

Supplementary Materials

Recovery of Fluorinated Refrigerants from Decommissioned RAC Equipment in Germany—Implications for National Emission Reporting under the UNFCCC

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Table S1. Number of decommissioned units filled with fluorinated refrigerants in the VDKF-LEC database for the different sectors and subsectors.

Sector	Subsector	Gas	2017	2018	2019	2020	2021	Sum
2.F.1.a Commer- cial refrigeration	Compound sys- tems	R134a	27	39	43	26	43	178
		R143a	0	1	0	0	0	1
		R401A	0	3	0	3	0	6
		R402A	1	2	0	2	0	5
		R403B	0	1	0	0	0	1
		R404A	91	92	70	101	65	419
		R407C	20	15	11	3	18	67
		R407F	0	5	1	4	1	11
		R409A	1	0	0	0	0	1
		R410A	5	5	4	6	3	23
		R413A	1	5	1	1	0	8
		R417A	0	1	0	1	0	2
		R422A	2	1	0	0	0	3
		R422D	8	7	7	6	5	33
		R437A	0	0	0	1	0	1
		R448A	0	0	0	0	1	1
		R449A	0	3	4	12	7	26
		R450A	0	0	6	0	1	7
		R452A	0	1	0	2	2	5
		R502	1	0	0	0	0	1
		R504	1	0	0	0	0	1
		R507A	8	20	8	7	2	45
	Plug-in units	R134a	17	12	5	4	14	52
		R401A	0	0	0	2	0	2
		R404A	9	21	22	12	19	83
		R407A	0	1	0	0	0	1
		R407C	2	1	3	1	1	8
		R409A	10	0	1	0	0	11
		R410A	0	0	2	1	1	4
		R413A	0	1	0	0	1	2
		R422D	0	0	0	1	1	2
		R448A	0	0	2	0	0	2
		R449A	0	0	0	0	1	1
		R507A	1	1	0	0	0	2
-	R134a	120	149	79	146	145	639	

2.F.1.c Industrial refrigeration		R143a	0	0	0	1	0	1
		R23	0	1	7	4	3	15
		R402A	0	0	2	0	0	2
		R404A	22	19	16	30	19	106
		R407C	40	58	35	34	50	217
		R407F	0	1	0	0	3	4
		R410A	4	9	7	8	6	34
		R417A	2	0	0	2	1	5
		R422A	0	0	0	1	1	2
		R422D	12	3	4	4	11	34
		R448A	0	1	0	1	0	2
		R449A	0	0	0	2	1	3
		R452A	0	0	0	1	2	3
		R507A	4	5	7	7	1	24
2.F.1.f Stationary air-conditioning	Decentral split units (single/multi)	R134a	35	44	30	45	25	179
		R23	0	0	0	0	1	1
		R32	0	2	5	8	7	22
		R404A	3	4	2	2	8	19
		R407B	0	1	0	0	0	1
		R407C	147	186	167	117	86	703
		R407D	0	0	0	0	1	1
		R407F	1	0	0	0	1	2
		R410A	290	396	388	361	357	1792
		R417A	2	2	8	0	2	14
		R422D	8	5	7	1	2	23
		R427A	0	1	0	0	0	1
		R450A	0	0	1	0	0	1
		R507A	0	0	1	0	0	1
	Decentral VRF/VRV units	R134a	0	2	2	1	2	7
		R407C	9	9	8	8	6	40
		R410A	17	28	25	33	37	140
		R422D	0	1	1	0	0	2
	Unspecified decentral units	R407C	14	8	6	4	4	36
		R410A	7	10	5	4	4	30
	Central air handling units	R134a	1	2	1	3	4	11
		R404A	2	1	0	2	0	5
		R407C	17	18	19	20	14	88
		R410A	12	11	9	15	9	56
		R417A	1	0	1	0	0	2
		R422D	2	1	4	1	0	8
		R513A	0	0	1	0	0	1
	Unspecified central units	R134a	7	17	14	55	35	128
		R32	0	0	0	1	0	1
		R404A	1	1	1	3	2	8
		R407C	26	34	18	33	15	126
		R410A	27	13	16	18	13	87
		R417A	0	1	0	0	1	2
		R422D	2	4	2	1	0	9
		R427A	0	0	1	0	0	1

