# Impact assessment of F-gas free medium voltage switchgear

Fraunhofer Institute for Energy Economics and Energy System Technology IEE and Grenoble Ecole de Management (GEM) have performed a research study to investigate the impact of the application of the greenhouse gas sulfur hexafluoride (SF6) in power distribution grids.

The study analyzes the application of SF6 and of fluorinated gas (F-gas) free alternatives in medium voltage grids and is intended to support the COP 21 Paris Agreement, and industry's sustainability commitments towards the nature and the planet.

The focus is on medium voltage (MV) switchgear in electricity grids in the European Union. The study is open to all electricity grid stakeholders.

The study comprises two parts: the modeling of MV switchgear installation development under different boundaries and a survey and choice experiment to analyze market acceptance of SF6-free alternatives, as well as barriers and drivers to adoption.

Final results from the modeling of the MV switchgear installation development will highlight the impact of different policy measures especially regarding the lifetime and forced exchange of MV switchgear using SF6 with F-gas free alternatives on the overall SF6 emissions by 2035, 2050 and 2100.

Detailed final results from analysis of the survey and the choice experiment will be available by end of April. Results will notably include detailed information on choice of technologies for primary and secondary MV switchgear by operators in the past three years and over the next three years. Results on technology acceptance, perception of policies and willingness to pay for different switchgear attributes will be presented.

First results will be available for the EU regulatory action to control greenhouse gases as part of its policy to combat climate change. The final results will be presented publicly (planned for the Hannover Fair in April 2020).

Main trends for both parts of the study are summarized below.

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# Modeling scenarios of MV switchgear installation development

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The yearly emissions of SF6 from MV switchgear and its climate impact are derived from a detailed asset based model developed by Fraunhofer IEE.

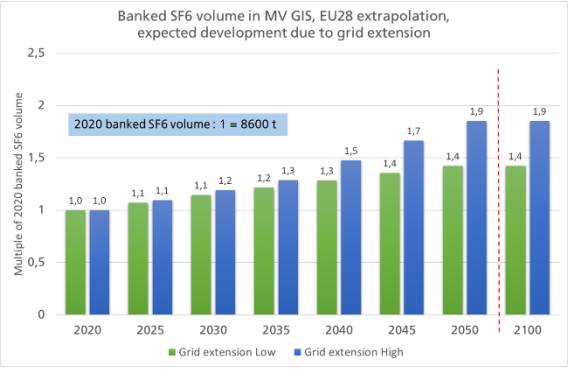
This methodology gives the possibility to investigate the impact of future trends like grid extension and policy measures or like incentives and regulations to reduce the use of F-gases in power distribution systems. Using its expertise in power system development and operation Fraunhofer IEE follows a bottom-up approach to calculate the actual installations of MV switchgear in Germany, France and Spain. Thus, official top-down reporting can be verified. On the basis of the calculation the overall SF6 emissions from MV switchgear in Europe is extrapolated. Scenarios are built showing the impact of different parameters like switchgear lifetime, recycling rates and phase-downq by incentives or regulations for the years 2025, 2035, 2050 and 2100.

## Intermediate results of the modeling

An asset based grid structure model was developed using grid planning guidelines and experiences from various grid development projects. It distinguishes between MV primary and secondary switchgear. The model was validated with data from public reports on assets as well as applied research projects and reported SF6 volumes.

### *Impact of network extensions due to the energy transition*

Expected network extensions are mainly due to the energy transformation towards carbon neutrality. For network extensions following the political objectives of the share of renewable energy and e-mobility, we expect an addition of MV switchgear functional units between 40% and 90% until 2050. Provided a steady share of SF6 applications this leads to the same increase of the banked SF6 volume.




### *Impact of end-of-life handling*

End-of-life handling of the MV switchgear and the losses during decommissioning and recycling have a key role. There is a wide gap between industry best practice of about 1.5% end-of-life leakages and the worst case assumption of about 40% end-of-life leakages for mainly uncontrolled end-of-life handling. In the study, we made an educated guess of 10% end-of-life leakages as average in EU28 countries to show the impact.

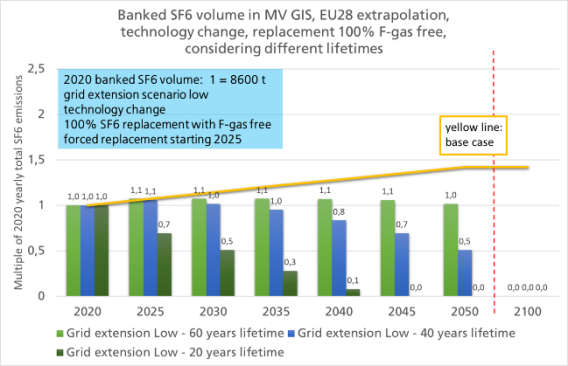
The leakages in operation for MV switchgear are 0.1% per year according to international standards.

