An aerial photograph of a city, likely San Francisco, showing a dense urban landscape with various buildings, streets, and a large stadium. A semi-transparent architectural rendering of a modern building complex is overlaid on the image, showing a different design for the same area. The text "Progress is: undoing the changes implemented by our ancestors." is centered over the image.


Progress is: undoing the changes implemented by our ancestors.



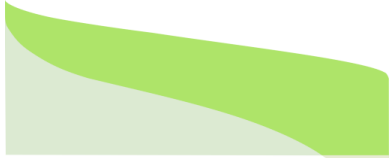
Opportunities and Challenges of Implementing SF₆-free technologies in Developing Countries

Technologies for decarbonization of Electrical Transmission and Distribution Grids through F-gas regulations and policies

CTCN & National Designated Entity (NDE) of Germany learning event
Berlin July, 7 2023 – Karsten Burges | RE-xpertise



giz Deutsche Gesellschaft
für Internationale
Zusammenarbeit (GIZ) GmbH



RE-xpertise

Agenda

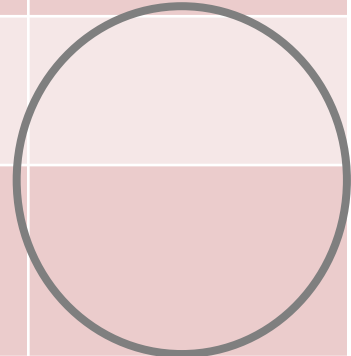
1. SF₆ in electrical switchgear - what are the relevance and challenges?
2. SF₆-free technologies – some (non-technical) facts.
3. What is specific for developing countries?
4. What opportunities are there?

RE-xpertise | Karsten Burges

- 30+ years of experience in policy support
- focusing on the power sector
- with a strong engineering background.

Independent since 2017.

	Integration of renewables in power systems	E-mobility and charging infrastructure	SF6 strategies
Technical consultancy			
Policy support			
Trainings and moderation of stakeholder processes			





SF₆ in electrical switchgear – relevance and challenge.

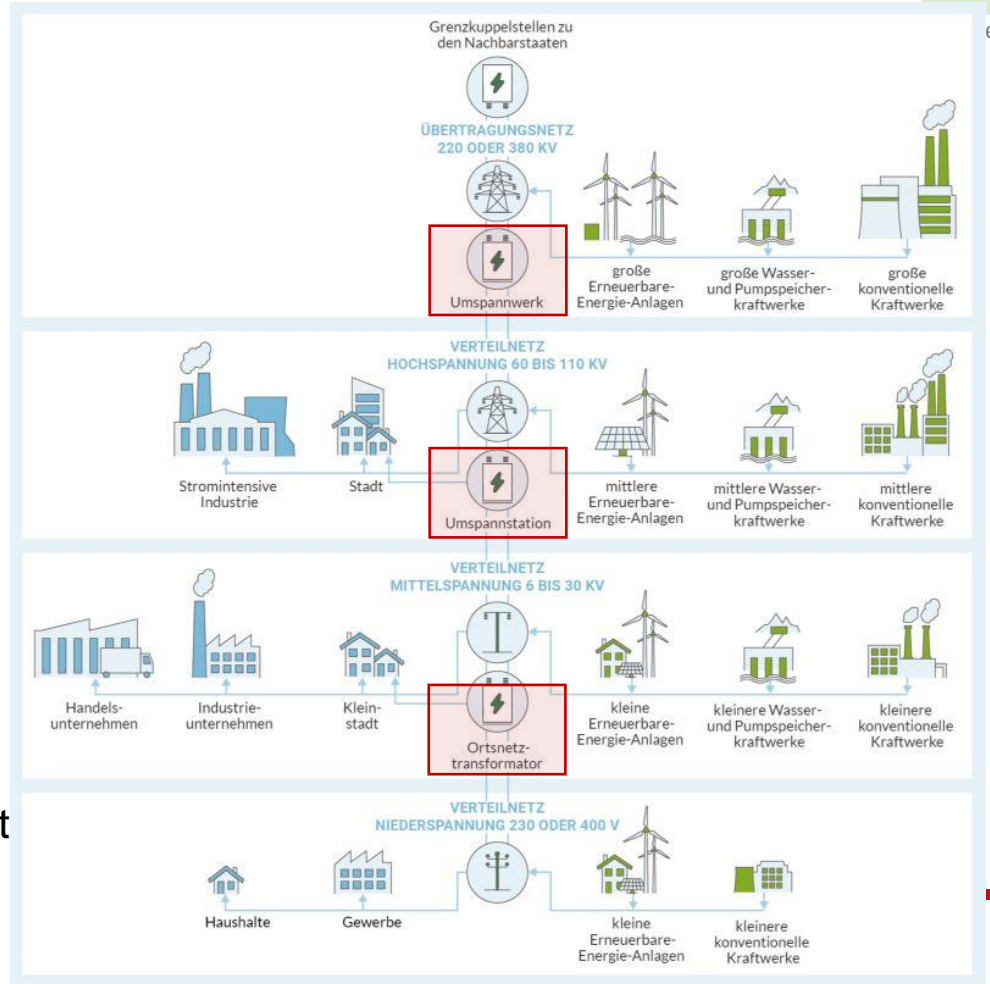
Where is it used?

