



# SF6 – Impact on climate, energy systems and regulations

**Berlin**  
21. June 2023

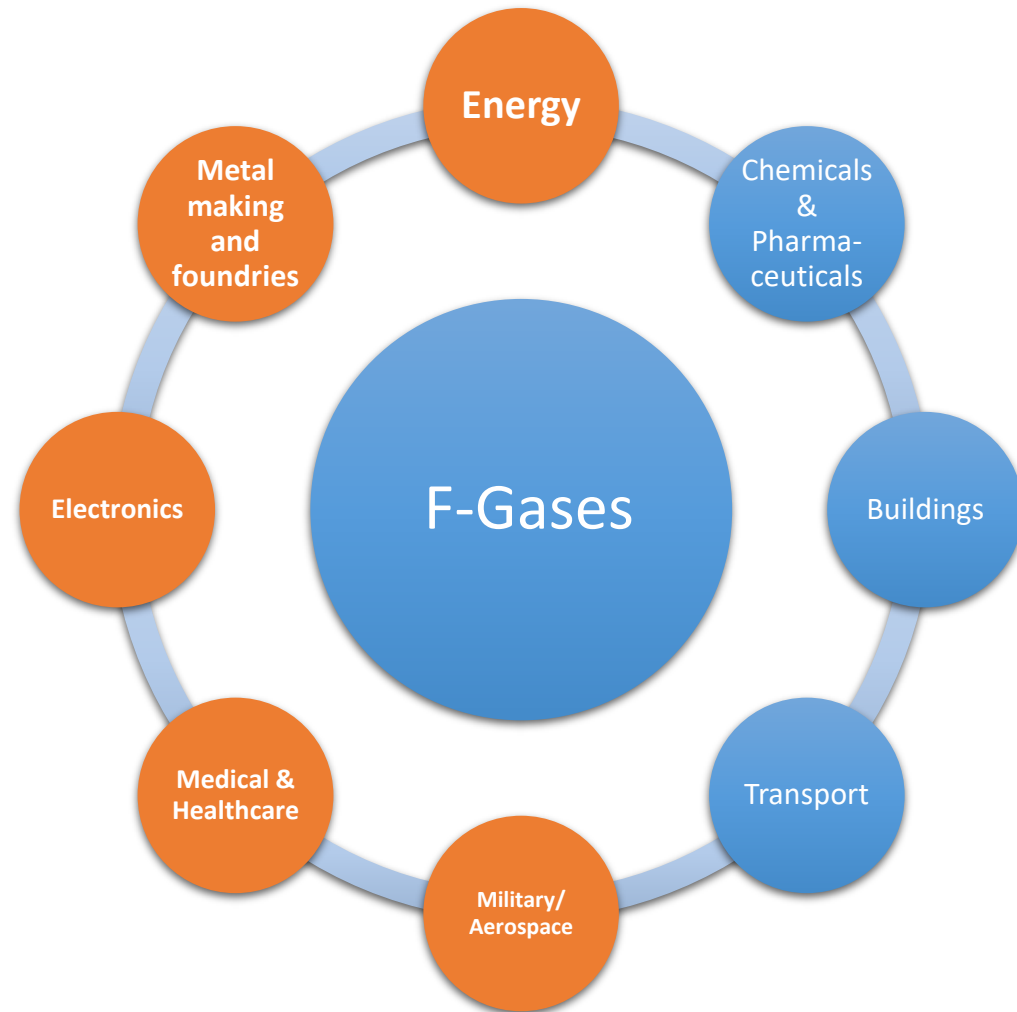


# SF6 and F-Gases in Technology and our Society



# SF6 as part of F-Gases & use cases

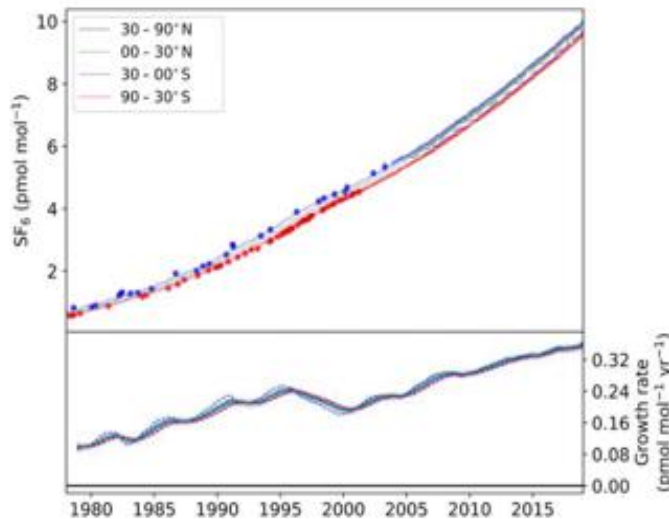
- **Hydrofluorocarbons (HFCs):**  
Refrigeration and air cooling;  
foams, solvents and others
- **Perfluorocarbons (PFCs):**  
LCD, semiconductors, solar panels,  
Aluminium
- **Sulfur hexafluoride (SF6)**
- **Nitrogen trifluoride (NF3):** Etching  
agent silicon wafers



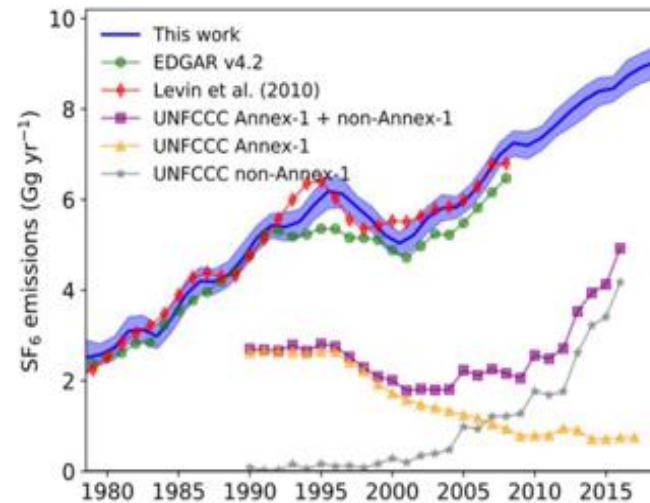
 = areas with use of SF6

# SF6 - Global Emissions

Wachstum der SF6 Konzentration und Emissionen (Quelle: (Simmonds and Rigby, 2020))



SF6 Konzentration in der Atmosphäre



SF6 Emissionen global, Annex 1 und non-Annex1

- Continuous increase in atmospheric concentrations
- Derived emission significantly higher than reported emissions +25% 2008/18
- Total 2018 emissions of 212 Mt CO<sub>2</sub>eq.
- Decrease in Annex I emissions & very strong increase in non-Annex I

# SF6 (were) widely used

Electric infrastructure such as switchgears, which is a significant problem for decarbonisation/electrification strategies. **But, there are alternatives as well will see during this workshop.**

## More common present/past uses of SF6:

- Eye Surgery
- Tennis Balls (*right: 1978 Patent from Ohio, USA*)
- The Shoe Industry
- Etching gas for silicon wafers, semi conductors, solar panels
- Soundproofing windows
- Truck Tires