Unspecified units	R134a	0	3	0	0	0	3
	R407C	1	0	1	0	0	2
	R410A	0	1	0	0	0	1
Moveable units	R134a	1	0	0	0	0	1
	R404A	3	0	0	0	0	3
	R407C	1	1	3	1	0	6
	R410A	1	2	2	4	3	12
Heat pumps (direct evaporation)	R134a	0	1	1	2	1	5
	R32	0	0	0	1	0	1
	R407C	1	1	0	0	2	4
	R410A	4	4	12	2	5	27
	R422D	1	1	0	0	0	2
Heat pumps (multi-circuit)	R134a	2	5	1	3	1	12
	R407C	0	1	0	1	3	5
	R410A	1	2	0	3	2	8
Total		1056	1308	1110	1190	1082	5746

Table S2. Number of decommissioned units filled with fluorinated refrigerants in the VDKF-LEC dataset for the different sectors and subsectors. Shown is the dataset for the calculation of operating years.

Sector	Subsector	Refrigerant	2017	2018	2019	2020	2021	Sum
2.F.1.a Commercial refrigeration	Compound systems	R134a	24	32	39	25	41	161
		R404A	79	81	63	97	62	382
		R407C	20	12	10	3	18	63
		R449A	0	2	4	12	7	25
		R507A	8	16	3	7	1	35
	Plug-in units	R134a	13	10	3	4	11	41
2.F.1.c Industrial refrigeration	-	R404A	6	15	19	12	18	70
		R134a	119	146	78	142	144	629
		R404A	22	19	16	28	18	103
		R407C	37	57	32	33	46	205
		R410A	4	9	4	6	5	28
2.F.1.f Stationary air-conditioning	Decentral split units (single/multi)	R422D	9	1	2	4	9	25
		R134a	3	16	10	32	14	75
		R407C	126	165	137	103	77	608
	Decentral VRF/VRV units	R410A	237	332	322	305	316	1512
		R407C	8	8	7	8	6	37
	Central air handling units	R410A	11	26	24	30	33	124
		R407C	14	18	19	17	11	79
		R410A	11	11	9	14	9	54
	Unspecified central units	R134a	7	16	13	55	34	125
		R407C	25	34	16	31	15	121
		R410A	26	13	15	17	13	84
	Heat pumps (direct evaporation)	R410A	2	4	12	2	5	25
Total			811	1043	857	987	913	4611

Table S3. Average initial charge of fluorinated refrigerants in decommissioned equipment in the VDKF-LEC database in kg.

Sector	Subsector	Refrigerant	2017	2018	2019	2020	2021	Total
2.F.1.a Commercial refrigeration	Compound systems	R134a	7.8	19.0	25.3	12.7	13.7	16.6
		R404A	35.0	43.0	46.6	44.1	36.0	41.0
		R407C	16.6	16.2	25.1	38.8	22.5	20.5
		R422D	9.8	21.9	15.1	16.9	7.7	14.5
		R449A	-	17.5	76.6	32.9	29.9	37.0
		R507A	18.5	28.2	25.5	16.0	31.0	24.3
	Plug-in units	R134a	0.7	1.4	1.1	0.7	0.9	1.0
		R404A	3.0	1.2	1.5	2.2	1.5	1.7
2.F.1.c Industrial refrigeration	-	R134a	11.3	8.9	15.8	5.0	10.3	9.6
		R404A	17.6	19.1	11.8	119.7 ¹	24.5	47.1 ²
		R407C	17.4	23.0	33.7	31.8	19.7	24.3
		R410A	16.7	2.5	7.4	4.1	2.1	5.5
		R422D	59.9	6.5	49.9	7.8	66.8	50.1
2.F.1.f Stationary air-conditioning	Decentral split units (single/multi)	R134a	0.7	0.8	0.8	0.9	0.8	0.8
		R407C	3.4	4.4	5.0	3.3	3.8	4.1
		R410A	2.9	2.5	2.9	2.6	2.4	2.6
	Decentral VRF/VRV units	R407C	23.1	5.0	5.4	5.8	10.2	10.1
		R410A	15.9	11.6	13.1	10.2	11.5	12.0
	Unspecified decentral units	R407C	2.0	1.7	1.2	1.5	1.2	1.6
		R410A	2.1	1.5	1.4	2.0	1.0	1.6
	Central air handling units	R407C	27.1	12.4	39.8	12.7	30.0	24.0
		R410A	12.8	2.6	3.6	2.6	2.5	4.9
	Unspecified central units	R134a	1.7	15.6	46.2	3.0	4.5	9.7
		R407C	12.1	9.6	18.2	8.9	21.1	12.5
		R410A	5.7	8.6	3.4	2.4	2.3	4.5
	Heat pumps (direct evaporation)	R410A	14.3	18.9	6.2	6.0	19.9	11.8

¹ Excluding one single unit with 1800 kg charge, the average is 61.7 kg.² Excluding one single unit with 1800 kg charge, the total average is 30.4 kg.

