Für Mensch & Umwelt

Umwelt Bundesamt

NDE Germany SF_6 Event 2023

Sulfur hexafluoride in electrical equipment

Dr. Cornelia Elsner
Section III 1.4 – Substances-related Product Issues

Overview

1. **THE SUBSTANCE SULFUR HEXAFLUORIDE**
   - 1.1 properties and GWP use
   - 1.2 environmental effects

2. **REGULATIONS**

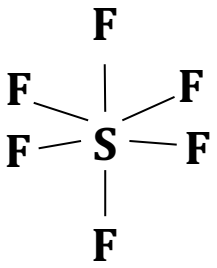
3. **REPORTING**
   - 2.1 international obligations
   - 2.2 national implementation

4. **USE AND EMISSIONS**
   - 3.1 Overview of all applications
   - 3.2 electrical equipment

5. **THE REVISION OF THE EU REGULATION 517/2014**

Properties of SF_6

- very stable
- colourless and odourless
- fluorine in the molecule
- heavier than air
- well detectable in air samples



- Greenhouse potential (CO_{2eq}) (time line 100 Jahre):

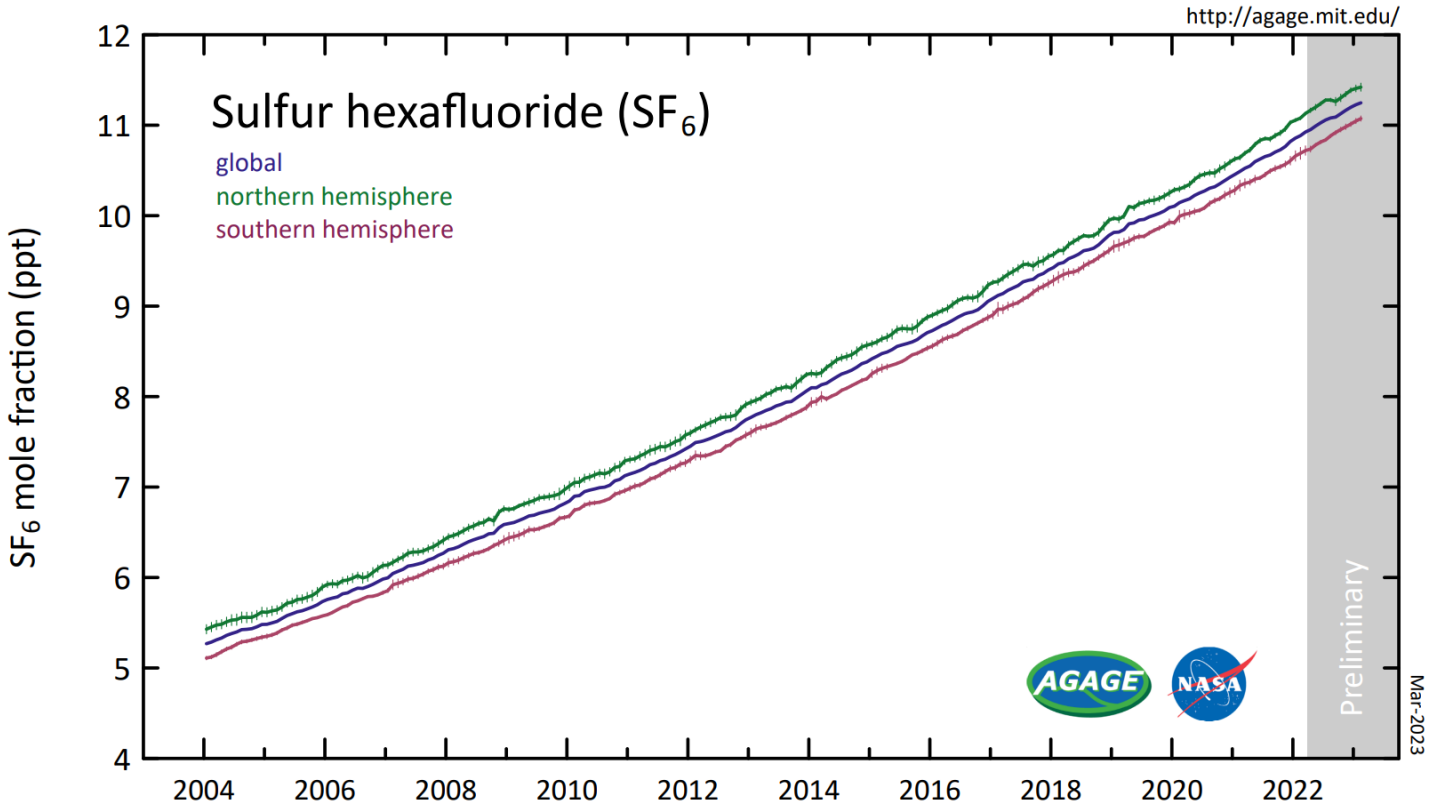
  IPCC - AR 4 = 22 800 (previously used for UNFCCC reporting and the F-Gas-Regulation (EU) 517/2014)

  IPCC - AR 5 = 23 500 (from 2022 onward (reporting year 2021) is used for reporting under the Paris agreement)

  IPCC - AR 6 = 24 300 (will be used for the new EU regulation)

AR= Assessment Report

Atmospheric concentration



Quelle: https://agage.mit.edu/data/agage-data

Tripling of atmospheric concentrations by 2050 with no change in emission control

Regulations

EU

Regulation (EU) 517/2014 on fluorinated greenhouse gases

Implementing regulation (EU) 2015/2066
minimum requirements and the conditions for mutual recognition **for the certification of natural persons** carrying out installation, servicing, maintenance, repair or decommissioning of electrical switchgear containing fluorinated greenhouse gases or recovery of fluorinated greenhouse gases from stationary electrical switchgear

Germany

Climate Protection Ordinance

Chemicals Sanction Ordinance

Competent authority of the federal states

Regulation (EU) 517/2014 about fluorinated greenhouse gases

- **Ban of SF_6 used in:**
  - 04.07.2006 shoes
  - 04.07.2007 tyres
  - 04.07.2007/ 04.07.2008 soundproof windows in different buildings
  - 04.07.2007/ 01.01.2018 Magnesium-die casting (850 kg/a)
- **Rules for SF6:**
  - Tightness of some equipment (Art. 4)
  - Recovery requirements (Art. 8)
  - Personnel certification requirements (Art. 10)

Climate Protection Ordinance

- Determines who is responsible for which tasks

  - §4: Obligations to take back

    Producers and distributors of fluorinated greenhouse gases are obliged to take them back after use or to ensure that they are taken back by a third party designated by them.