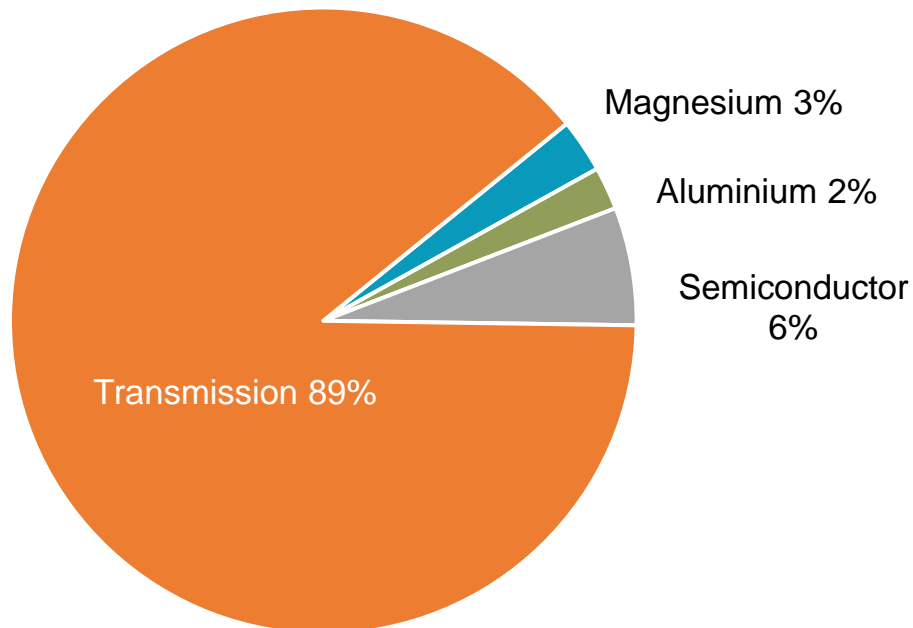
<b>United States Patent</b> [19]		[11]	<b>4,098,504</b>
Koziol et al.		[45]	<b>Jul. 4, 1978</b>
[54]	TENNIS BALL		
[75]	Inventors: Dale Lee Koziol, Marion, Ind.; Thomas Freeman Reed, Akron, Ohio	2,402,418 7/1974 Fed. Rep. of Germany .... 273/61 D 8,777 9/1974 South Africa ..... 273/61 R	
[73]	Assignee: The General Tire & Rubber Company, Akron, Ohio	FOREIGN PATENT DOCUMENTS	
[21]	Appl. No.: 627,721	OTHER PUBLICATIONS	
[22]	Filed: Oct. 31, 1975	"Flow of Gases through Polyethylene" Journal of Polymer Science, vol. L, 1961, pp. 413-439.	
[51]	Int. Cl. <sup>2</sup> ..... A63B 41/00	Primary Examiner—George J. Marlo	
[52]	U.S. Cl. .... 273/61 R; 273/65 ED; 273/DIG. 20	[57] ABSTRACT	
[58]	Field of Search ..... 273/61, DIG. 20, 58 B, 273/58 BA, 65 ED, 65 B, 65 EE, 65 E; 152/330	A pressurized game ball including an air-permeable elastomeric wall defining a cavity containing a compressible inflation gas with the improvement being that the inflation gas includes predetermined mixed amounts of air and sulfur hexafluoride (SF <sub>6</sub> ) gas which effectively enables the ball to retain its pressurized state within a desired range of pressures for a period of time significantly longer than the ball would remain pressurized if the inflation gas were air alone.	
[56]	References Cited	1 Claim, No Drawings	
	U.S. PATENT DOCUMENTS		
	2,012,283 8/1935 Miller ..... 273/61 D		
	3,047,040 7/1962 Gross ..... 152/330		
	3,819,040 6/1974 Coons ..... 273/61 D		

# SF6: Emissions and Environmental impact



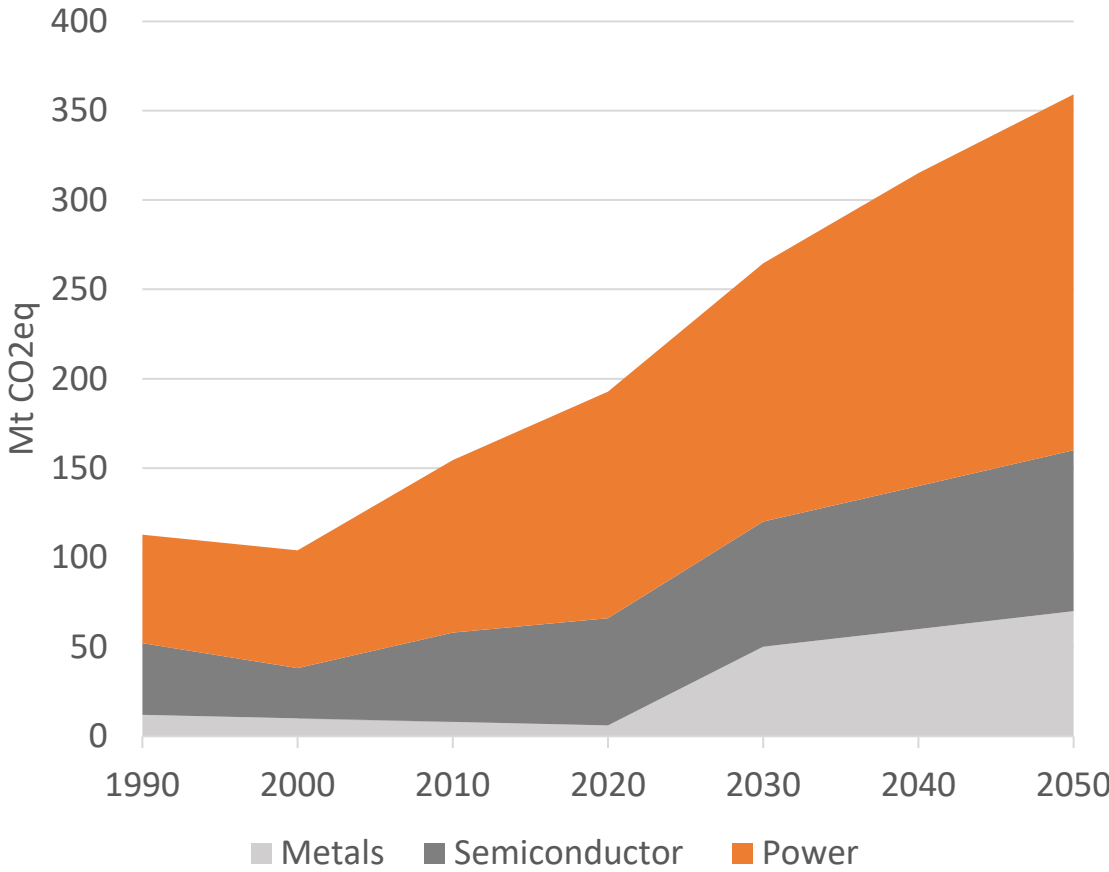
# SF6 – transmission as the main source of emissions

