Öko-Recherche

Büro für Umweltforschung und -beratung GmbH

CAPACITY BUILDING WORKSHOP ON THE IMPLEMENTATION OF THE 2006 IPCC GUIDELINES IN NATIONAL GREENHOUSE GAS INVENTORIES

IPPU – F gases

Overview of issues identified by Member States for consideration
Experiences from Member States

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Content

1. New reporting requirements for F-Gases

   New tiers from 2006 IPCC Guidelines

   GWP values from IPCC 4th Assessment Report (AR4)

   Additional F-gases

2. New emission source categories. Electronics

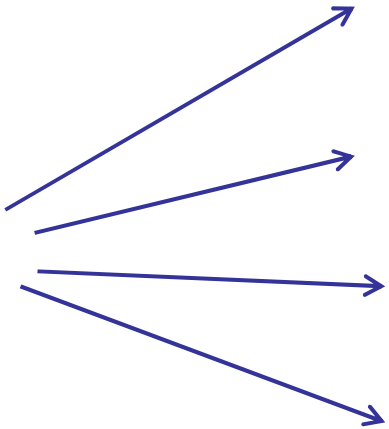
3. Six new HFCs – only HFC-245fa and HFC-365mfc relevant

4. NF_3 and two new PFCs

5. The Recovery “puzzle” in 2.F. What does mean “recovery”?

Application of 2006 IPCC Guidelines
New Approaches (Tier)

Old	*New*
Tier 1: Estimates of potential emissions	No longer potential emissions but only actual emissions
Tier 2: Estimates of actual emissions - Bottom-up - Top-down	Tier 1a: Emission factor approach at the level of applications
	Tier 1b: Mass-balance approach at the level of applications
	Tier 2a: Emission factor approach at the level of sub-applications
	Tier 2b: Mass-balance approach at the level of sub-applications



→ Only Tier 1a and Tier 2a can match CRF split into emissions from (1) manufacturing, (2) stocks, and (3) disposal

GWPs from IPCC AR4 and 9 new F-gases

	GWP_{100} SAR	GWP_{100} AR4
HFC-23	11.700	14.800
HFC-32	650	675
HFC-41	150	92
HFC-43-10-mee	1.300	1.640
HFC-125	2.800	3.500
HFC-134	1.000	1.100
HFC-134a	1.300	1.430
HFC-143	300	353
HFC-143a	3.800	4.470
HFC-152	-	53
HFC-152a	140	124
HFC-161	-	12
HFC-227ea	2.900	3.220
HFC-236cb	-	1.340
HFC-236ea	-	1.370
HFC-236fa	6.300	9.810
HFC-245ca	560	693
HFC-245fa	-	1.030
HFC-365mfc	-	794
PFC-14 (CF_4)	6.500	7.390
PFC-116 (C_2F_6)	9.200	12.200
PFC-216 (c-C_3F_6)	-	>17.340
PFC-218 (C_3F_8)	7.000	8.830
PFC-318 (c-C_4F_8)	8.700	10.300
PFC-3-1-10 (C_4F_{10})	7.000	8.860
PFC-4-1-12 (C_5F_{12})	7.500	9.160
PFC-5-1-14 (C_6F_{14})	7.400	9.300
PFC-9-1-18 ($C_{10}F_{18}$)	-	>7.500
SF_6	23.900	22.800
NF_3	-	17.200

GWP values mostly higher than in SAR - especially of most common HFC refrigerants (yellow shaded)