SF₆ is being used as insulating gas in electrical switchgear.

Switchgear is part of

- Substations connecting different voltage levels in public networks.
- Switchyards directing the power in different directions.
- Connection facilities of larger generation sites or industrial networks.

There is also non/switching equipment containing SF₆.



Where is it used? Medium voltage - distribution



Switchgear is part of electrical infrastructure. In distribution networks in Europe there are several million ‚functional units‘. There are more units in industry and generation.

In EU 10...15 kg SF₆ per 1000 inhabitants is stocked in MV switchgear (guess).

Future drivers:

- Renewables
- E-mobility / sector coupling (power to heat etc.)

For Germany ZVEI / FNN/ VKI assume a 2% per year net-growth until 2050 (corresponds to about twice as many installations).



Where is it used? High voltage - transmission / sub-transmission.



Pressure in HV is higher than in MV.
 Despite the lower number of installations the total mass of SF6 in HV is equal or higher than in MV.

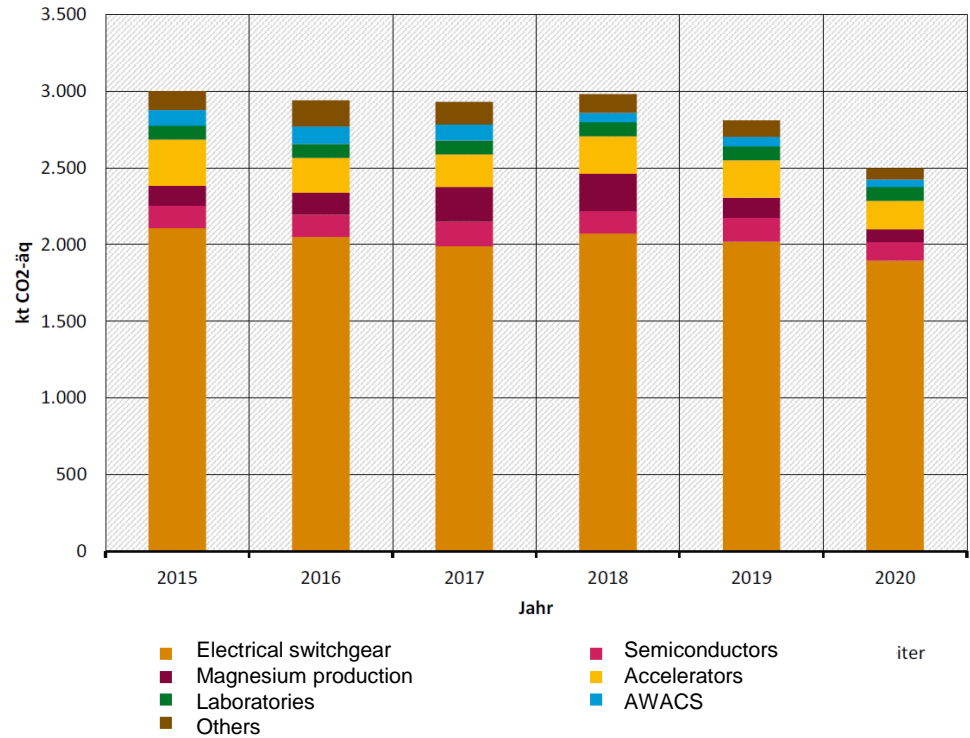
Future drivers:

- Renewables (offshore wind!) and Sector coupling
- Increasing transits transnational electricity trade



Reported SF₆ emissions from electrical switchgear are dominating the picture.

Reported SF₆ emissions EU27 + UK



Remark: Emissions from sound proof windows have been intentionally ignored.