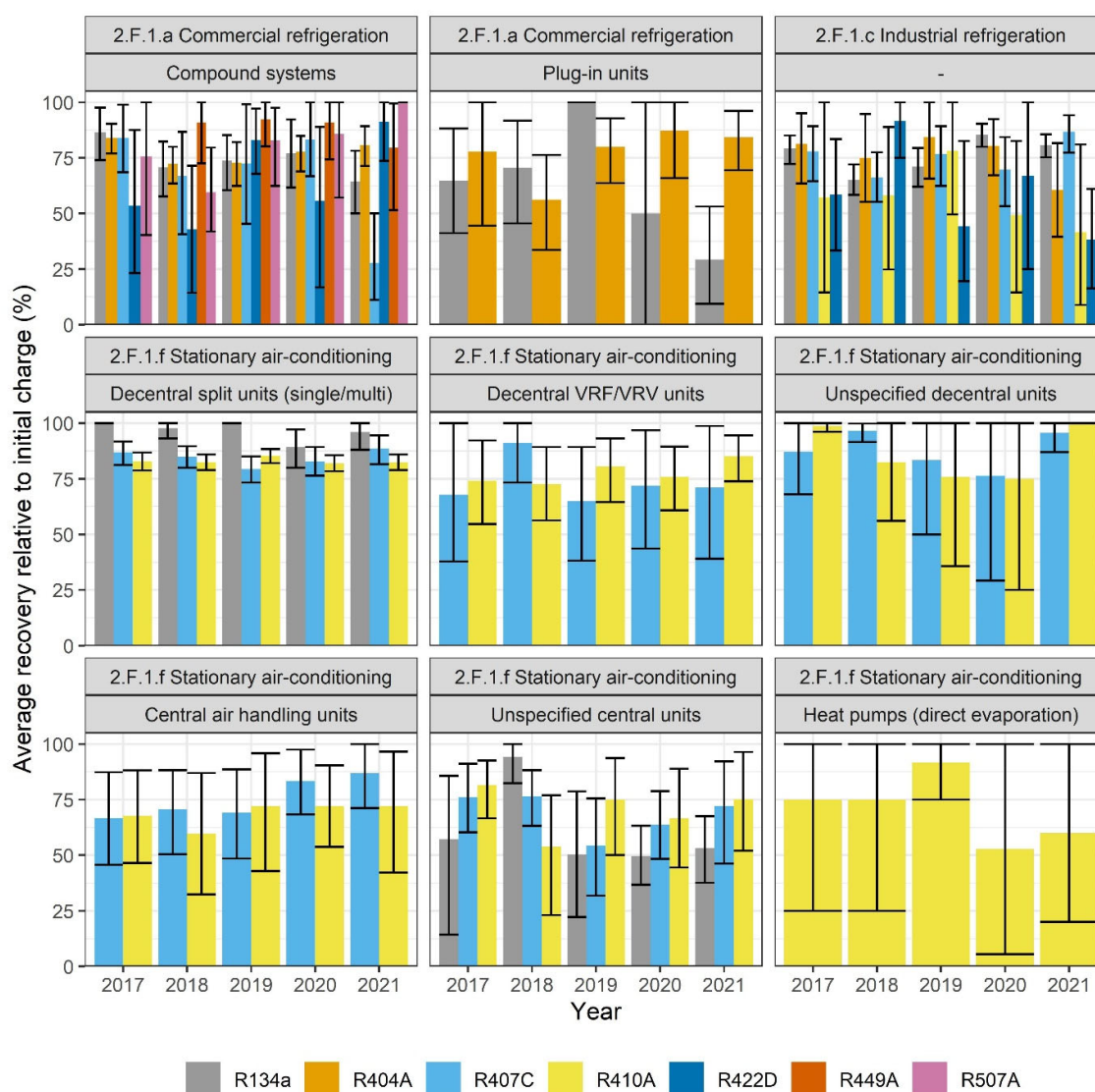


Figure S1. Average recovery of fluorinated refrigerant from decommissioned equipment relative to the initial charge for the different sectors and subsectors by type of refrigerant in the VDKF-LEC database. Error bars are nonparametric bootstrapped 95 % confidence intervals for the group mean, based on 1000 bootstrap resamples.