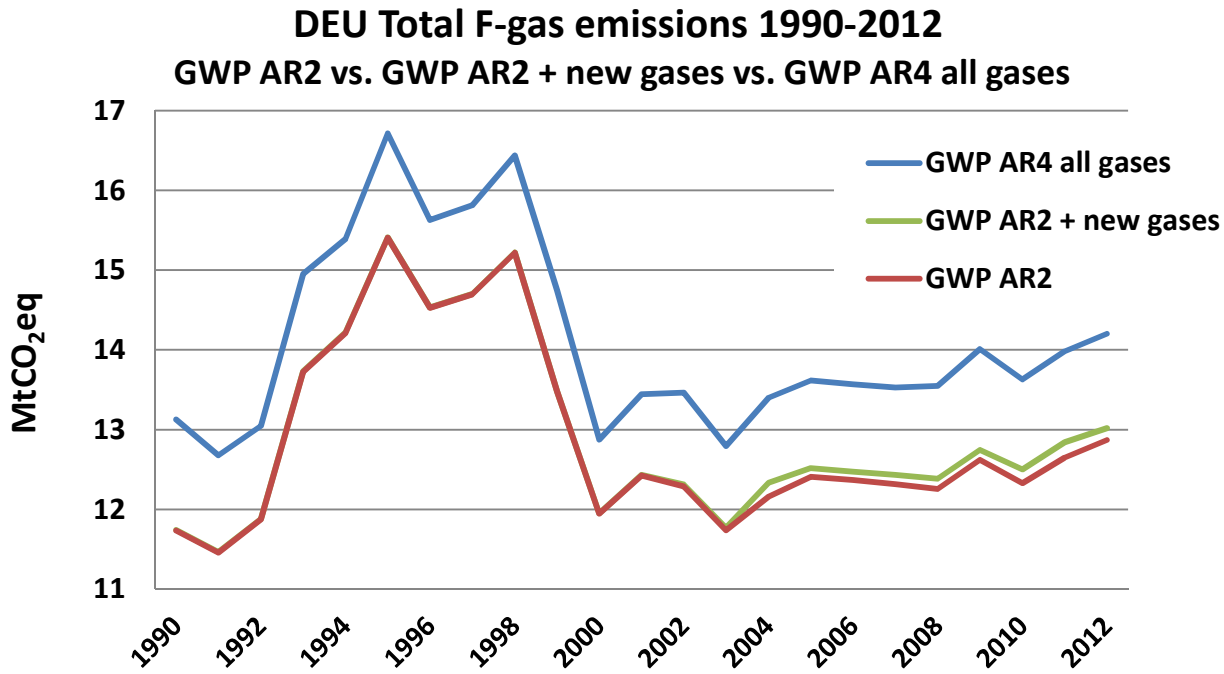
Grey shaded: New F-gases to be reported under UNFCCC

Impact from GWP AR4 and additional F-gases on the German inventory

New reporting requirements: general GWP_{100} AR4 + new F-gases

Increase in F-gas emissions by 10.5% in 2012 (+ 1.33 $MTCO_2eq$):

- **9.0% from introduction of the GWP values of the IPCC 4AR**
- **1.5% from new gases: HFC-245fa, -365mfc, NF_3 and $C_{10}F_{18}$**



New emission source categories (Electronics)

Most source categories and sub categories are substantially the same in old and new reporting, with renumbering or repositioning only*. One major exemption:

Semiconductor Manufacture “advance” from 2.F subcategory to full 2.E category.

2.F
1. Refrigeration
2. Foam Blowing
3. Fire Extinguishers
4. Aerosols
5. Solvents
6. Other applications using ODS substitutes
7. Semiconductor Manufacture
8. Electrical Equipment
9. Other *(please specify)*

2.E Electronics industry
1. Integrated circuit or semiconductor
2. TFT flat panel display
3. Photovoltaics *(SF6, NF3)*
4. Heat transfer fluid *(C6F14)*
5. Other

Consequence: increased attention towards the F-gas applications „TFT display“, „Photovoltaics“, and „Heat transfer fluid“.

* In Germany, only two new subcategories result from inclusion of new F-gases: “ORC -organic rankine cycle” (HFC-245fa, -365mfc) and “medical/cosmetic products” ($C_{10}F_{18}$). The 3rd new application “heat pump tumble dryers”, dating as of 2007, uses common HFCs (134a/R-407C).

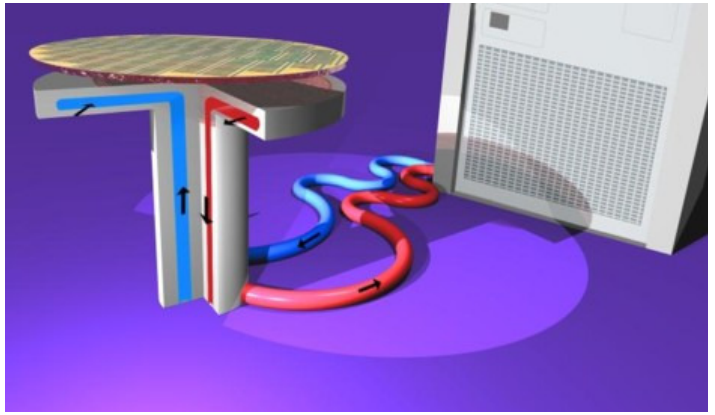
Example Heat Transfer Fluid (HTF)*

By today, only FRA and BEL have reported the most important HTF C_6F_{14} .

In 2013, German inventory makers identified two main applications in DEU:

1. Since early 1990s, C_6F_{14} (3Ms "Fluorinert FC-72", produced in BEL, 50-150 t/y) in use in semiconductor manufacture - for defined temperature of wafer production tools.