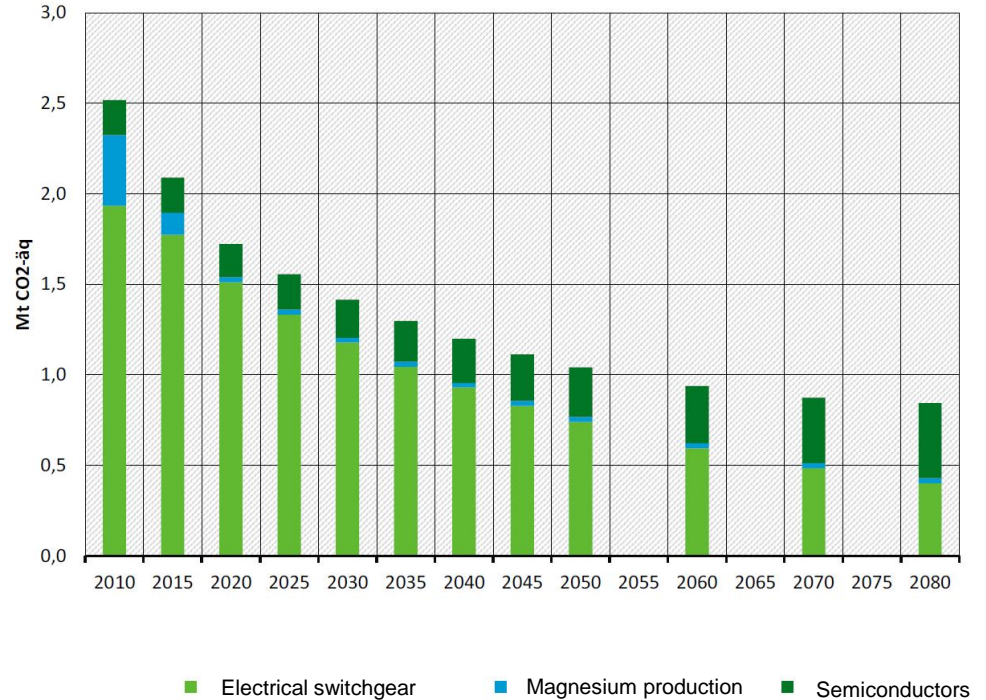
Source: Ökorecherche processing of UNFCCC Reporting

The picture is not going to change fundamentally.

Anticipated SF₆ emissions EU27 + UK

With continued use, after 2050, no further emission reductions are expected.

This is in line with other scenario studies.

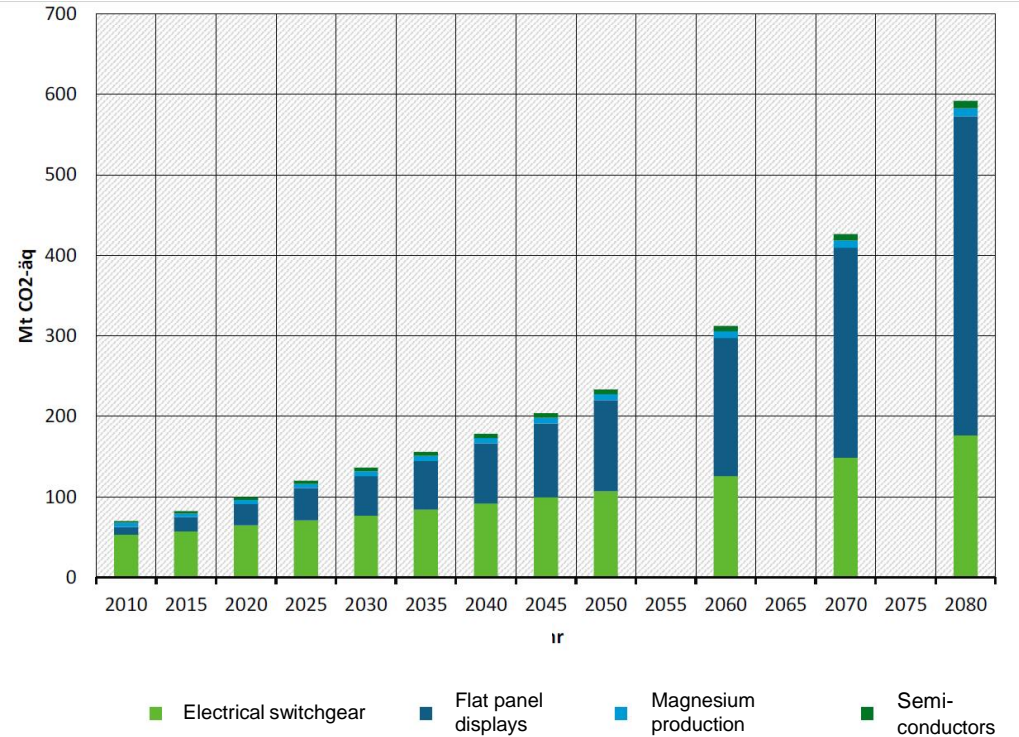


Source: Ökorecherche based on https://www.epa.gov/sites/default/files/2020-05/documents/epa_non-co2_greenhouse_gases_rpt-epa430r19010.pdf

In a business as usual scenario, the picture is going to change fundamentally.