SF6 emissions by subsector  
(from Simmonds and Rigby, 2020).



- 89% of emissions in the area of **grid infrastructure/transmission** (switchgear and circuit breakers)
- **Smaller amounts used for magnesium, aluminium and semiconductors** (almost no longer used in Annex I, unclear picture in Non-Annex I, little/no reporting); alternatives available;

# SF6 - Emission projections by subsectors



Source: Wwn analysis based on Simmond 2020; Schaefer EPA and others

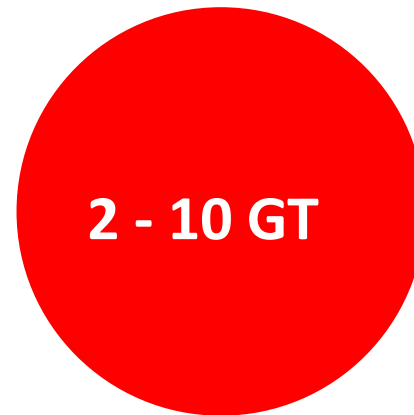
# SF6 - Global potential emissions (CO2eq)

---



## POTENTIAL EMISSIONS FROM SF 6 BANKS

(from historic installation since about 1960 and SF6 used in these installations)



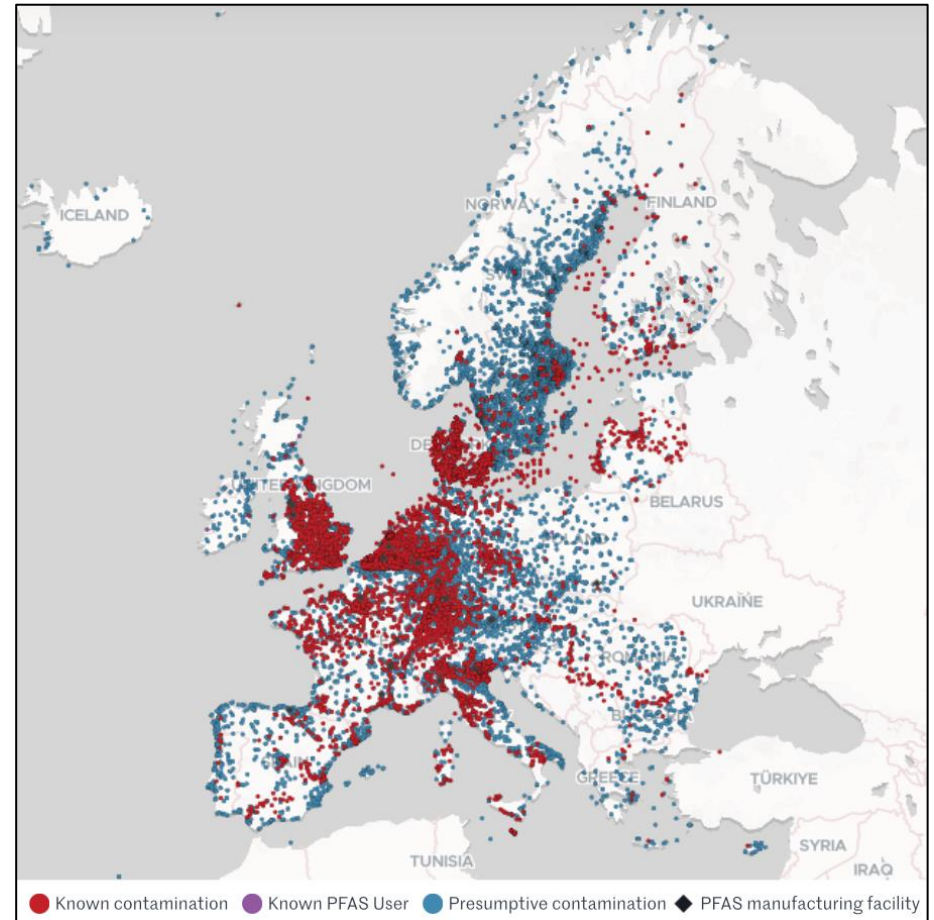
## POTENTIAL FUTURE EMISSIONS

(For each installed GW the current use of SF6 is 40-66 t or 1.1 to 1.5 MtCO2eq; cumulative emissions until 2050)

# F-Gases and Health Impacts

- F-Gases are/can produce “Forever Chemicals”
  - PFAS: Per- and polyfluoroalkyl substances; 4700 different chemicals**