  - §5: Certification of persons

    The ordinance specifies who may issue certificates of competence. The competent authorities of the federal states may grant a certificate to training institutions, further training institutions or a company to conduct examinations and issue certificates of competence.

    It also ensures that certificates of competence from other European countries are recognised in Germany.

  - §8: Operator obligations

    The operator of electrical switchgear must ensure that activities on electrical switchgear are carried out by persons holding a certificate of competence.

Principles of emissions reporting

UNITED NATIONS FRAMEWORK CONVENTION ON CLIMATE CHANGE (UNFCCC)

Decision 24/CP.19: Revised UNFCCC Annex I Inventory Reporting Guidelines

Annex I Parties shall use the methodologies in the 2006 IPCC Guidelines

Annex I Parties could use EFs or parameters provided in the IPCC Emission Factor Database (https://www.ipcc-nggip.iges.or.jp/EFDB/main.php)

2006 IPCC GUIDELINES FOR NATIONAL GREENHOUSE GAS INVENTORIES

Decision IPCC/XLIV-5: ”2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories“

IPCC 4TH ASSESSMENT REPORT: CLIMATE CHANGE 2007

GWP values for F-gases until reporting year 2020

PARIS AGREEMENT

Art. 13: Framework for transparency

Each party “shall“ regularly provide a national inventory report using good practice methodologies accepted by the IPCC

since last year GWP values of the 5th assessment report

PARIS2015
COP21·CMP11

Source categories

2.B 9	Production of halocarbons and SF_6
2.C3a,b/C4	SF_6 and HFC used in aluminium and magnesium foundries
2.E 1	Electronics industry
2.E 2	Flat panel display production
2.E 3	Photovoltaic production
2.E 4	Heat transfer fluids
2.F	Product uses as substitutes for ODS
2.G 1	Electrical equipment
2.G 2	SF_6 and PFC from other product use
2.G 4	Further product manufacture and use (ORC)
2.H 3	Other (confidential data and gases to be reported voluntarily)

2023 Annex I Party GHG Inventory Submissions:

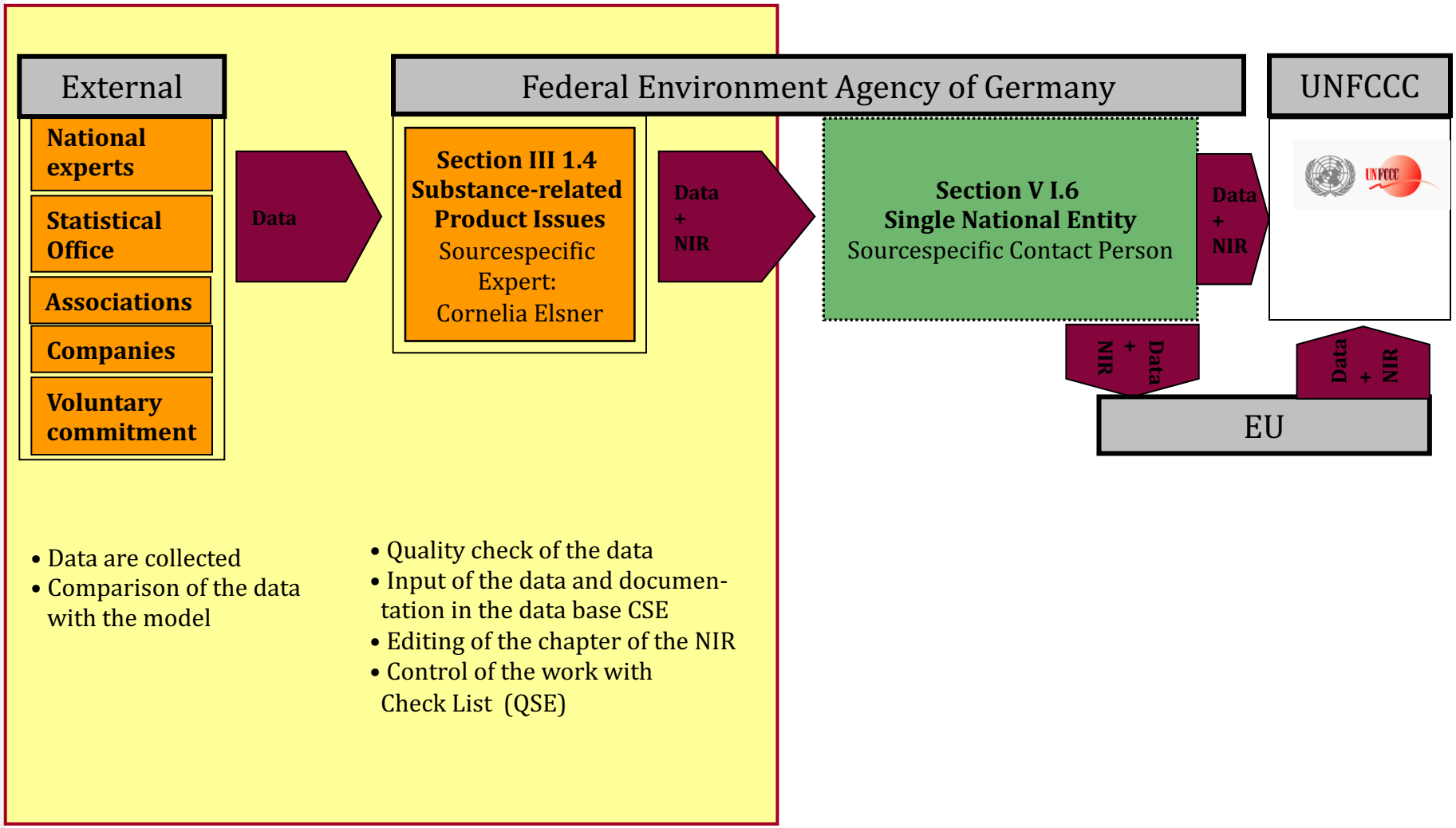
https://unfccc.int/process-and-meetings/transparency-and-reporting/reporting-and-review-under-the-convention/greenhouse-gas-inventories-annex-i-parties/national-inventory-submissions-2023