2. In 1990s, cooling of power converters in High Speed Trains (TGV, ICE).



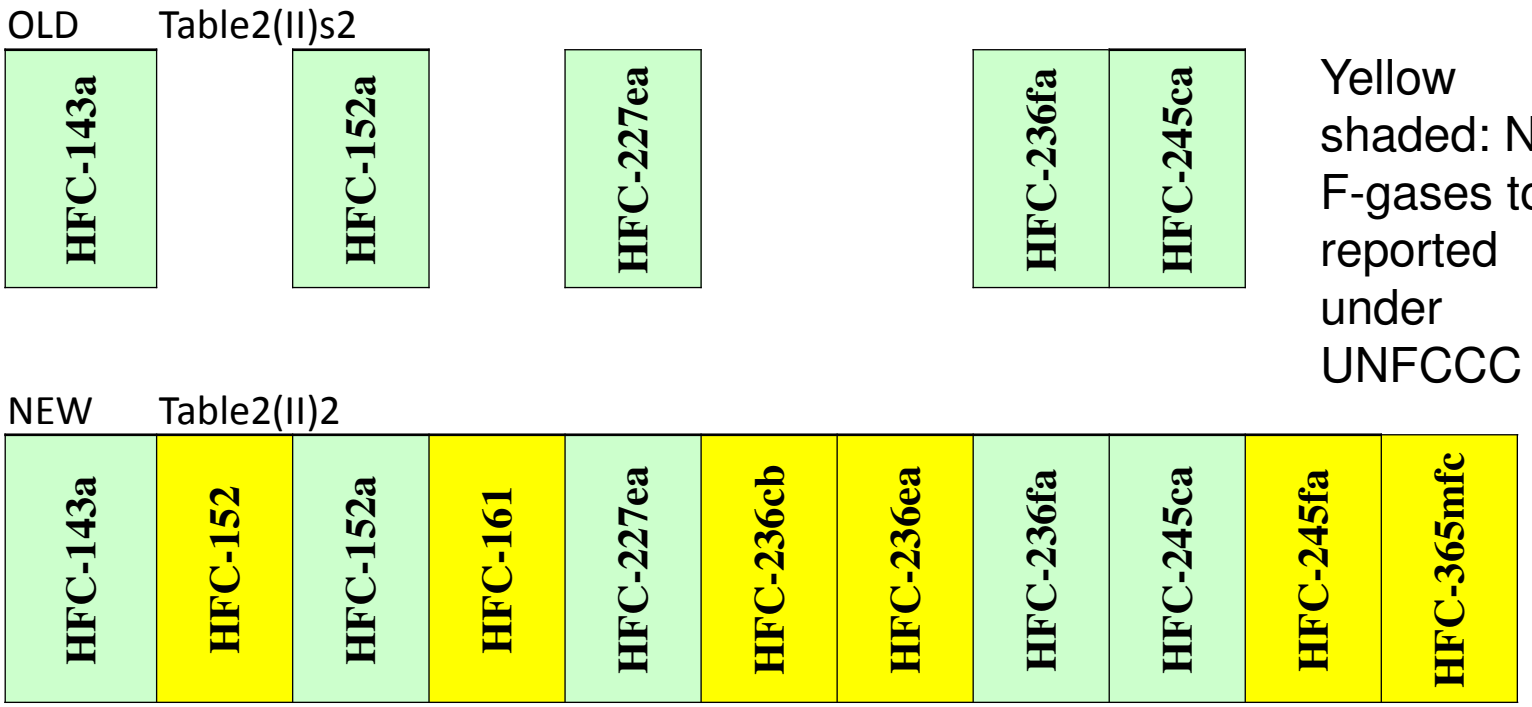
Heat transfer in wafer production (Foto 3M)

3. Stock: 2012: 50–100 t (peak 2000: 300 t), declining due to substitution (by HFEs)

4. So far, reported by FRA only. DEU reporting planned for next submission. Further 7 MS with semiconductor industry are encouraged to collect data.

** TFT displays are not being manufactured in Europe. Photovoltaics with F-gases (SF_6, NF_3) only in 3 MS – see following slides.*

Six New HFCs in 2015 CRF-Reporting



Yellow shaded: New F-gases to be reported under UNFCCC

Next UNFCCC submission: Mandatory reporting of six additional HFCs: HFC-152, -161, -236cb, -236ea, -245fa, and -365mfc (yellow shaded)

New HFCs: HFC-245fa and HFC-365mfc

- Today, the two (liquid) HFCs are the most relevant:
  HFC-245fa (Honeywell, USA) and HFC-365mfc (Solvay, FRA)
- Introduction to EU market 2002 (365mfc), 2004 (245fa)
  → time series for recalculation comparably short
- Use all over EU. Reported by AUT, DEU, FIN, FRA, LTU in Table9(b)
- Main application: Polyurethane-foam blowing agent
  (PU closed cell foam and integral PU-foam)
- PU closed cell: 10-15% manufacturing EF. Remainder enclosed in foam cells up to 50 years. Lifetime EF 1%. So far no disposal
- MS with highest consumption: ESP (PU spray foam for roof insulation)
- Further applic.: solvent, refrigerant, increasingly working fluid in organic rankine cycle (ORC), especially DEU
- Confidentiality issue (two suppliers only)