Anticipated global SF₆ emissions

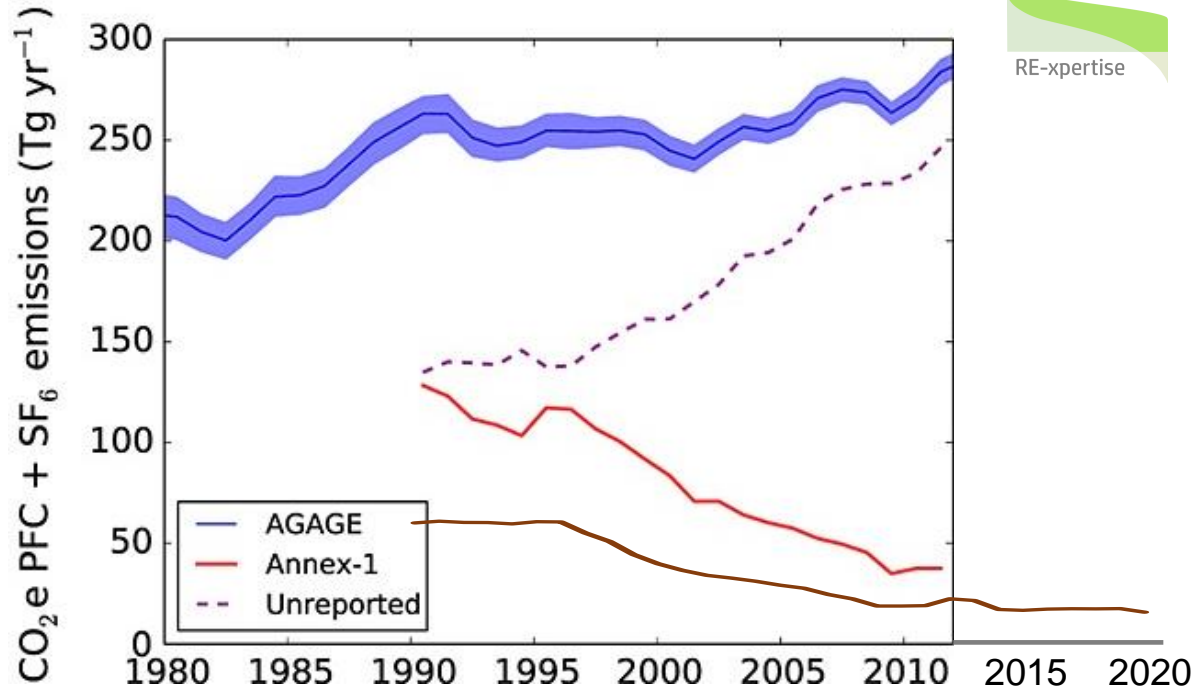
Looking at electrical switchgear only, scenarios suggest that emissions triple until the end of the century.



Source: Ökorecherche based on https://www.epa.gov/sites/default/files/2020-05/documents/epa_non-co2_greenhouse_gases_rpt-epa430r19010.pdf

But we do not even know what is going on.

- Only $\pm 10\%$ of the observed global SF₆ emissions are covered by reporting. (15 Tg/a vs ≈ 200 Tg/a CO₂ eq.).
- Reportings suggest a decline of emissions. The opposite is true. The discrepancy is growing.
- This lack of understanding makes it difficult to design effective policies.