Application areas of SF_6

- Production of aluminium and magnesium
- Semiconductor industry
- Production of photovoltaik cells
- Production and use of electrical equipment (switchgear)
- Use in particle accelerators (in research and medicine)
- Tracer gas (for testing industrial halls, laboratory fume cupboards, earth flows)
- Production of optical glass fibres
- Military use (AWACS aircraft)

- Sport shoes (prohibited since 2006)
- Tyres (prohibited since 2007)
- Soundproof windows (prohibited since 2007/2008)

Overview of data collection and treatment



National implementation – Federal Statistical Office

Environmental Statistics Act - Questionnaire "SF_6"

- Questionnaire to the producer, importers and exporters

production	import	export	Amount in the country

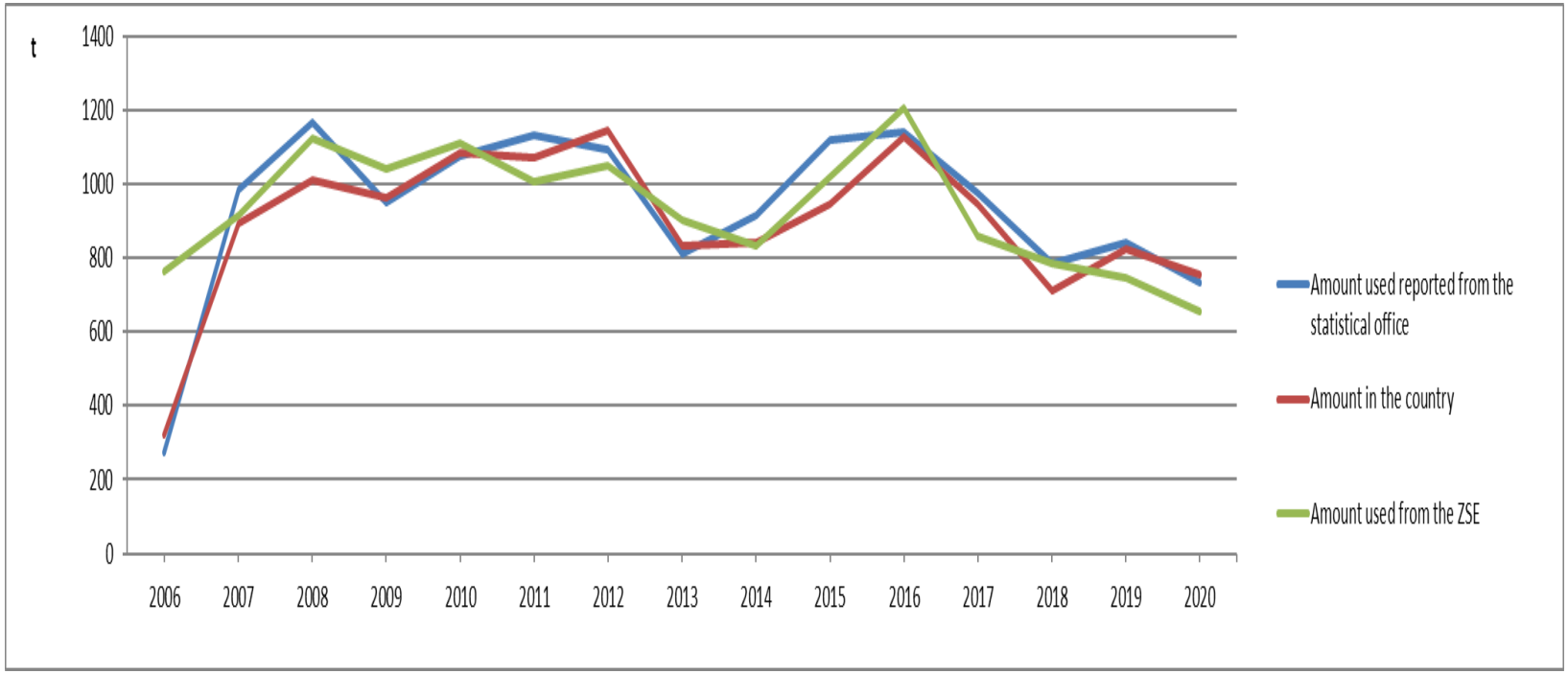
- Questionnaire to the gas dealer about the amount sold

Mg foun-dries	Alu foun-dries	Equipment manu-facturing	Re-search use	Aircraft (AWACS)	Optical fibers	Semi-conductor industry	Other	Amount used

- Quantities used
  - received from voluntary commitments
  - direct from companies and from the external experts

Mg foun-dries	Alu foun-dries	Reports from companies	Re-search use	Aircraft (AWACS)	Optical fibers	Voluntary committ-ments	Other (experts)	Amount used in the CSE

Control system for use of SF_6



Emission factors

Table 201: Overview of the methods and emission factors used, for the current report year, in the categories 2.G.1 (Electrical equipments), 2.G.2 (SF_6 and PFC from other product use)