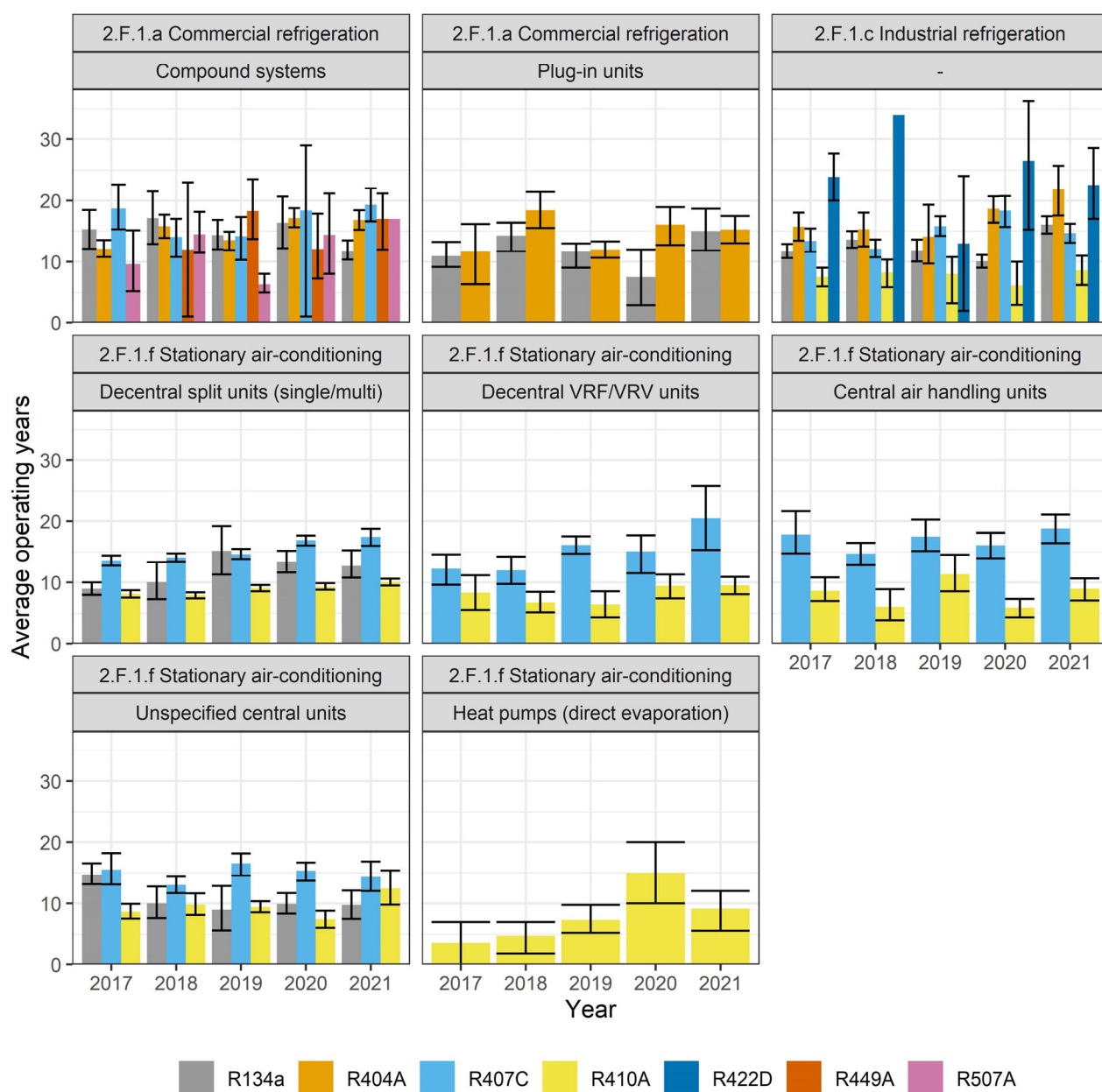


Figure S2. Average operating years of decommissioned equipment by sector, subsector, and refrigerant in the VDKF-LEC database. Error bars are nonparametric bootstrapped 95 % confidence intervals for the group mean, based on 1000 bootstrap resamples.