Study Committee B3
Substations and Electrical Installations
Paper B3-10674

Life Cycle Assessment comparison of different high voltage substation technologies using SF_6 and alternative insulation gases

Lukas TREIER, Maxime PERRET, Yannick KIEFFEL, Bertrand PORTAL,
GE Renewable, Grid Solutions

Identify GHG emissions in energy sector to reduce them - on time

- IPCC states clearly that actual **climate actions isn't sufficient** to limit the warming to 1.5°C nor 2.0°C.
- A drastic GHG emissions reduction is required: this imply to **identify the sources** to master and limit them.
- The complete life cycle of a product should be considered to **avoid pollution transfer** from one source to another.
- **LCA (Life Cycle Assessment)** is the recognized method, standardized in the **ISO 14040 and ISO 14044**

Raw materials

Minerals extractions, processing into usable raw material, recycling

HV switchgear: Aluminum, steel, copper, etc.

Parts manufacturing

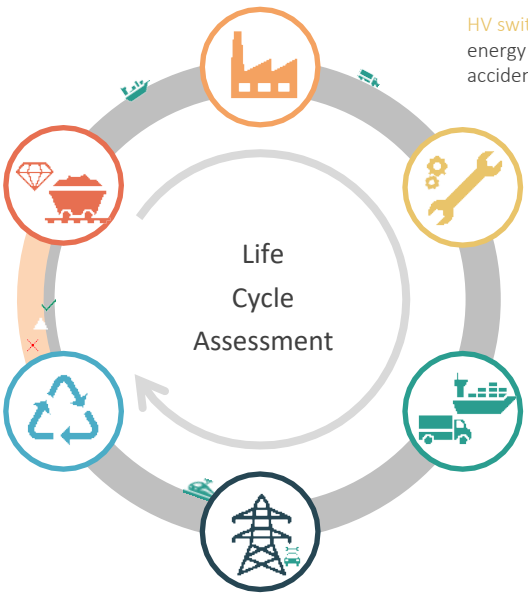
Fabrication of the parts, from casting, to machining and transport to the factory

HV switchgear: Castings, machined parts, porcelain, etc.

Assembly and testing

Assembly of the equipment, routine testing

HV switchgear: Factory and offices energy and water consumption, accidental gas emissions, etc.



End of life

Materials are separated and valorized when possible (energy / water consumption, results are variable:

- Potentially up to 100% recyclable
- Recyclable with some losses (or re-use)
- Not recyclable, no re-use

HV switchgear: Recycled aluminum cannot be used for pressure vessels, epoxy not recyclable, copper, etc.

Transport

Transport occurs at every step of the product's life

HV switchgear: Transport depending on production and application locations

Use phase

From the equipment delivery until decommissioning, including the complete related emissions

HV switchgear: Joule losses, gas emissions, building consumption, service and maintenance team emissions, etc.

LCA, complex but powerful

- LCA is a powerful tool for evaluating the **environmental footprint ($CO_{2\ equ.}$)** of a product.
- Implementing a LCA is a complex process. It is advised to **get expertise from a certified third party**.
- **This paper's ambition is to provide an objective comparison tool that anyone can use or improve.**

"LCA is the right approach to evaluate the global impact on a technological choice." [EU "Buying green handbook]
"LCA is the state-of-the-art tool to evaluate the impact of products and systems on the environment." [T&D Europe]

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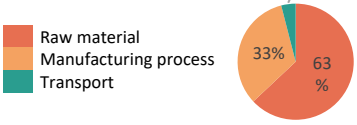
An objective LCA simplification for pre-studies

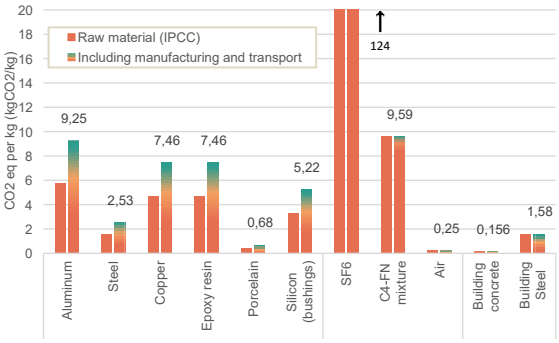
Impact of materials

- Equivalent CO_2-emissions of the use materials can be determined
- Values are calculated with a software using IPCC 2013 guidelines
- Raw material, manufacturing process and transport are evaluated

Typical distribution for metals



CO_2-emissions related to the use of typical materials



Impact of use

- Emissions during service
- Losses should be finely adapted by the end-users

Joule losses

- Main circuit
- ITR (secondary)
- LV control and auxiliary circuit

Gas emissions

- Leakage per year
- Losses during maintenance

Operation

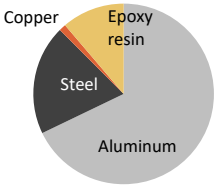
- Building
- Maintenance team

Reference model - Inputs

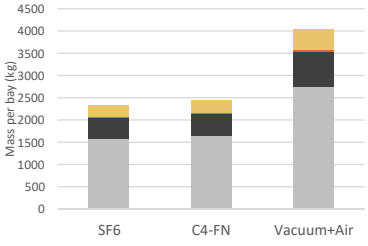
- Very few manufacturers make their LCA / parameters publicly available. Data for SF_6 and C4-FN are published.
- It is possible to rely on published information to extrapolate. T&D Europe: Vacuum footprint = 120% SF_6 footprint.
- The using phase parameters may vary a lot depending on the user. General values are provided.