	QG	Method	Gas			Lifetime	Emission factor (dimensionless)		
			SF_6	HFC	PFC	[years]	Production	Application	Waste management
Electrical equipments	**2.G.1**								
Switchgear and controlgear	2.G.1a	Tier 3	SF_6			40	0.02 (CS)	0.001 – 0.01 (CS)	0.015 (CS)
SF_6 and PFC from other product use	**2.G.2**								
AWACS	2.G.2a	CS	SF_6				NO	1 (CS)	NO
Particle accelerators	2.G.2b	CS					0.15 - 1 (CS)	0.006 – 0.003 (CS)	NO
Insulated glass windows	2.G.2c	Equ. 3.24 ff					0.33 (D)	0.01 (D)	1 (D)
Adiabatic behaviour	2.G.2d								
- Automobile tyres		Equ. 3.23	SF_6				NO	NO	1 (D)
- Athletic shoes		Equ. 3.23	SF_6		PFC		NO	NO	1 (D)
Other	2.G.2e								
- Trace gases		Equ. 3.22	SF_6				NO	1 (D)	NO
- Welding		CS	SF_6				NO	1 (CS)	NO
- Optical glass fibre		CS	SF_6				C	NO	NO

Source: National Inventory Report (NIR)

German country specific emission factors for electrical equipment

Production

- MV: 0.15%
- HV: 0.43%
- Other: 3.02% (started with 40%)

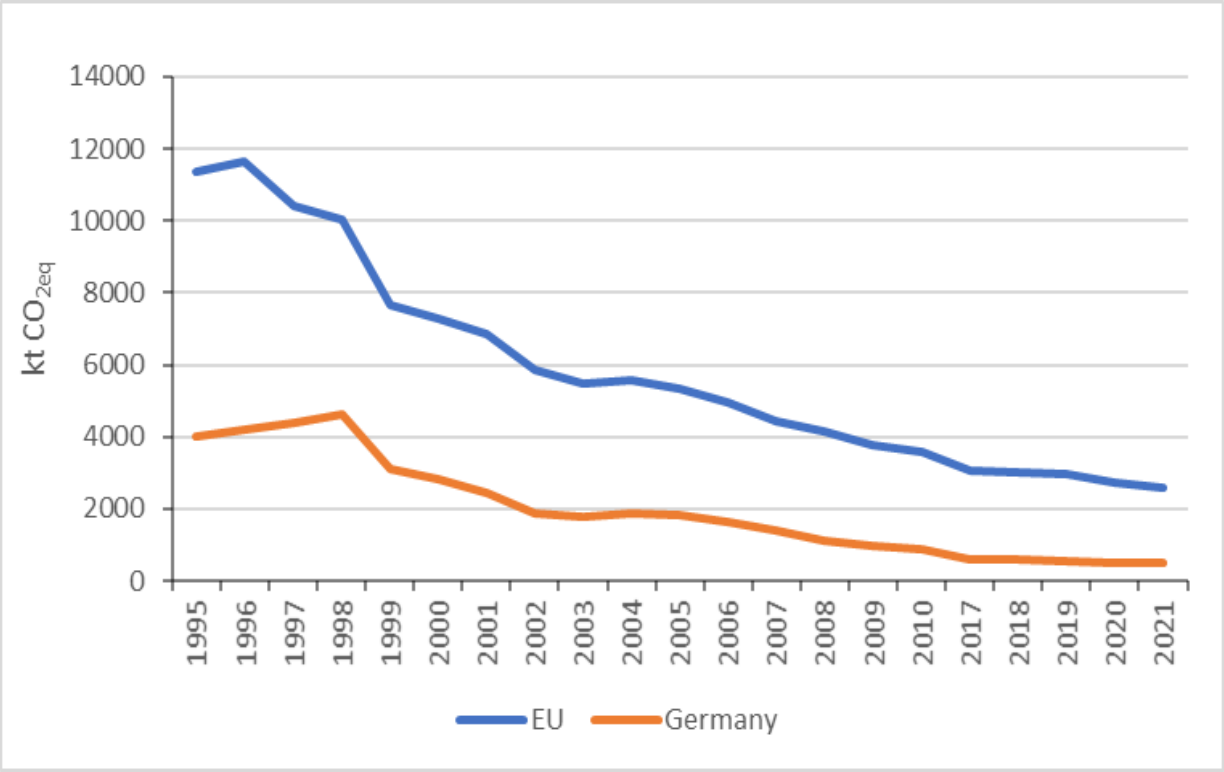
Use

- MV GIS: 0.10%
- HV GIS (class A: 0.15 %, class B: 3.5 %): 0.26%
- Others: 0.28%
  (circuit breacker (outdoor, 110-380 kV): 0.60%
  transformer (outdoor, 110-380 kV): 0.30%)