The other 4 new HFCs – so far hardly used

Substance	Formula	GWP_{100}	Areas of application
HFC-152	$C_2H_4F_2$	53	Inflammable (less than 3 F atoms in molecule (!) No currently known application in EU.
HFC-161	C_2H_5F	12	Inflammable. Low GWP refrigerant, one of many possible alternatives to HFC blends in room air conditioners for export from Asia to Europe. Tests in Asia reported. Use in Europe unlikely because natural refrigerants (propane) are cheaper and already commercialized.
HFC-236cb	$C_3H_2F_6$	1,340	Solvent No use known today
HFC-236ea	$C_3H_2F_6$	1,370	High-temperature refrigerant for multistage heat pumps and working fluid in geothermic ORC-systems (not in use today)

NF_3 and two new PFCs: $C_{10}F_{18}$, c-C_3F_6

OLD Table2(II)s2

CF_4	C_2F_6	C_3F_8	C_4F_{10}	c-C_4F_8	C_5F_{12}	C_6F_{14}

SF_6

Yellow shaded: New F-gases to be reported under UNFCCC

NEW Table2(II)2

CF_4	C_2F_6	C_3F_8	C_4F_{10}	c-C_4F_8	C_5F_{12}	C_6F_{14}	$C_{10}F_{18}$	c-C_3F_6	SF_6	NF_3

Nitrogen trifluoride (NF_3) Semiconductors

- High quantities for Silicon-removing („CVD chamber cleaning“) in Korea, Taiwan, Japan in TFT-LCD manufacture: > 4,000 tons/year
  No TFT-LCD manufacture in EU
- Main EU application: CVD chamber cleaning in semiconductor industry, replacing PFCs like CF_4 or C_2F_6 (shorter process time)
- Market introduction in EU already in 1990 (long recalculation!)
- MS with semiconductor industry:
  AUT, CZE, DEU, FIN, FRA, GBR, IRL, ITA, LTU, NLD. Other?
- EU consumption 2007: ~ **300** tons (manufacturer association ESIA)

	1995	1999	2001	2005	2007
NF3 (purchase data kg)	9,705	24,899	76,592	193,392	299,791
Emissions ktCO2eq	28,860	51,018	46,647	111,951	95,520
Implied Emission factor	17%	12%	4%	3%	2%

- EF according to DEU : ~ 4% (effective abatement systems installed)

Nitrogen trifluoride (NF_3) Photovoltaics

- Same process as in semiconductor industry, however much bigger CVD reactor chambers to be “cleaned” from Silicon deposition (wafer surface area in PV up to 5 m^2 vs. wafer surface area in Semicon ~ 0.1 m^2
- Applied only to one type of photovoltaic (PV) cell manufacture: Silicon-thinfilm technology (< 5% of solar cell production)
- Negligible quantities of SF_6 in 1990s (1 mini plant for pocket calculators!); rapid increase from 2006 in four plants
- From 2008 application of NF_3 instead of SF_6 in new plants
- EU NF_3 2008-2012 consumption **15-90** t/y. SF_6 consumption **6-60** t/y
- Si-thinfilm technology: So far only known in DEU, ESP, ITA
- Current crisis in solar cells → reduced quantities of SF_6 and NF_3
- German Si-thinfilm PV plants in 2009: 10. German plants 2013: 2
- EF: 4% (abatement systems like in semiconductor industry)

Two new PFCs

Substance	Formula	GWP_{100}	Areas of application
PFC-216 Perfluorocyclopropane	c-C_3F_6	>17,340	Production of semi-conductors (not in use today in Germany, very likely not in use in EU)
PFC-9-1-18 Perfluorodecalin	$C_{10}F_{18}$	>7,500	Global production ~ 10 tons (estimate) Only EU producer: F2 (GBR) Cosmetic products: e.g. anti-aging creams, nail polisher (< 10 kg/a) Medical applications: eye surgery, for organ transplantations, contrast agent Market introduction in 2000, time series available Consumption in DEU 2012: < 800 kg
Voluntary reporting			
SF_5CF_3 Trimethyl sulphur pentafluoride	SF_5CF_3	17,700	Tracer gas (used by German research institute in Pacific Ocean – no DEU emissions)

Recovery “Puzzle” in 2.F

New CRF requires „Recovery“, in addition to 3 emission types

OLD Table 2(II).Fs1

EMISSIONS		
From manufacturing	From stocks	From disposal
(t)		

NEW TABLE 2(II).F1

EMISSIONS[(2)]			
From manufacturing	From stocks	From disposal	Recovery[(3)]
(t)			

Recovery is placed under the heading EMISSIONS.
If emissions FROM recovery were meant, „from“ should have been added, what is not the case.
→ Recovery means NON-EMISSIONS.

