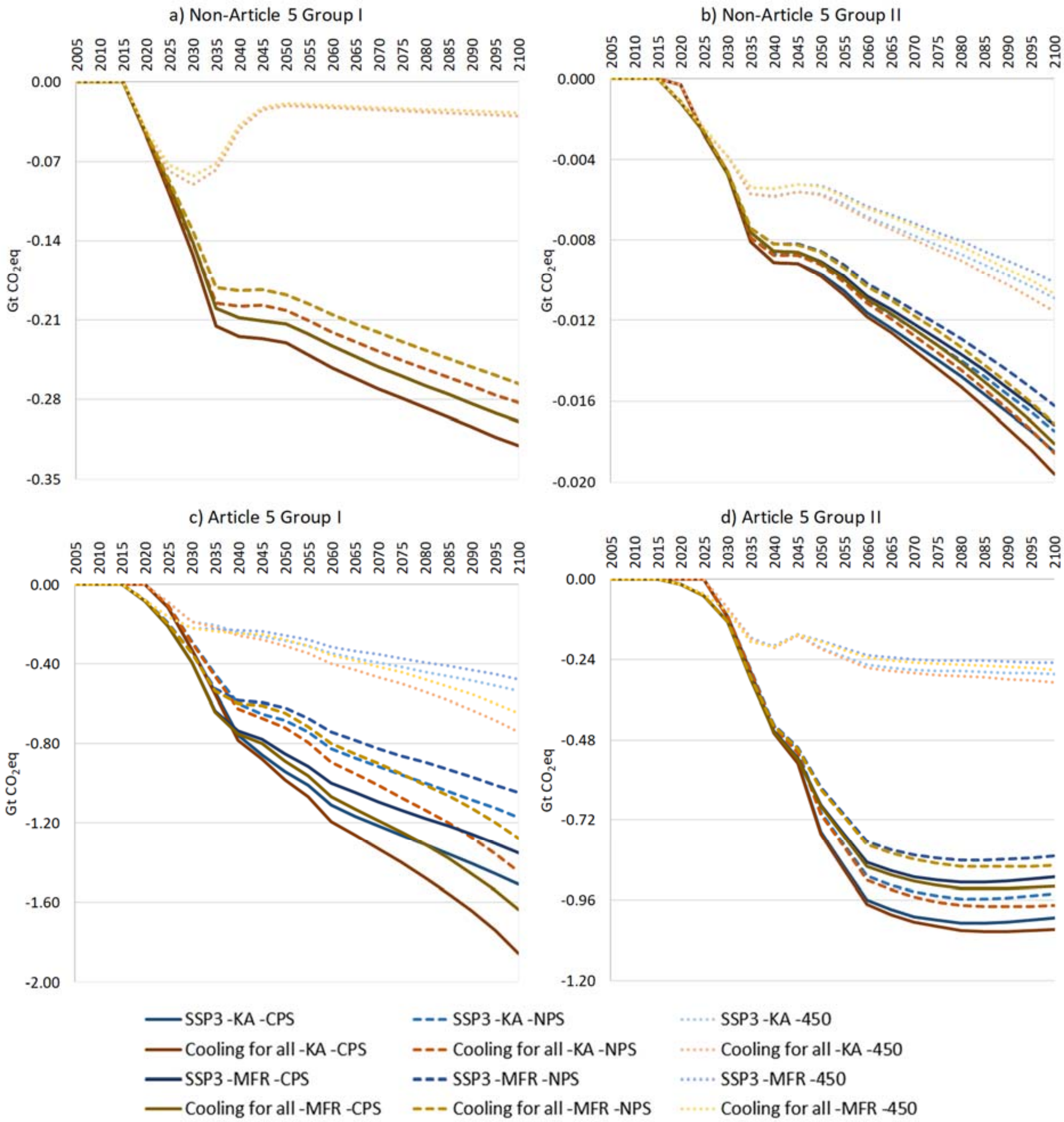

Figure S6: GHG emissions reductions in the baseline (SSP3 and Cooling for All) and alternative (KA and MTFR) scenarios due to economic electricity savings potential by different party groups

References

CLASP (2013). *Technical Evaluation of National and Regional Test Methods for Commercial Refrigeration Products*. Collaborative Labeling and Appliance Standards Program (CLASP), Washington, D.C. (Available at: https://storage.googleapis.com/clasp-siteattachments/SEAD-Evaluation-of-National-and-Regional-Test-Methods-for-Commercial-Refrigeration-Equipment.pdf accessed on 18/09/2018).