End of life

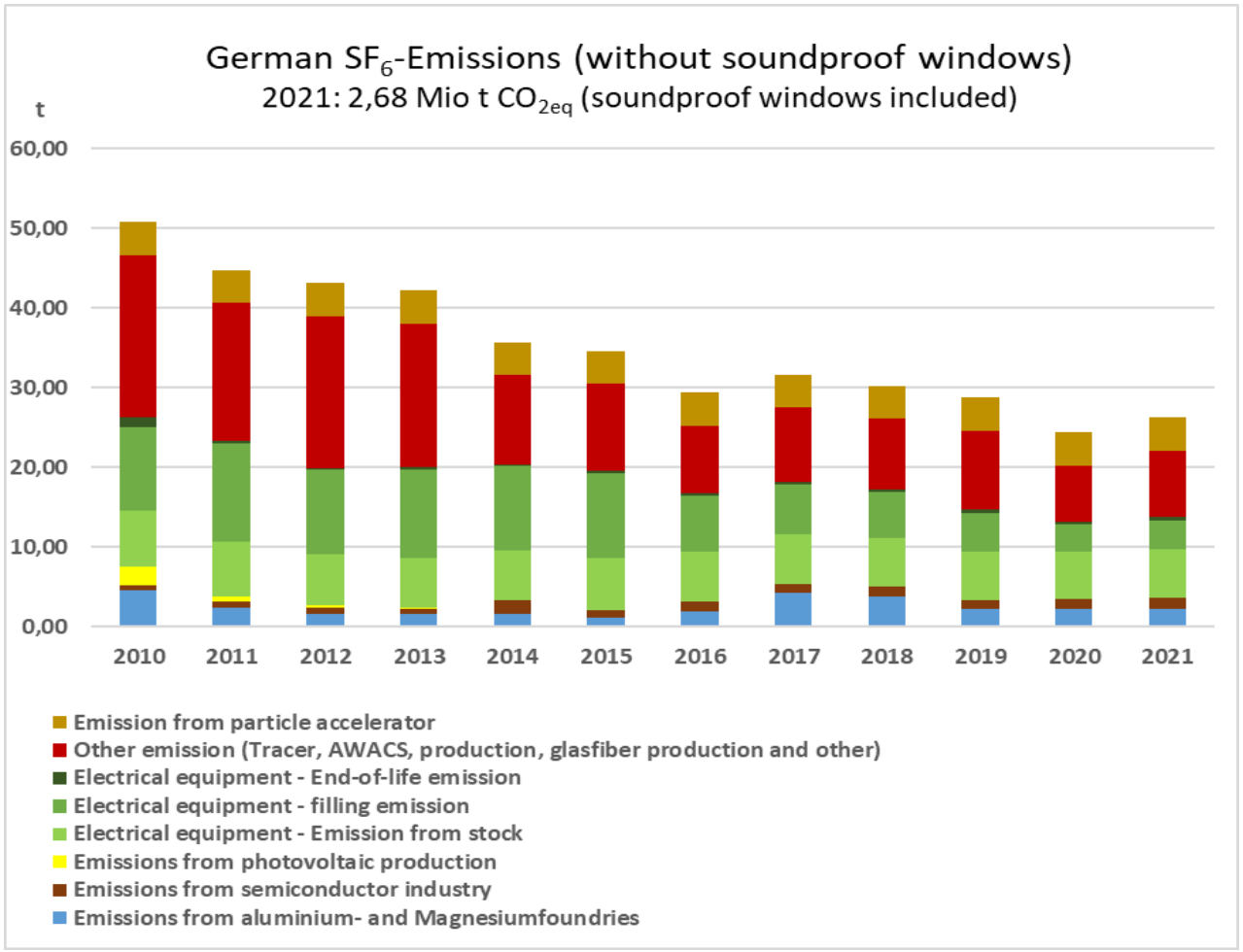
- Decommissioning: 1.50%
- Re-use or destruction: 0.04%

SF_6 -Emissions in the EU and in Germany (without soundproof windows)



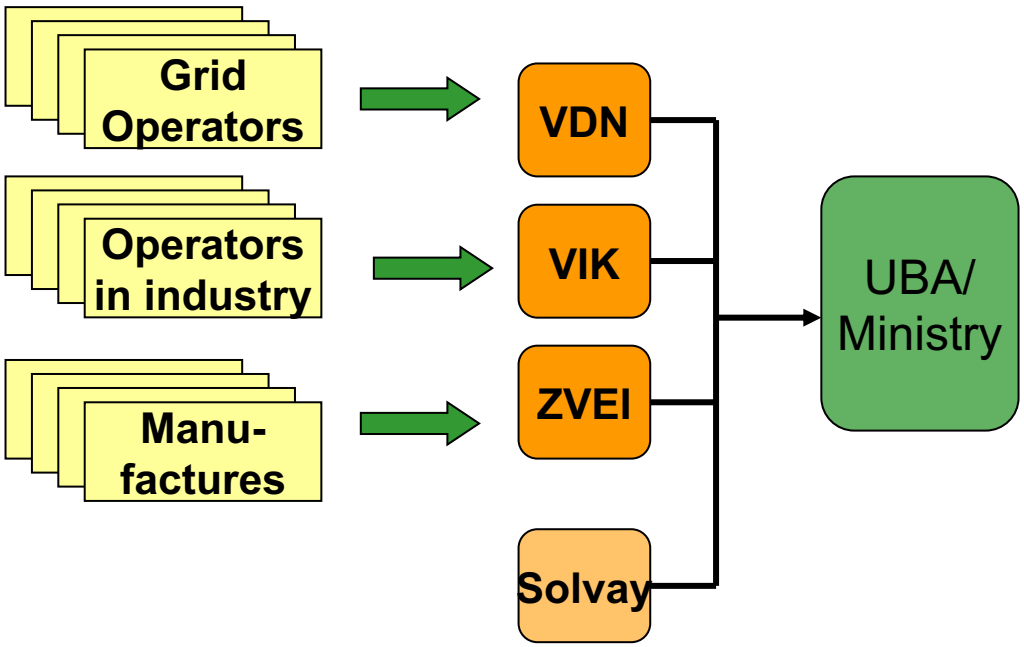
- Reduction of SF_6-emissions in the EU 40% (since 1990)
- 19% of the SF_6-Emissions in the EU from Germany (2021)
- More than 50% of the SF_6-Emissions in the EU from production of electrical equipment in Germany