Unclear Definition of “Recovery”:

(3) “Amounts of emission recovery, oxidation, destruction or transformation, including from disposal emissions, where applicable”.

Comment: Definition fits Chemical Industry (2.B) with on-site „recovery“ (abatement) systems to capture emissions and to oxidize or destroy waste gas.

Not appropriate to F-gases (2.F.1, 2.F.8) which are removed and stored on-site from old equipment and sent offsite for recycling, reclamation and destruction.

What does mean „Recovery“?

IPCC 2006 GL (ch. ODS substitutes):

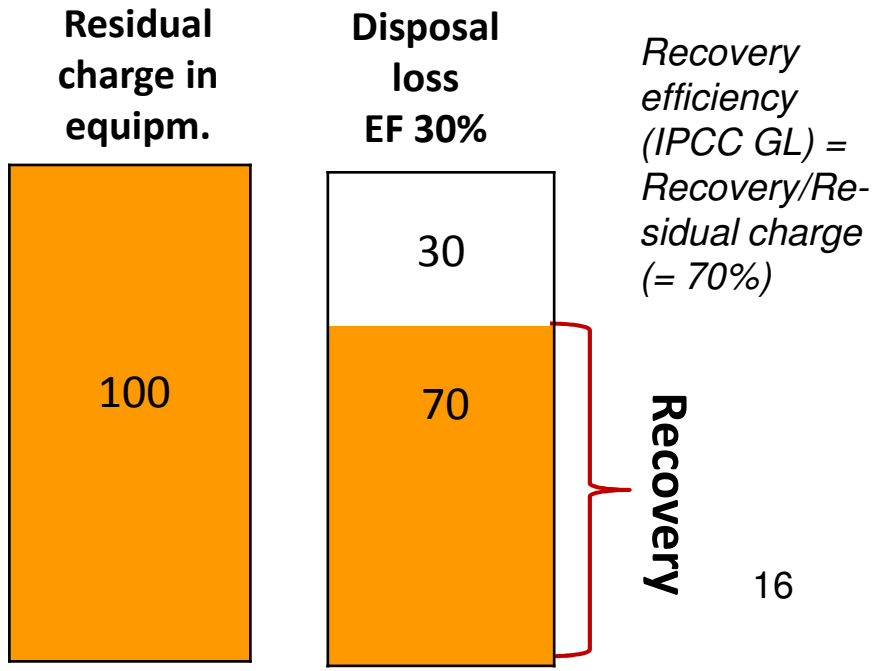
No explicit definition of „recovery“. In the definition of „recovery efficiency“ („ratio of recovered HFC referred to the HFC contained in the system“) recovery itself is simply presumed to be known.

New F-gas Regulation:

“(14) ‘recovery’ means the collection and storage of fluorinated greenhouse gases from equipment …prior to the disposal of the equipment.”

Evidently, recovery means simply removal of residual F-gas from old equipment. Not recovered residual gas = disposal emissions.

Recovery does not include recycling, reclamation, or destruction (RRD).



Entering Recovery in CRF

[Disregarding recovery emissions]

Recovery =
Amount in products at decommissioning minus disposal emissions
[Example: 100 – 30 = 70]

	ACTIVITY DATA *Amount*			IMPLIED EMISSION FACTORS[1]			EMISSIONS[2]			
	Filled into new manufactured products	In operating systems (average annual stocks)	A Remaining in products at decommissioning	Product manufacturing factor	Product life factor	Disposal loss factor	From manufacturing	From stocks	B From disposal	C Recovery[3]
	(t)			%			(t)			
F.1. Refrigeration and air conditioning			100			30%			30	70
F.1. Refrigeration and air condtioning			available						available	A – B

C = A – B.
Simple approach, because A and B are available in inventories

What is the use of such „recovery“ in CRF?

„Recovery“ is a tautological quantity, and implicitly available, anyway.
It does not provide additional information.

We ask: Why enter only on-site recovery instead of „real“ end-of-life recovery which includes RRD?