CLASP (2014). *Analysis of EU policy proposals for DG ENER Lot 12 Commercial Refrigeration Including comparison with policy thresholds and product data from other regions*. Collaborative Labeling and Appliance Standards Program (CLASP), Washington, D.C. (Available at: https://www.eceee.org/static/media/uploads/site-2/ecodesign/products/commercial-refrigerators-freezers/clasp-2014-11-analysis-eu-policy-proposals-dgenerlot12-regional-comparisons.pdf accessed on 24/09/2018).

DOE (2011). *Technical Support Document for Energy Conservation Standards for Residential Refrigerators, Refrigerator-Freezers, and Freezers*. Office of Energy Efficiency and Renewable Energy, U.S. Department of Energy (DOE), Washington, D.C. (Available at: https://www.regulations.gov/contentStreamer?documentId=EERE-2008-BT-STD-0012-0128&contentType=pdf accessed on 23/09/2018).

DOE (2018). *U.S. Department of Energy's Compliance Certification Database*. Washington, D.C. (Available at: https://www.regulations.doe.gov/certification-data/#q=Product_Group_s%3A* accessed on 12/09/2018).

DOE-/FEMP (2018). *Purchasing Energy-Efficient Air-Cooled Electric Chillers*. The Federal Energy Management Program (FEMP), U.S. Department of Energy (DOE), Washington, D.C. (Available at: https://www.energy.gov/eere/femp/purchasing-energy-efficient-air-cooled-electricchillers accessed on 19/09/ 2018).

EU (2006). 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. *Official Journal of the European Union*, L161: 12-18.

EU (2014) Regulation (EC) No 517/2014 of the European parliament and of the council of 16 April 2014 on fluorinated greenhouse gases and repealing Regulation (EC) No 842/2006. *Official Journal of the European Union*, L150: 195-230.

Feng J, Yan H, Zhang B, & Zhang J (2012). Prediction of HFC-23 Emission and Analysis of CDM Project Impact in China (in Chinese). *Acta Scientiarum Naturalium Universitatis Pekinensis*, 48: 310-316.

Fenhann J (2014). *UNEP DTU CDM Pipeline*. UNEP DTU Partnership, Copenhagen, Denmark.

Höglund Isaksson L, Winiwarter W, & Purohit P (2013). Non-CO_2 greenhouse gas emissions, mitigation potentials and costs in the EU-28 from 2005 to 2050: GAINS model methodology. International Institute for Applied Systems Analysis (IIASA), Laxenburg, Austria.

Höglund-Isaksson L, Winiwarter W, Purohit P, Rafaj P, Schöpp W & Klimont Z (2012). EU low carbon roadmap 2050: Potentials and costs for mitigation of non-CO_2 greenhouse gas emissions. *Energy Strategy Reviews*, 1 (2): 97-108.

IEA-4E (2012a). *Benchmarking report for refrigerated vending machines*, IEA Technology Collaboration Programme on Energy Efficient End-Use Equipment (4E). International Energy Agency (IEA), Paris (Available at: https://mappingandbenchmarking.iea-4e.org/shared_files/392/download accessed on 26/09/2018).

IEA-4E (2012b). *Benchmarking report for Retail display cabinets*, IEA Technology Collaboration Programme on Energy Efficient End-Use Equipment (4E). International Energy Agency (IEA), Paris (Available at: https://mappingandbenchmarking.iea-4e.org/shared_files/453/download accessed on 26/09/2018).

IEA-4E (2014). *Benchmarking report for domestic refrigerated appliances*. International Energy Agency (IEA), Paris (Available at: http://mappingandbenchmarking.iea-4e.org/shared_files/526/download accessed on 22/11/2018).

IEA-4E (2015). *Policy benchmarking for Packaged Liquid Chillers and evaluating the lack of comparability between economies*. International Energy Agency (IEA), Paris (Available at: https://mappingandbenchmarking.iea-4e.org/shared_files/710/download accessed on 22/11/2018).