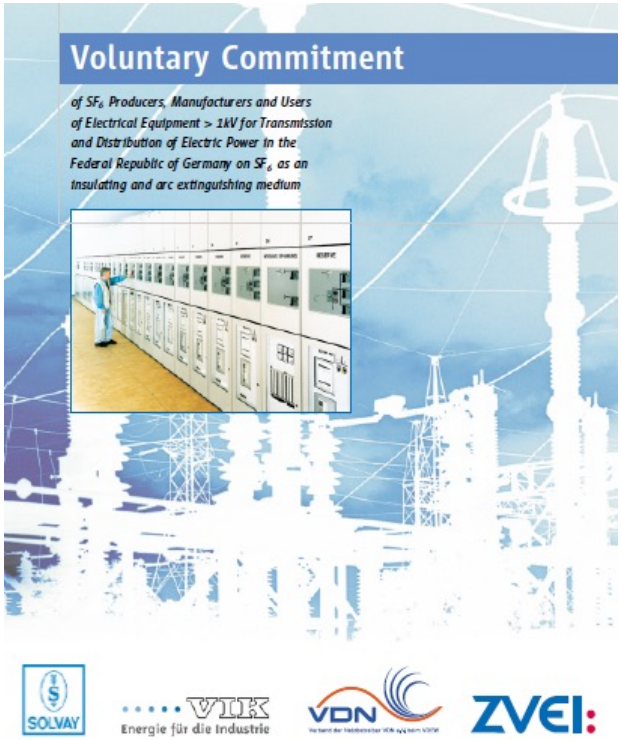
SF_6 – Emissions in Germany



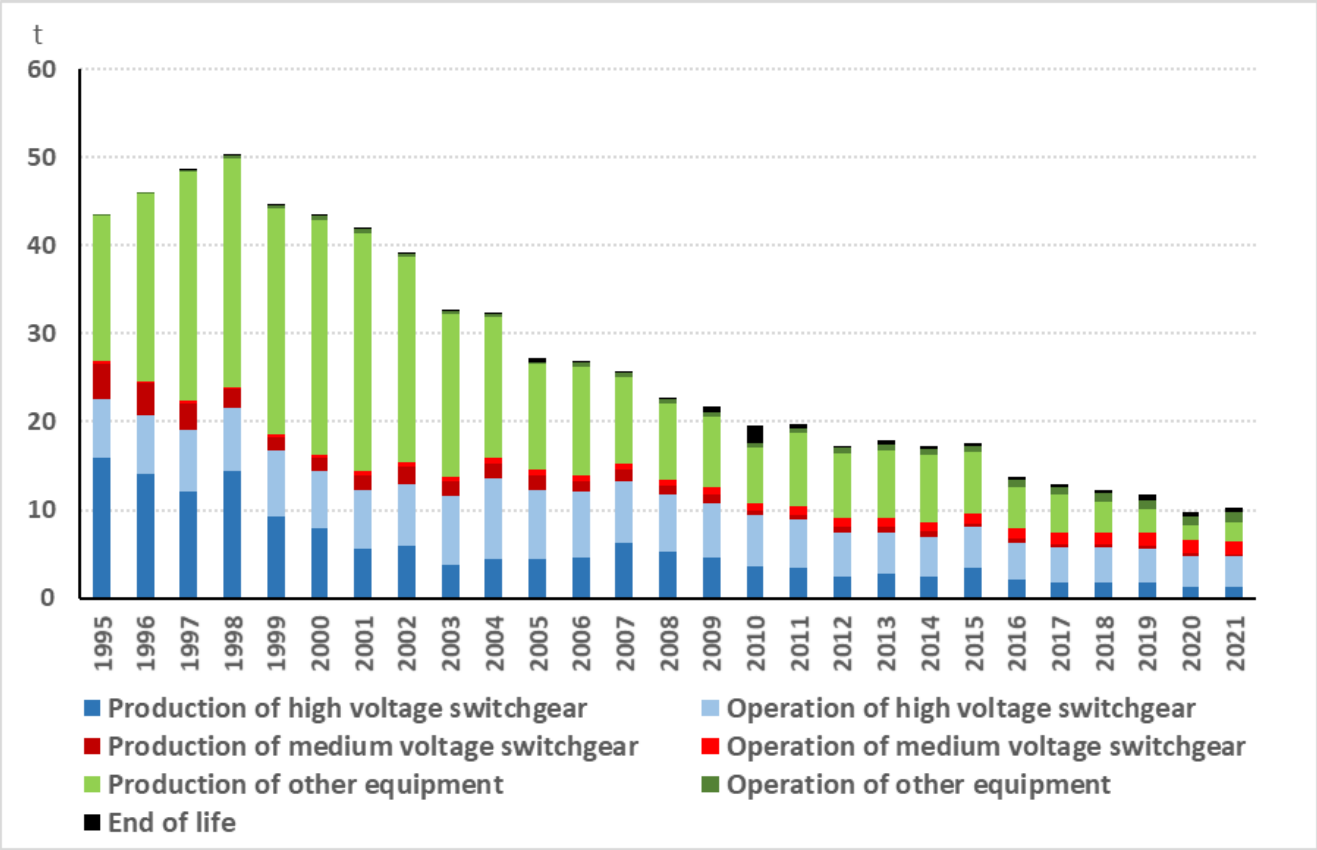
- About 50% from electrical equipment
- Compared to other F-gases, SF_6- applications have low emissions
- Use of SF_6 often in plants with waste gas purification

Production, use and end of life of SF_6 in electrical equipment
Voluntary commitment





Emissions from electrical equipment in Germany



- **Other:**
  more awareness of SF_6
- **High voltage equipment:**
  - old
  - not hermetic tight
- **Priority replacement**