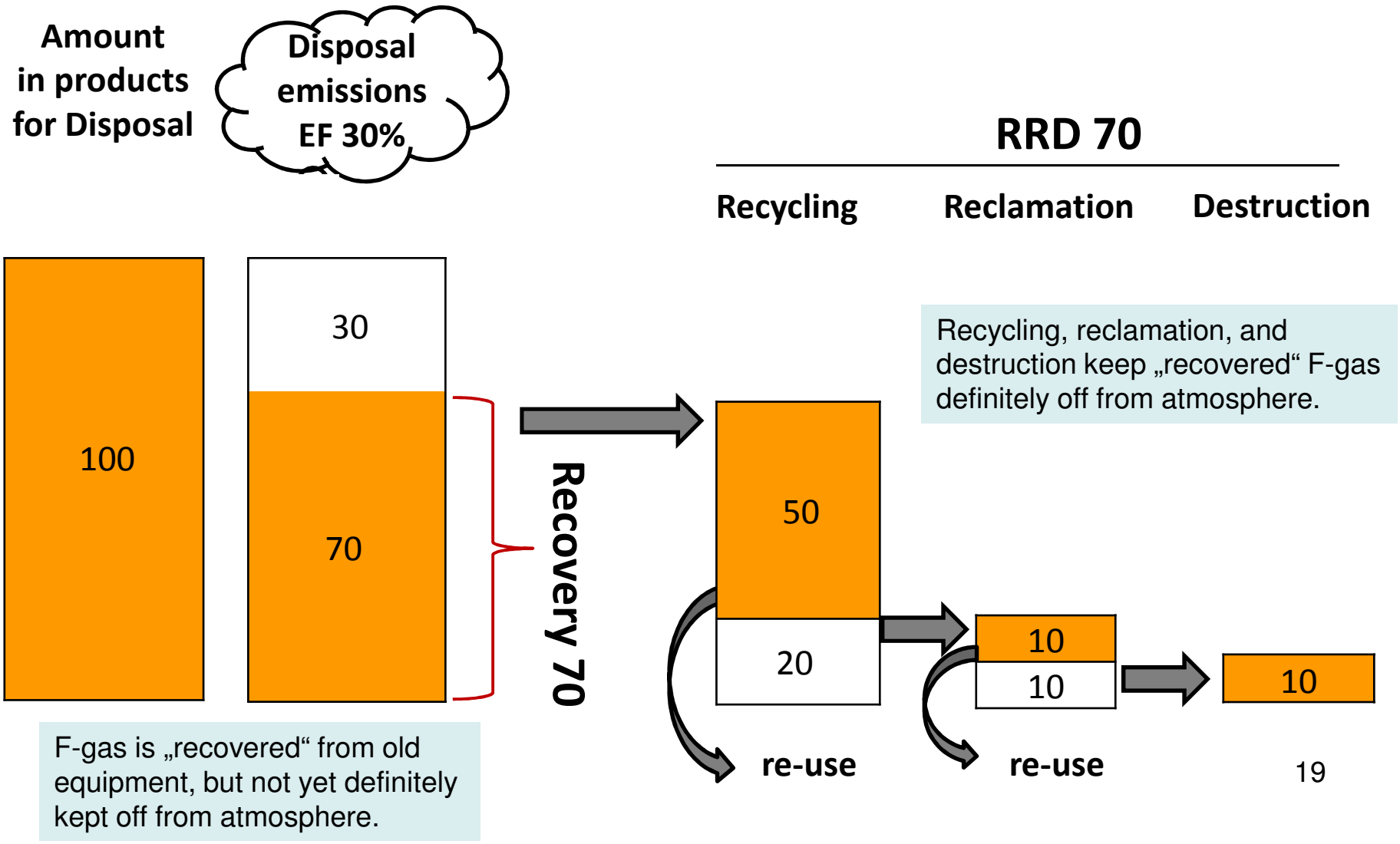
Real end-of-life recovery means that F-gas amount which is definitely kept off from the atmosphere, not just temporarily stored.

Real end-of-life recovery accounts not only for disposal loss but for all end-of-life emissions, including emissions from RRD.

As a consequence, „real recovery“ is lower than onsite removal from old equipment, due to emissions from recycling, reclamation, destruction.