  - trifluoroacetic acid (TFA)**
- PFAS accumulates in human tissue and in nature and is causing significant pollution problems (water, soil)
- Long-term exposure to TFA can potentially damage the liver and the thyroid function in humans.

**17,000 Contaminated Sites reported in EU**



# Increase in TFAs in our Environment



TFA levels in the Arctic ice are 10 times higher than before 1987.<sup>1</sup>



The concentration of TFA in urban landscape waters in Beijing, China, increased 17-fold between 2002 and 2012.<sup>3</sup>



Monthly measurements of TFA in rainwater in Germany increased by three-to-five times in the last 25 years.<sup>2</sup>



High levels of TFA were found in the blood plasma of Chinese adults, with a median concentration of 8.46µg/L.<sup>4</sup>



TFA deposition is projected to be 10,000 metric tons per year by 2040 over European land, rising from about 2,000 metric tons in 2020.<sup>2</sup>



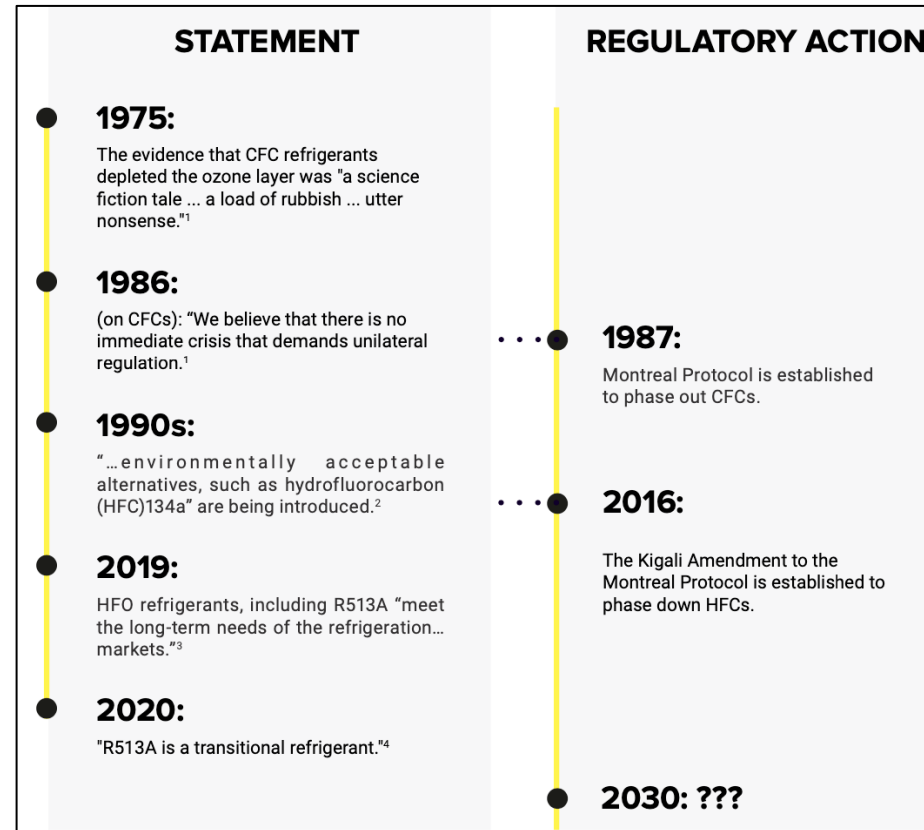
TFA has been found in beer samples from 23 countries.<sup>5</sup>