Studied case: GIS 145 kV - 3 technologies

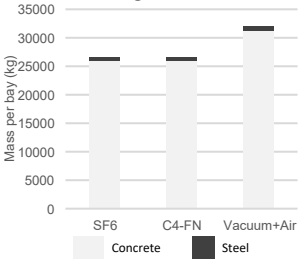
Typical material distribution (mass)



Typical material masses for 145 kV GIS



Building and concrete



Source

Time %	Current (A)
75%	625
20%	1500
5%	2500
100%	894

Energy mix
237 g/kWh

Gas	SF_6	C4-FN mixture	Air
Leakage rate IEC	0.1%/y	0.5%/y	0.5%/y
GWP	23500	640	-
Mass (kg)	64	31	32
CO_2-$_{equ}$ (t)	1504	19.8	-

Source	Loss
Bay	92 µΩ
ITR	100 W
LV	160 W

http://www.cigre.org

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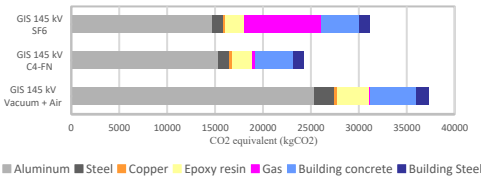
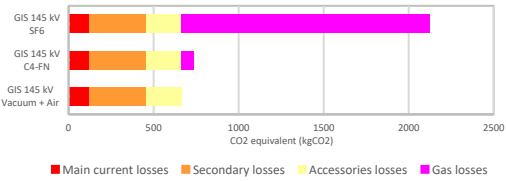
Reference results – Distribution and overview

- LCA is based on standards, like the ISO 14040 / 14044, and back-up by major entities.

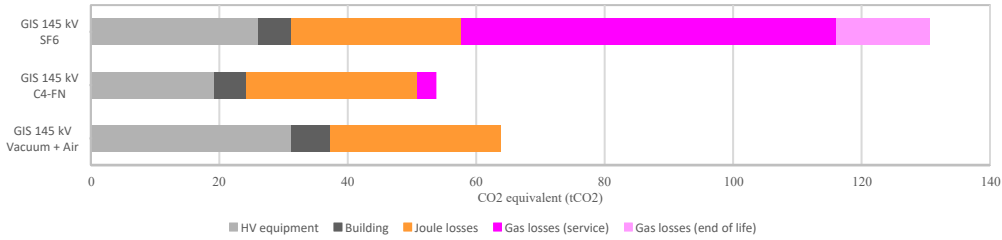
Grey energy pollution from **manufacturing**



CO_2-emissions **per year**



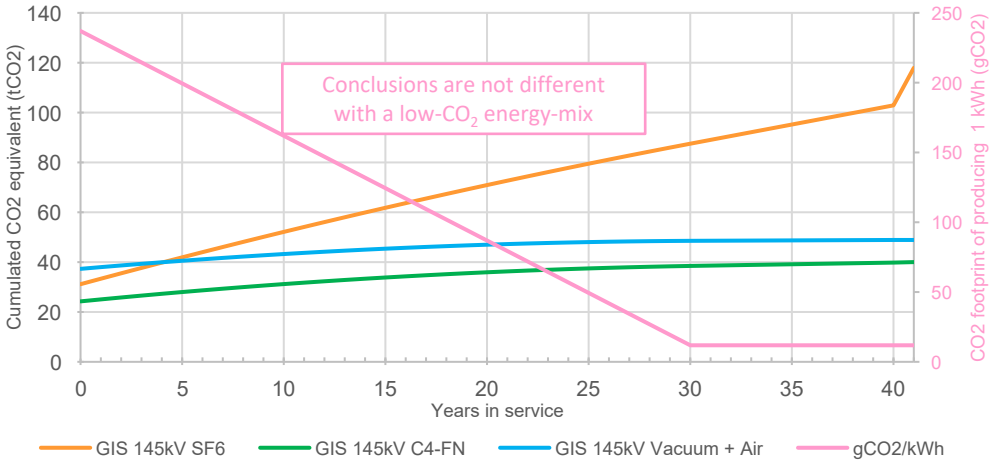
Total CO_2-emissions **during the equipment lifetime**



Summary over time of the emissions

- The CO_2-equivalent emissions can be displayed in time. Data are the same as presented above.
- **Immediate reduction is necessary to reach Paris Agreement**. Emissions to be cut by 2030-2040.
- Manufacturing's pollution happen now, often partially in high-emissions countries, and therefore not affected.

CO_2 footprint evolution in time



ISO based methodology shows that C4-FN mixture solutions offer the best and fastest CO_2-equivalent reduction