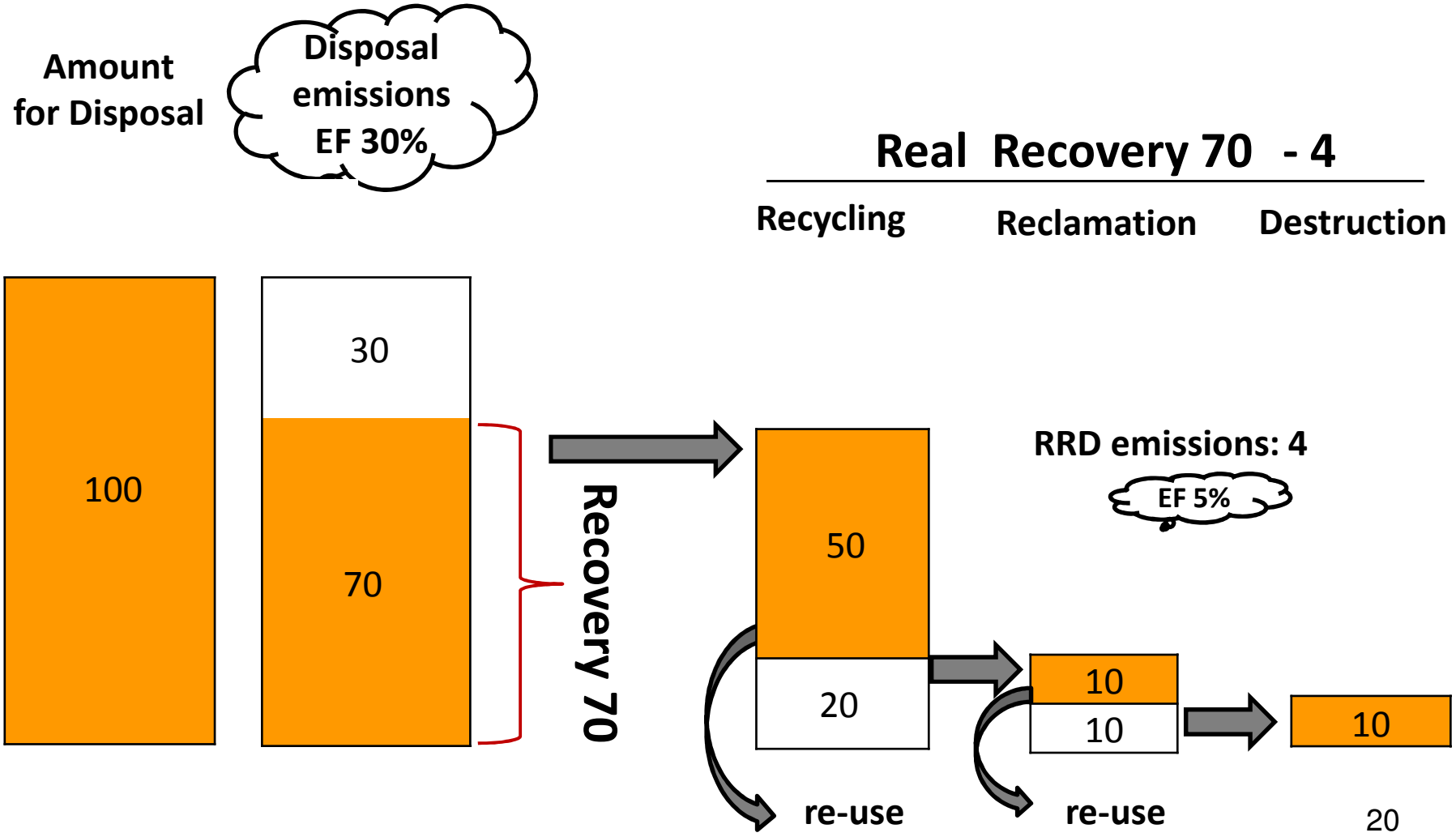
F-Gas Flow at End of Equipment Life - ideal

Recycling, reclamation, destruction (RRD) follow gas removal from old equipment (recovery), and are ideally same size.



F-Gas Flow at End of Equipment Life - real

[Considering RRD emissions]



Entering Real Recovery

[Accounting for recovery emissions]

Real Recovery = Recycling + Reclamation + Destruction – Recovery emissions

[Example 50 + 10 + 10 - 4]

	ACTIVITY DATA *Amount*			IMPLIED EMISSION FACTORS[1]			EMISSIONS[2]			
	Filled into new manufactured products	In operating systems (average annual stocks)	Remaining in products at decommissioning	Product manufacturing factor	Product life factor	Disposal loss factor	From manufacturing	From stocks	From disposal	Recovery[3]
	(t)			%			(t)			
F.1. Refrigeration and air conditioning			100			30%			30	66

Serious Reservation: No RRD data in 2.F.1

So far, such data are only exceptionally available: 2.F.8 (SF_6 switchgear). This is a clearly defined and uniform sector, with limited number of players, and only one F-gas, and with existing industry commitment for monitoring and reporting.

In Refrigeration/Air Conditioning (2.F.1) data collection on <u>recovery processes</u> (recycling - reclamation - destruction) and arising emissions is extremely difficult, and quite impossible for the 6 subsectors individually.

For the time being, we stick to „ideal“ recovery to be entered in CRF. C = A – B.