The German power grid

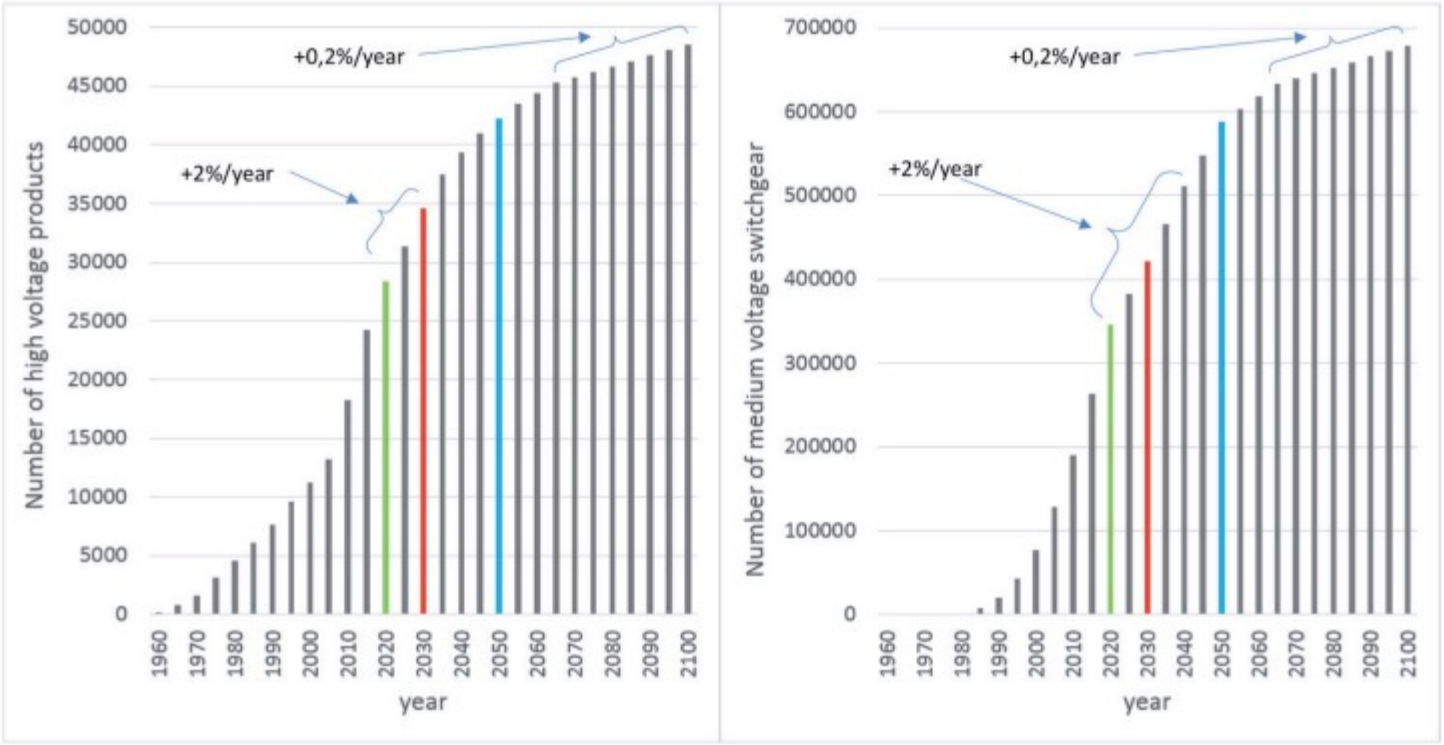
- Transmission system operator (50Hertz, Amprion, TenneT, TransnetBW)
- Distribution system operator (more than 880)

- More switchgear is needed
  - for renewable, decentralized energy generation,
  - to handle the electrification of transport
  - for the expansion of digitalization

It is expect, that the expansion requirements for the distribution networks will need an amount of 27.61 billion euros in the next 10 years. (Source: BNetzA, 2021)

Quelle: Elsner

Prediction of the expected equipment population until 2100 for medium and high voltage in Germany



Source: ZVEI (https://www.zvei.org/fileadmin/user_upload/Presse_und_Medien/Publikationen/2020/April/SF_6_Reduktion/Szenario-zur-Reduktion-von-SF6-Betriebsemissionen-final-eng.pdf)

Examples for medium voltage switchgear available on the market

Primary and secondary distribution (including RMU) until 24 kV (RMU= Ring Main Unit)

Company	Product	isolation/ switch	GWP_{100}
ABB	ZX2 Airplus, Unigear ZS1, PrimeGear ZX0, SafeRing Air, SafePlus Air	air/ solid material/ vacuum; Fluoroketone (no more in future)	0
Driescher	ECOS-C	esther/ vacuum	0
Eaton	Xpert FMX, Xpert UX, Xiria E	air/ solid material/ vacuum	0
Efacec	Normacec, NeoGEN	air/ solid material/ vacuum	0
LS Electric	C-AIS	air/ vacuum	0
Mitsubishi Electric	HS-X	air/ vacuum	0
Orecco Electric	AIS	air/ vakuum	0
Ormazabal	sbp.zero24, cgm.zero24	air/ vakuum	0
Schneider Electric	GM AirSeT, SM AirSeT, RM AirSeT	air/ solid material/ vacuum	0
Siemens	8DAB 12, 24, NXAIR, NXPLUS, 8DJH 12, 8DJH 24	air/vacuum	0
SGC	DF-2	air/vacuum	0
Toshiba	KA-20M25, VEZ, VDZ	Air/ solid material/ vacuum	0

Some have almost the same base area or volume as SF_6 equipment some are larger.

Roadmaps for SF_6-free high voltage switchgear (>52 kV)

company	already available	2023	2024/ 2025	2026	2028	2029/ 2030
Siemens Energy	145 kV[1,2,3] 145-420 kV[4], 420 kV[1]		245 kV[2,3]	362 kV[3], 420 kV[2]	245 kV[1]	
Mitsubishi Electric	72 kV[3]	145kV[3], 72,5 kV[1]	245 kV[3], 170 kV[3], 145kV[1]	245 kV[1], 170 kV[1]	362 kV[3], 362 kV[1]	550 kV[3,1], 420 kV[1]
Hitachi Energy	72,5 kV[1,2], 145 kV[1,2], 420 kV[1]	72,5 kV[3], 145 kV[3], 420 kV[3]	245 kV[1,2,3], 362 kV[3], 420 kV[2], 550 kV[1]			
GE	145 kV[1,2], 420 kV[1]	72,5 kV[1], 420 kV[3], 145 kV[3]	245 kV[1], 72,5[3], 245 kV[2,3], 170 kV[1], 420 kV[2]	362 kV[3], 550 kV[2,3]		

[1] Gas insulated switchgear (GIS)
[2] Live tank circuit breaker
[3] Dead tank circuit breaker
[4] Instrument transformer