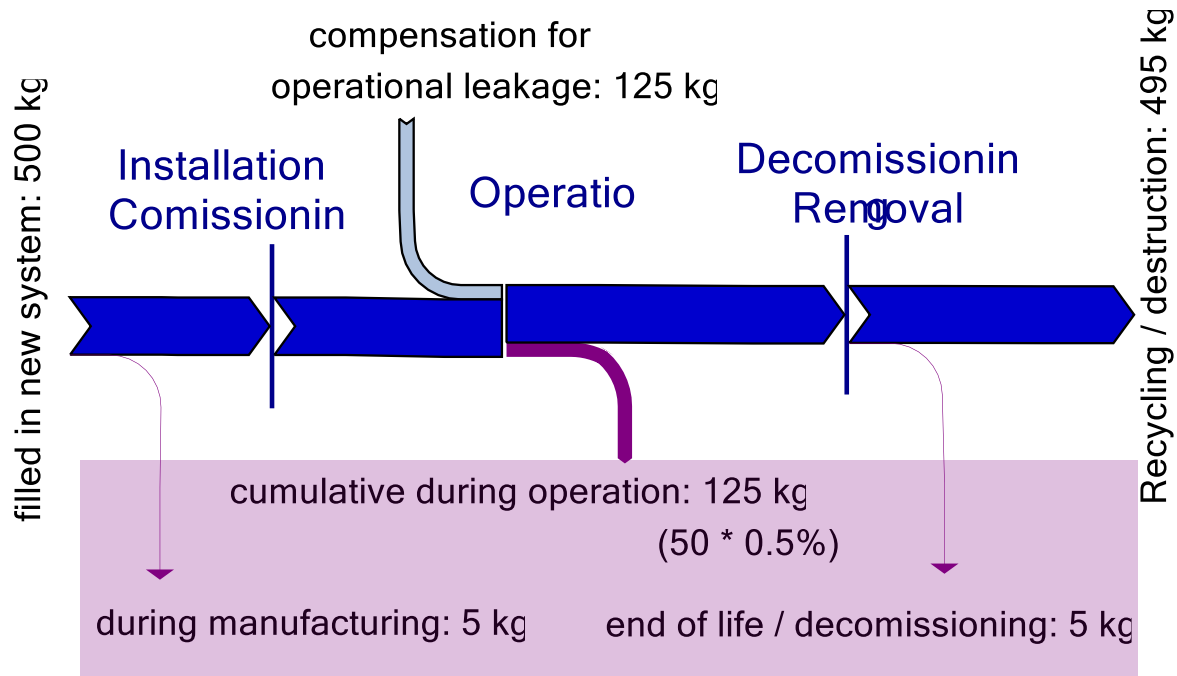


PFC and SF₆ CO₂-equivalent emissions derived from AGAGE observations (blue line and shading, representing 1-sigma uncertainties) compared to reported emissions from Annex 1 countries (red). Unreported emission, (AGAGE minus reported emissions) are shown in purple.

Source: Rigby et al. 2014 (<https://agupubs.onlinelibrary.wiley.com/doi/full/10.1002/2013GL059099>)

Additional (brown) line to 2020: SF₆ only (Source UNFCCC reportings, Annex I countries).

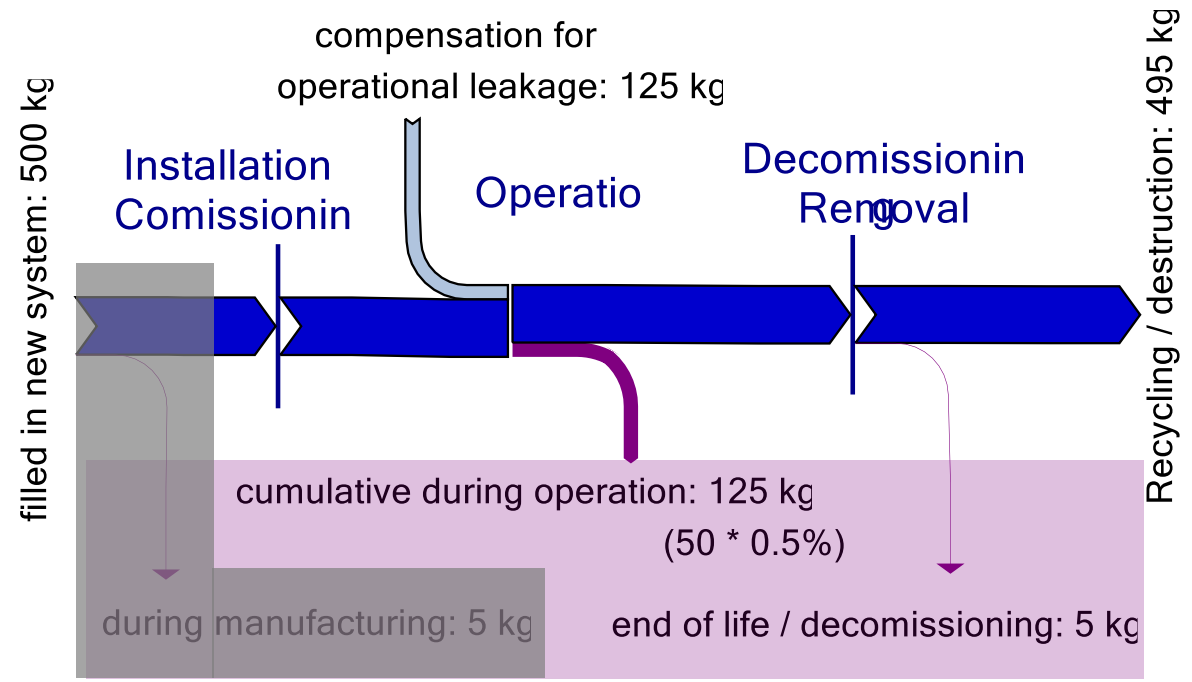
As long as we use SF₆, emissions cannot be avoided.



Emissions occur during all phases of the product life cycle. Emission rates differ per voltage level and equipment type.