# SF6 - Regulation



# Most F-gases are globally regulated, SF6 not yet

- In 1974, S. Rowland and M. Molina discovered that CFCs could deplete Earth's atmospheric ozone layer
- Within 11 years, the Vienna Convention for the Protection of the Ozone Layer was established (1985), paving the way for the Montreal Protocol (1987) to regulate CFCs.
- Since then, replacement of CFCs (HCFCs, then HFCs) have been found to also be dangerous and are being either phased-out or phased-down.
- Kigali Amendment: phase out of low-GWP HFCs



# Global SF6 Regulations championed in the US and EUROPE

- **California: 2021 CARB Regulations:** Phase out of SF6 in Gas Insulated Equipment by 2033
- **EU: Strengthening of F-gas Regulation 2014** is in discussion (with exceptions based on availability of alternative technologies)
- **Bans** decided or discussed, bans will be effective from:

Voltage Range	California (from 2022)	Europe (in finalisation stage on trilogue)
Low Voltage	2025-2028	2026-2030
Medium Voltage	2025-2031	2028
High voltage	2027-2033	2031-2032

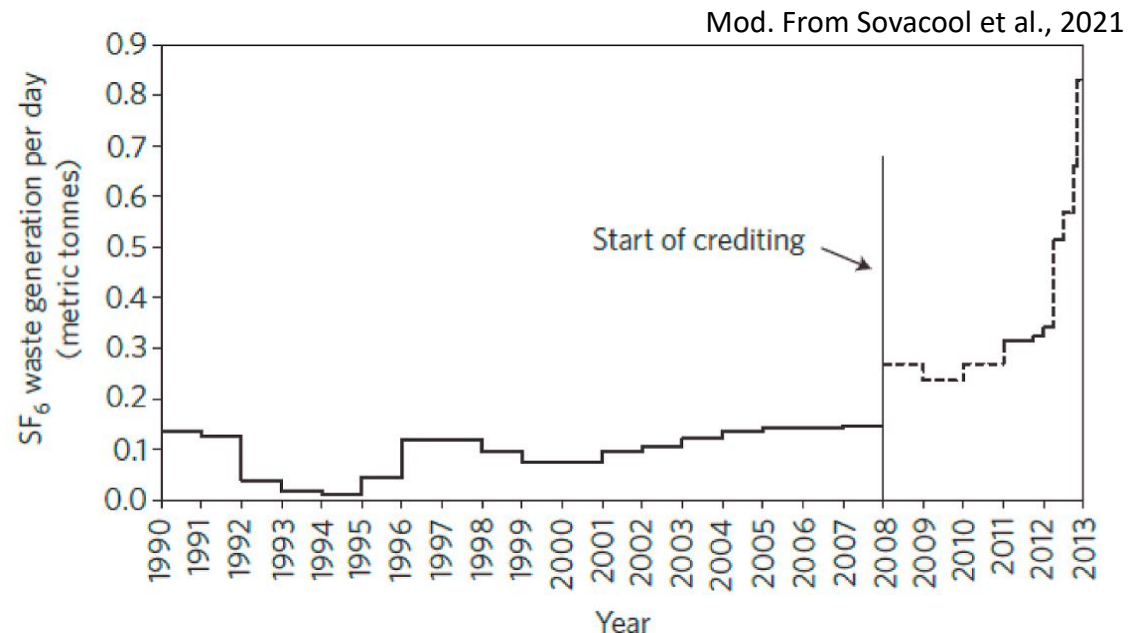
# SF6 regulations outside of EU, US

- **China:** little regulation on SF6 emissions. However, **China is considering new regulations** or standards to reduce SF6 usage and emissions.
  - **South Korea:** Significant increase in emissions due to semi-conductor industry in the early 2000s. A **GHG Emissions Trading Scheme** in 2015, which includes SF6 with free allocations for most sectors being decreased with time.
  - **Japan:** no laws that restrict the use of SF6 in the power sector, or that require emissions tracking and reporting. However, power equipment manufacturers and electric utilities formed a **voluntary action plan** in the late 1990's to reduce SF6 emissions and develop alternative insulation technologies.
-