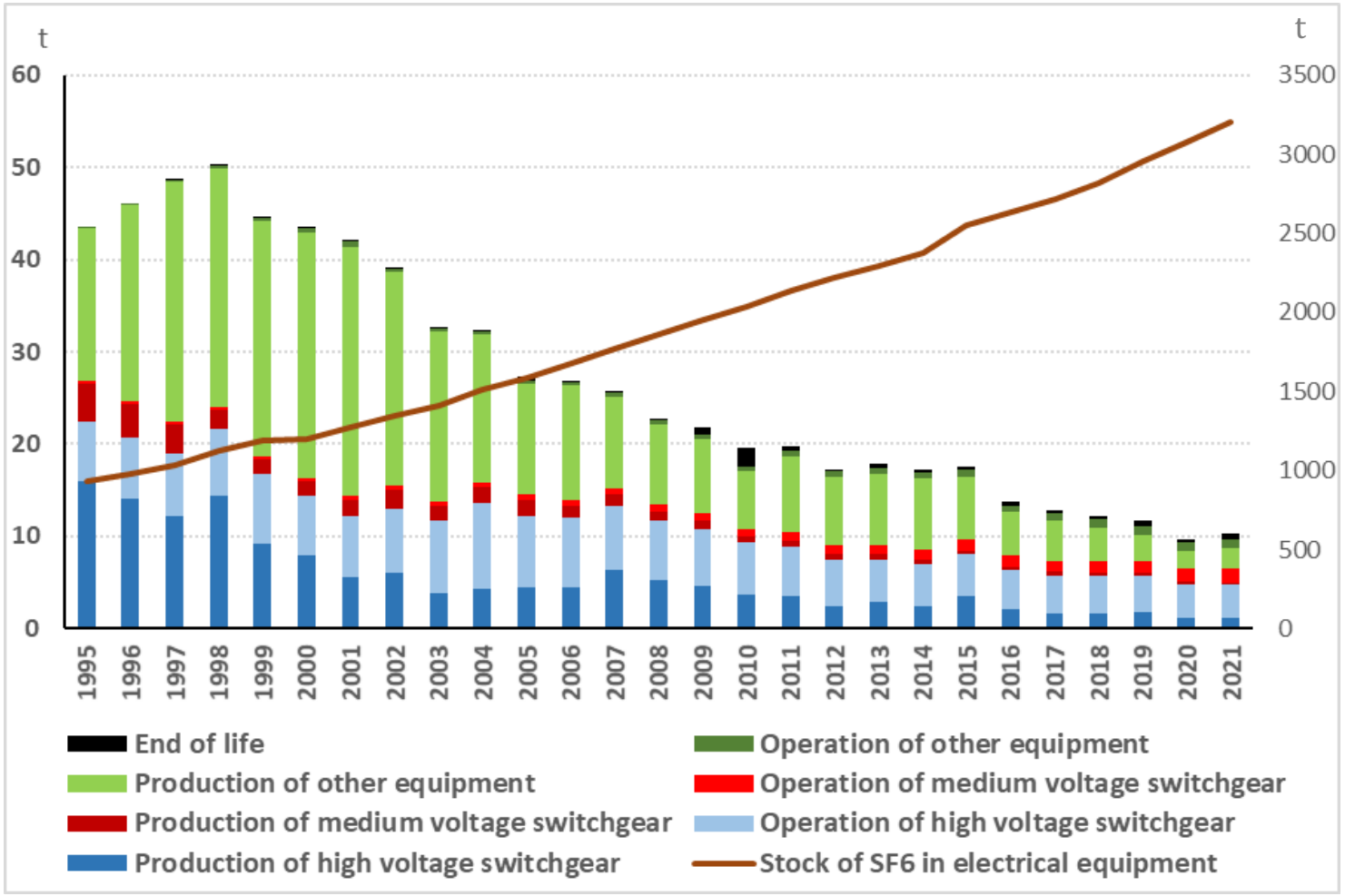
Fluorinated alternatives and PFAS discussion

- Definition of PFAS: "Perfluoroalkyl and polyfluoroalkyl substances" or "PFAS" means substances that include any member of the class of fluorinated organic chemicals containing at least one fully fluorinated carbon atom (-CF_2-; -CF3; without any H/Cl/Br/I attached to it)
- ECHA proposal: https://echa.europa.eu/de/restrictions-under-consideration/-/substance-rev/72301/term
- PFAS in products in state of Maine 2021: environment-pfas-main-law.pdf (thomsonreuters.com)

	Perfluorinated ketone	Perfluorinated nitrile
Trade name (3M)	Novec 5110	Novec 4710
chemical formula	$C_5F_{10}O$	C_4F_7N
CAS-Nr.	756-12-7	42532-60-5
GWP	0,29	2750
comment	Mixture with max. 14% ketone	Mixture with max. 6 mol% nitrile (GWP= 688)

- Producer 3M will stop production at the end of 2025

Potential emissions from electrical equipment in Germany



End of life

SF6 end-of-life treatment of T&D equipment (>1kV) in Substations

Develop practical guidelines for SF_6 end-of-life treatment

Source: CIGRE > Articles > SF6 end-of-life treatment of T&D equipment (>1kV) in Substations

- Certified personnel
- Toxicity assessment
- Special equipment for extracting and handling of SF_6

Quelle: DILO

Revision of the EU-regulation
Proposal of prohibitions for new electrical equipment

Voltage	Proposal for regulation	Ban from (Council)	Ban from (EP)
≤ 24 kV	GWP≤ 10; If not possible: GWP≤ 2000; If not possible: SF_6	**01.01.2026**	**01.01.2026**
>24 ≤ 52 kV		**01.01.2030**	**01.01.2028**
52 kV ≤ 145 kV ≤ 50 kA		**01.01.2028**	**01.01.2028**
> 145 kV > 50 kA		**01.01.2032**	**01.01.2031**

- Evidence: open call for tenders
- If no suitable alternative is available (taking into account the need and the specifics of the equipment required for the intended use)
- 2-year transition period, if only one supplier has made an offer

Revision of the EU-regulation
Proposal of prohibitions for virgin SF_6 for existing electrical equipment

- **From 01.01.2035, only recovered or recycled SF_6 shall be used for maintenance and repair**

  Exemptions:
  - it cannot be used for technical reasons or
  - there is not enough available in the event of an emergency repair and
  - military installations

Thank you for your attention

Dr. Cornelia Elsner

Section III 1.4 – Substances-related Product Issues

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- https://www.umweltbundesamt.de/en/topics/climate-energy/fluorinated-greenhouse-gases-fully-halogenated-cfcs/application-domains-emission-reduction/switchgear
- Schaltanlagen | Umweltbundesamt
- Emissionen | Umweltbundesamt