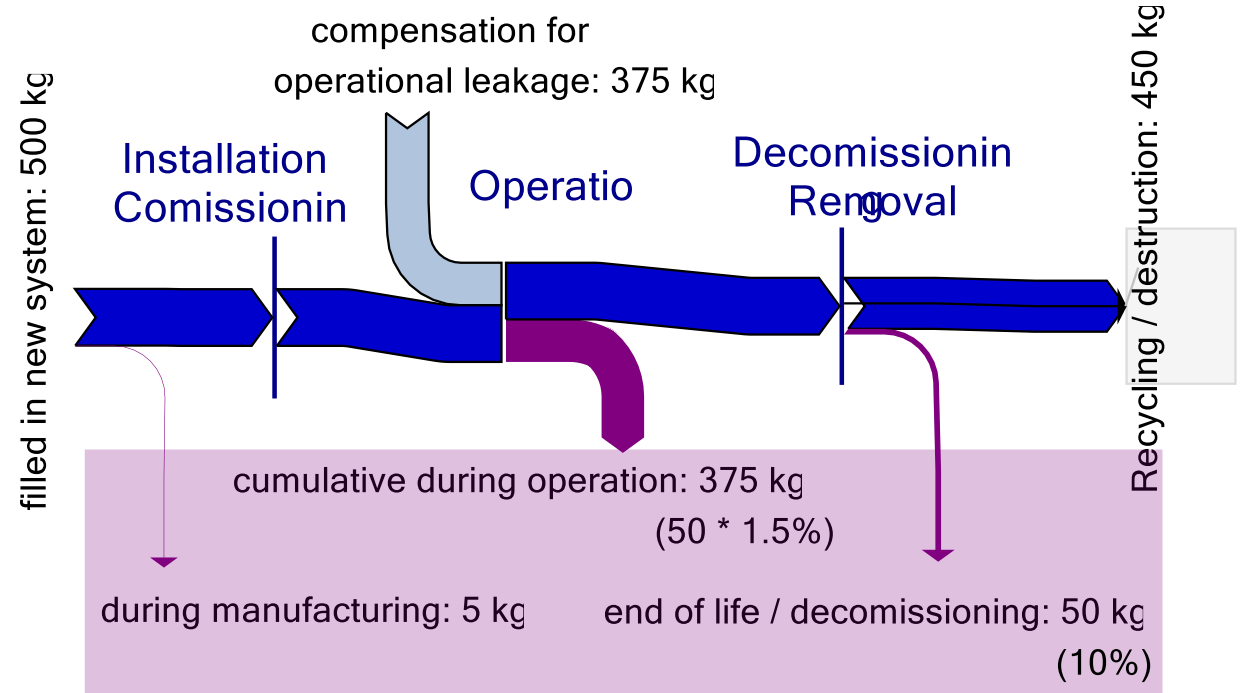
Emission rates in high voltage (transmission / sub transmission) are higher, however, the number of units in medium voltage (distribution) is large.

As long as we use SF₆, emissions cannot be avoided.

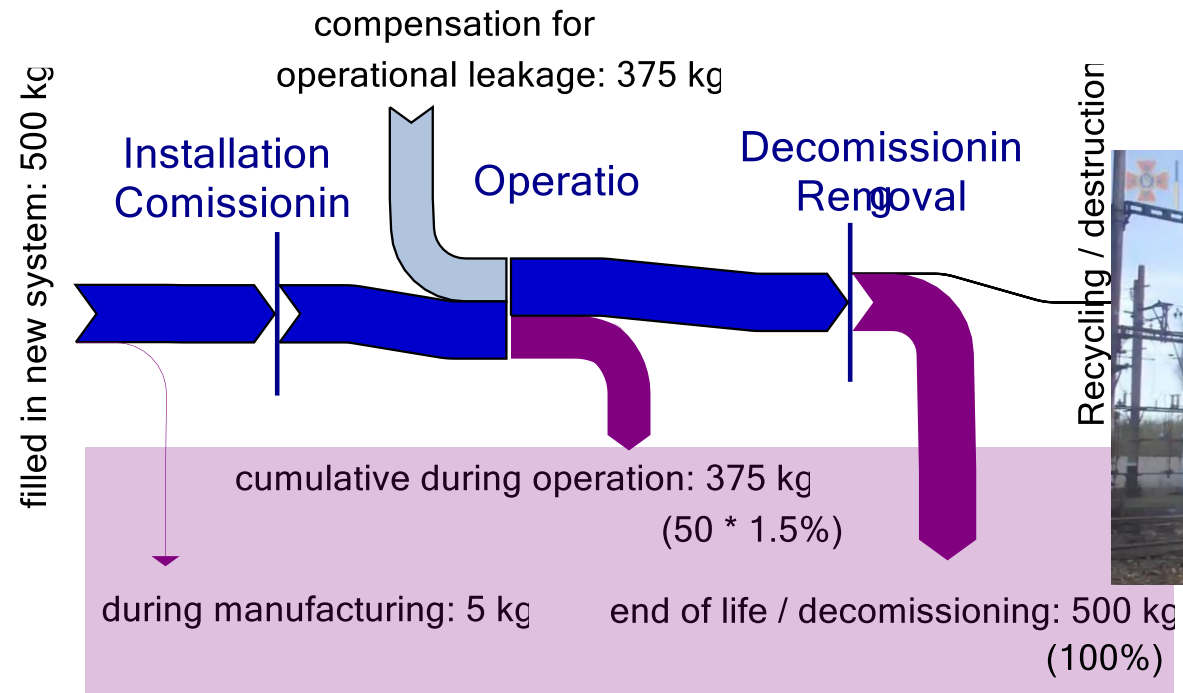


“We do not have national production. This part is not our problem.”

As long as we use SF₆, emissions cannot be avoided.



As long as we use SF₆, emissions cannot be avoided.