	ACTIVITY DATA *Amount*			IMPLIED EMISSION FACTORS[1]			EMISSIONS[2]			
	Filled into new manufactured products	In operating systems (average annual stocks)	A Remaining in products at decommissioning	Product manufacturing factor	Product life factor	Disposal loss factor	From manufacturing	From stocks	B From disposal	C Recovery[3]
	(t)			%			(t)			
F.1. Refrigeration and air condtioning			available						available	A – B

... assuming that our „emissions from disposal“ include all end-of-life emissions, and recovery is already reduced by RRD emissions.

Thank you for your attention !

Questions?

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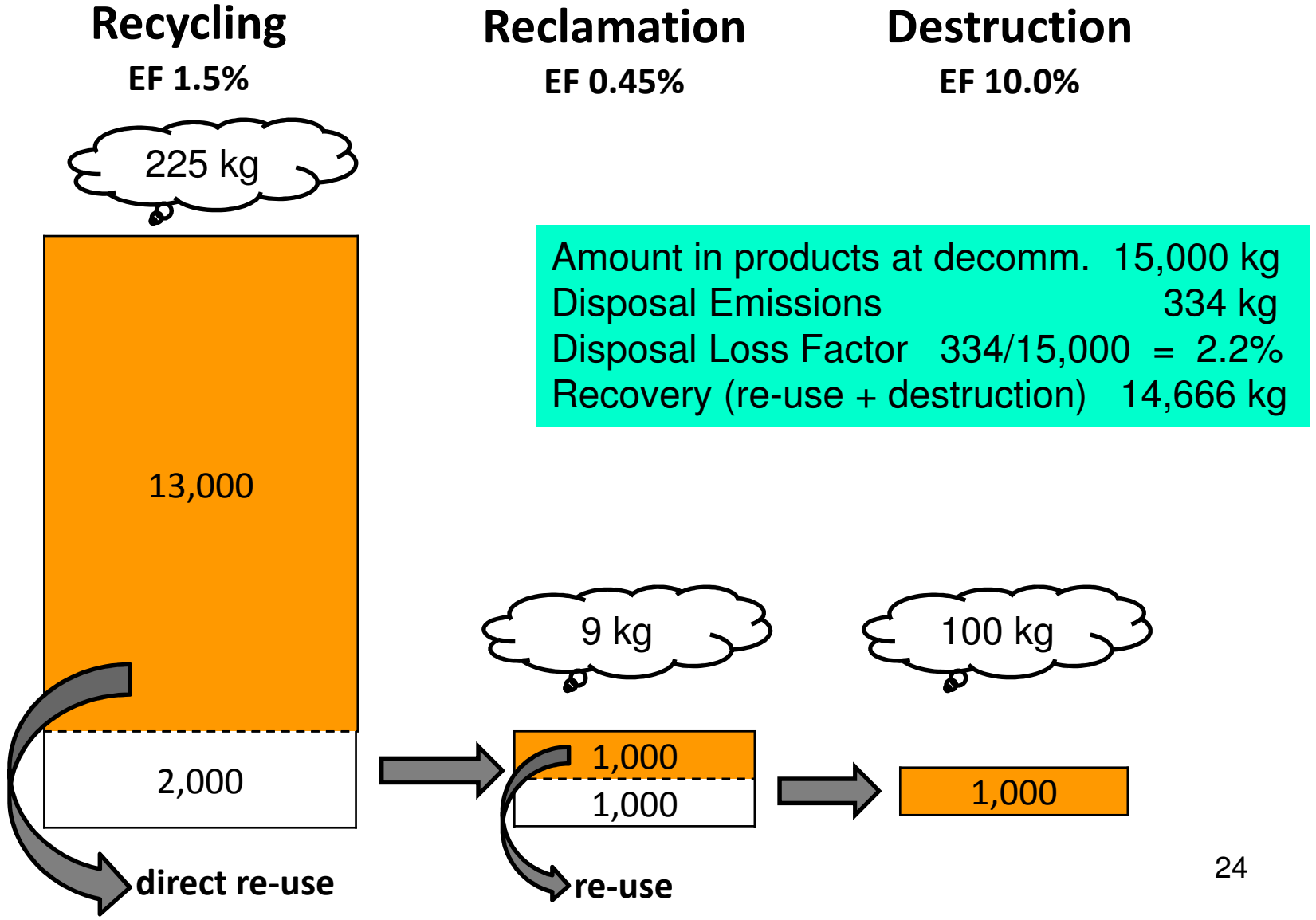
Successful example:
SF_6 Recovery from Switchgear 2.F.8 (DEU 2010)



Amount in products at decomm.	15,000 kg
Disposal Emissions	334 kg
Disposal Loss Factor	334/15,000 = 2.2%
Recovery (re-use + destruction)	14,666 kg