# Limiting SF-6 under (voluntary) Carbon Crediting Systems

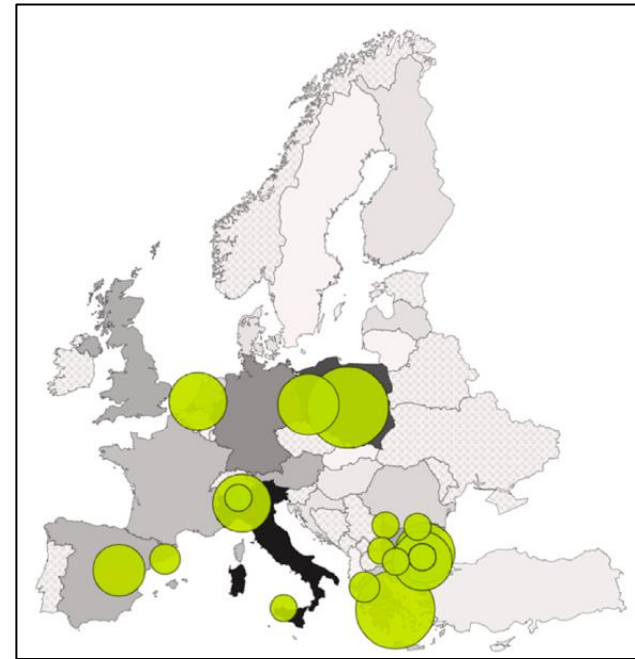
- **F-gases have given rise to carbon market manipulations in the past:** some firms produced SF6 only to destroy them and earn abatement credits
- Because F-gases are so potent, under certain pricing regimes **it became more valuable to earn carbon credits for abating them than to make them for particular products.**
- **Under Paris Agreement including Art. 6 risk of inverse incentives needs to be avoided**

The value of credits given to HFC-23 projects has been estimated at **€4.7 billion** but the **abatement cost** at only €100 million; (B. Southword, 2008)



# A Problem: Illegal trade

- A thriving “black market” for banned and illegal F-gas substances, especially in Europe.
- Across Europe, criminal networks (see below for trade routes seizures), sell up to 35 million tons of CO<sub>2</sub>e F-gases banned by European Union regulations
- **Equivalent to adding 25 million cars to European roads**



# Main consideration for controlling SF6 globally

---

- **Climate action:** Use of SF6 no longer in line with the Paris Agreement (GWP/ longevity/ lifetime of plants)
- **Marginal costs:** Low marginal costs (below 30 EUR /t CO2), economies of scale
- **Actor landscape:** Few actors - manufacturers, energy producers, grid operators, large end customers
- **Developed countries - SF6 Phase Out "in reach":** EU, UK, California, voluntary agreements.
- **Developing countries:** A about 5-10 GtCO2eq abatement potential

# "SF6 Net-zero Club" implementation options (brainstorming)



Club of countries joining a phase - out of SF6



Implementation roadmap  
as commitment

**Inventories**

**Standards for operation, new installations**

**Binding NDC targets**



Support package

**Technology support on alternative  
technologies, control of emissions**

**Training of technicians, certification**



Donor Strategy

**Results based financing**

# Conclusions

- **Rapidly rising SF6 concentration particularly in developing countries**
- **Emissions are not properly reported**
- **Risk of massively rising emissions from banks and new installations**
- **Emissions can be avoided at low costs through available, environmental friendly alternatives**
- **Available regulations existing or upcoming in the EU and parts of the US (California, MA)**
- **Need for front running developing countries to take action (through ambitious NDEs 😊 )**
- **Need for innovative support packages to back NetZero-SF6-free club**



## Geschäftsstelle der NDE Germany

c/o HEAT GmbH  
Seilerbahnweg 14  
61462 Königstein/Taunus  
E-Mail: [info@nde-germany.de](mailto:info@nde-germany.de)

Die Geschäftsstelle der NDE Germany arbeitet im Auftrag des Bundesministeriums für  
Wirtschaft und Klimaschutz (BMWK).

[www.nde-germany.de](http://www.nde-germany.de)