A large share of the emission risk occurs in future (second half of this century).
 Are we able to manage this adequately and reliably with today's policies?

TECHNICAL REPORT

26th February 2020

**Technical report on alternative to SF₆ gas in medium
voltage & high voltage electrical equipment**

SF₆-free technologies – some (non-technical) facts.

Technology progress is driven by regulation.

Without regulation, SF₆ use would be continued. Voluntary action improves gas management, but does not result in replacement of SF₆.

Reasons:

- SF₆-experience is extensive and satisfying, investments are low. From a narrow engineering perspective SF₆ appeared as the ideal gas.
- SF₆ is perceived as a de facto standard. Alternative solutions are diverse and not yet available for all ratings and all environmental conditions.
- The techno-economic parameters of alternatives are not completely identical with the SF₆ reference (e.g. technical specs, temperature ranges, investments, etc). Clients have to make choices matching their applications.
- Long term experience with (some) alternatives is lacking making users reluctant.

More and more SF₆ free solutions become available. However...

The timeframe set by European regulation is challenging. All European manufacturers are developing alternative solutions. But they have to set priorities and make choices. Users (network companies) have their own procedures taking time as well.

(For special requirements and niche applications,) the available product range might be limited. For users, this implies at least some inconvenience (legal uncertainties, derogations and related effort, lack of choice).

Replacements are an extra challenge. There are lock-in effects – mixing technologies requires attention.

By the way, some SF₆ free solutions always have been available and have been applied commercially (in niches).



What is specific about developing countries?

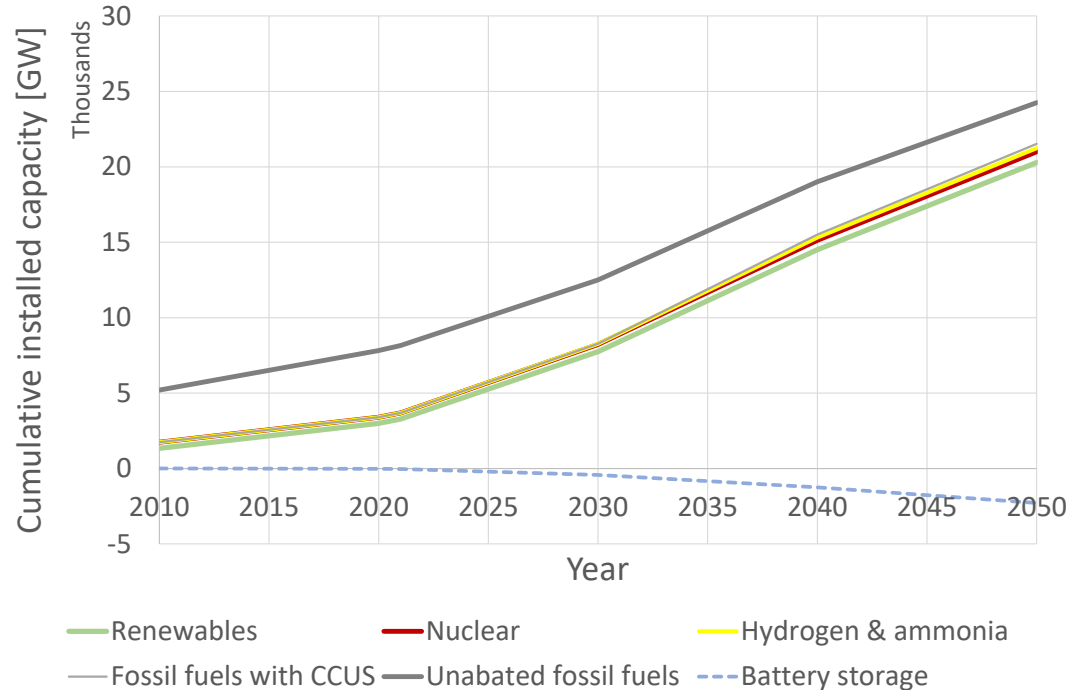
The International Energy Agency expects power plant capacity to grow with a factor four by 2050.

Much of the growth is likely to happen in developing economies.

Generation capacity may be seen as a proxy for network assets, including switchgear.

Urbanization will be an additional driver for distribution network development.

➔ With conventional technology, used SF₆ masses and, inevitably, emissions in developing countries would increase.



Potential emission abatement measures are:

1. SF₆ recycling
2. Leak detection and repair
3. Equipment refurbishment and upgrading (lower leakage rates)
4. Alternative gases
5. Improving SF₆ handling

Relevance for
distribution limited

Remember: As long as we use SF₆, emissions cannot be avoided completely.