IIASA (2017). *SSP Database (Shared Socioeconomic Pathways) - Version 1.1*. International Institite for Applied Systems Analysis, Laxenburg, Austria (Available at: https://secure.iiasa.ac.at/web-apps/ene/SspDb/dsd?Action=htmlpage&page=about accessed on 17/10/2018).

IPCC (2007). Climate Change 2007: The Physical Science Basis. *Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change* [Solomon, S., D. Qin, M. Manning, Z. Chen, M. Marquis, K.B. Averyt, M. Tignor and H.L. Miller (eds.)], Intergovernmental Panel on Climate Change (IPCC), Cambridge University Press, Cambridge, United Kingdom and New York, USA.

METI (2015). *Act on the Rational Use and Proper Management of Fluorocarbons (Act no. 64 of 2001)*. Ministry of Economy, Trade and Industry (METI), Tokyo, Japan.

Miller BR & Kuijpers LJM (2011). Projecting future HFC-23 emissions. *Atmospheric Chemistry and Physics*, 11: 13259-13267.

Miller BR, Rigby M, Kuijpers LJM, Krummel PB, Steele LP, Leist M, Fraser PJ, McCulloch A, Harth C, Salameh P, Mühle J, Weiss RF, Prinn RG, Wang RHJ, O'Doherty S, Greally BR, & Simmonds PG (2010). HFC-23

(CHF3) emission trend response to HCFC-22 (CHClF2) production and recent HFC-23 emission abatement measures. *Atmospheric Chemistry and Physics*, 10: 7875–7890.

Montzka SA, Kuijpers L, Battle MO, Aydin M, Verhulst KR, Saltzman ES, & Fahey DW (2010). Recent increases in global HFC-23 emissions. *Geophysical Research Letters*, 37: L02808.

NDRC (2015). *China's Intended Nationally Determined Contribution*. Submitted to the United Nations Framework Convention on Climate Change (UNFCCC), Bonn on June 30, 2015 (Available at: https://www4.unfccc.int/sites/submissions/INDC/Published Documents/China/1/China's INDC - on 2030 June 2015.pdf accessed on 12/11/2018).

Reilly, A. (2017). U.S. court rejects Obama-era plan to eliminate some potent planet warming chemicals. Science and Policy, 8 August 2017. doi:10.1126/science.aan7217.

Rosenquist, G. (2016). Energy Analysis and Environmental Impacts Division, Lawrence Berkeley National Laboratory (LBNL), Berkeley (*personal communication*).

Schneider LR (2011). Perverse incentives under the CDM: an evaluation of HFC-23 destruction projects, *Climate Policy*, 11: 851–864.

Shah N, Wei M, Letschert VE, & Phadke AA (2015). *Benefits of Leapfrogging to Superefficiency and Low Global Warming Potential Refrigerants in Room Air Conditioning*. LBNL-1003671, Lawrence Berkeley National Laboratory (LBNL), Berkley, CA.

UNEI (2017). *Accelerating the Global Adoption of Climate-Friendly and Energy-Efficient Refrigerators*. United Nations Environment Programme (UNEP), 2017, Paris.

UNEP (2014). *Ozone Secretariat – Data Access Centre*. United Nations Environment Programme (UNEP), Nairobi (Available at: http://ozone.unep.org/en/data-reporting/data-centre accessed on 05/11/2014).

UNEP (2016). *Further Amendment of the Montreal Protocol: Submitted by the Contact group on HFCs.* Twenty-Eighth Meeting of the Parties to the Montreal Protocol on Substances that Deplete the Ozone Layer, United Nations Environment Programme (UNEP), UNEP/OzL.Pro.28/CRP/10, Kigali, 10–14 October 2016.

US EPA (2015). *Protection of Stratospheric Ozone: Change of Listing Status for Certain Substitutes under the Significant New Alternatives Policy Program*. EPA–HQ–OAR–2014–0198, U. S. Environmental Protection Agency (EPA), Washington, D.C.

Velders GJM, Fahey DW, Daniel JS, Andersen SO, & McFarland M (2015). Future atmospheric abundances and climate forcing from scenarios of global and regional hydrofluorocarbon (HFC) emissions. *Atmospheric Environment*, 123: 200-209.

Wara M (2007). Is the global carbon market working? *Nature*, 445: 595-596.