Source: https://www.epa.gov/sites/default/files/2020-05/documents/epa_non-co2_greenhouse_gases_rpt-epa430r19010.pdf

Potential emission abatement measures are (reordered):

1. Alternatives to SF₆
2. Improving SF₆ handling
3. SF₆ recycling and destruction
4. Leak detection and repair
5. Equipment refurbishment and upgrading (lower leakage rates)

Source: https://www.epa.gov/sites/default/files/2020-05/documents/epa_non-co2_greenhouse_gases_rpt-epa430r19010.pdf

An aerial photograph of a large, multi-story building with a complex roof structure. The roof is covered with numerous solar panels, some of which are tilted at various angles. The building has a mix of brick and concrete facades. In the background, there are trees and a white bus parked on a road. The overall scene suggests a focus on sustainable energy and urban infrastructure.

What opportunities are there?

Stepping in with alternative solutions avoids hassle.

Some simplifying slogans:

- No technology to be phased out again in future.
- No specific procedures / overhead required for monitoring and reporting.
- No highly skilled people wasting their resources with gas management. No future cost for safe return and destruction of SF₆.
- No stimuli to criminal energy and perverted policy effects.
- No damage to the climate.

Implementing alternatives to SF₆ requires policies and supportive frameworks.

Users / network operators / utilities need

- To take an informed decision about technology options (homework);
- Certainty regarding future legal provisions (governmental authorities);
- Experience in house and from other users (national or international knowledge transfer and dissemination);
- Facilities to cover extra investments (national or international support);

Implementing alternatives to SF₆ requires stringent policies AND supportive frameworks.

A potential advantage of many developing countries: the electricity sector is vertically integrated and closely related to governmental authorities. A single stakeholder and centralised structures may be helpful when implementing policies.

If policy makers are weak or unaware of the challenge: we need to educate and establish networks.

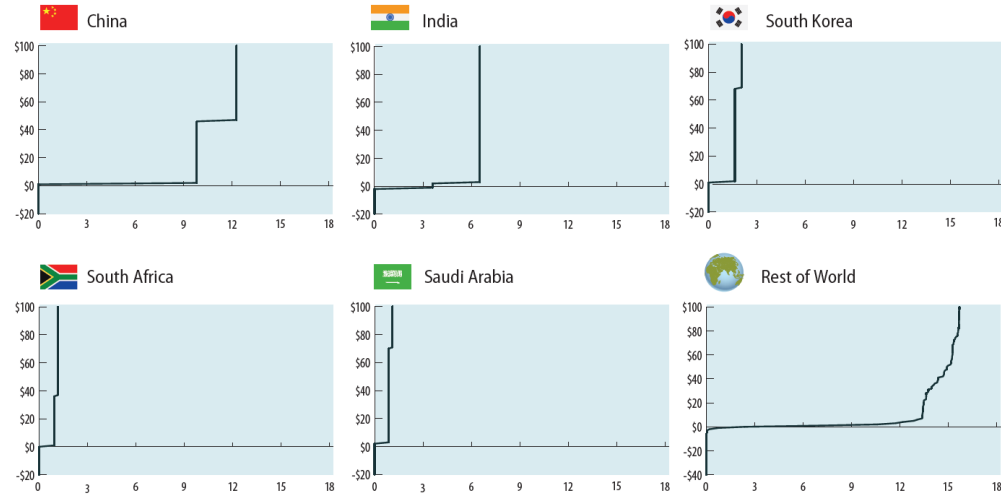
My personal(!) conclusion:

When investment decisions are taken, there is no evidence of emissions. The risk occurs in future and any claim is speculative. But once SF₆ equipment is installed, you only can manage emissions, not avoid them.


- ➔ Trivial and modest market based approaches related to the stocked gas will not be effective neither efficient.
- ➔ There is a risk of perverting effects of monetary policy instruments targeting at SF₆ emission control.

Marginal Abatement Cost Curves, 2030

China has the highest baseline emissions for the electric power systems source category in 2030, followed by India, South Korea, South Africa, and Saudi Arabia. China contributes to 34% of global abatement potential, and the top 5 emitters combined contribute to 60% of global abatement potential.

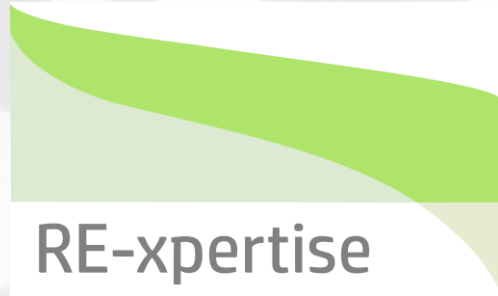


Source: https://www.epa.gov/sites/default/files/2020-05/documents/epa_non-co2_greenhouse_gases_rpt-epa430r19010.pdf

An aerial photograph of a city, likely Berlin, showing a mix of old and new buildings. A semi-transparent architectural rendering of a modern building complex is overlaid on the image, showing how it would fit into the existing urban fabric. The rendering includes a large, multi-story building with a flat roof and a central courtyard area. The text "Progress is: undoing the changes implemented by our ancestors." is superimposed over the lower half of the image.

Progress is: undoing the changes implemented by our ancestors.

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