Therefor the end-of-life leakages of SF6 are equivalent to the leakages of 15 to 100 years of operation. To minimize the impact of end-of-life leakages high quality processes and monitoring should be established Europe-wide.

### *Impact of the application of F-gas free alternatives*

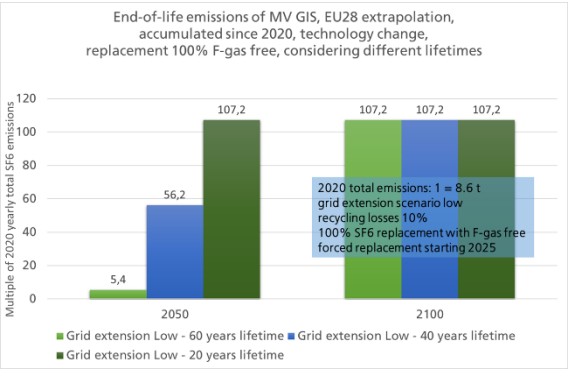
The impact of the exchange with F-gas free alternatives was investigated under the assumption that the technology for all MV levels (12, 24, 36 kV) is available.

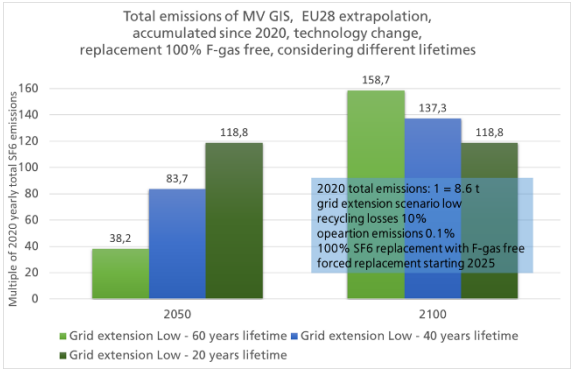
Switchgear equipment, as most power system equipment, is designed for a long lifetime. Therefore, the end-of-life exchange of existing equipment with of F-gas free alternatives shows only long-term effects. Carbon neutrality by 2050 is only achievable using a forced exchange before the usual commercial or technical end-of-life, see example of the development of the banked volume for a forced exchange after a lifetime of 20 years in dark green below.




But the overall emissions until 2100 are dominated by the end-of-life handling with

- equal end-of-life emissions for the different lifetimes in the long term and
- relatively smaller, but visible, differences in total emissions due to operation leakages.




### *Preliminary conclusions*

➔ Strict monitoring and control of the end-of-life handling for all switchgear operators is essential.

- Total emissions are dominated by end-of-life
- Actual end-of-life leakages are uncertain (ranging between 1.5% and 40%)

- Process monitoring is important
- Reducing end-of-life leakages from 10 to 5% leads to a reduction of total emissions by 39% (in case equipment lifetime 40 years)

➔ network extension
- expected increase of the number of functional units up to 90% by 2050 (for high extension scenario) driven by renewable installations
- start as soon as possible using F-gas free equipment to minimize network extension effects

➔ operation emissions
- yearly operation emissions are significantly smaller than and-of-life emissions per functional unit
- the sooner the exchange with F-gas free technology starts the better, if high quality end-of-life handling is established

## Empirical study investigating the environmental and socio-economic impact of SF6 and its alternatives in medium voltage switchgear

Authors: Marie-Charlotte Guetlein and Carine Sebi, Grenoble Ecole de Management

### Survey and choice experiment

New alternatives to SF6 in medium voltage switchgear have not yet fully penetrated the market. Thus, empirical analysis cannot draw on observed adoption behavior to elicit market acceptance of these alternatives. In order to analyze market acceptance of SF6-free alternatives, as well as barriers and drivers to adoption, Grenoble Ecole de Management (GEM) carried out a survey, including stated preferences choice experiments (SPCE) among users of primary and secondary switchgear in different industries across five European countries.

### Methodology

SPCE involve constructing hypothetic choice scenarios where alternatives are described by a range of attributes. In our SPCE, participants repeatedly choose between different MV switchgear option that differ by the following attributes: price, size, global warming impact, possibility of F-gas leaks, and warranty period. Participants are expected to make trade-offs between these different attributes and select their most preferred alternative. This allows estimating importance weights and the willingness to pay for multiple attributes. The results can be used to predict the market development under various scenario assumptions.

Other parts of the survey more directly elicit respondents' acceptance of the proposed solutions (e.g., intention to invest in different SF6-free technologies) and investigate barriers and drivers to technology adoption (e.g., technical specifications, health and safety concerns, policies and regulation, etc.). The survey also examines respondents' knowledge and perception of current and future policies on F-gas emissions and environmental labels.

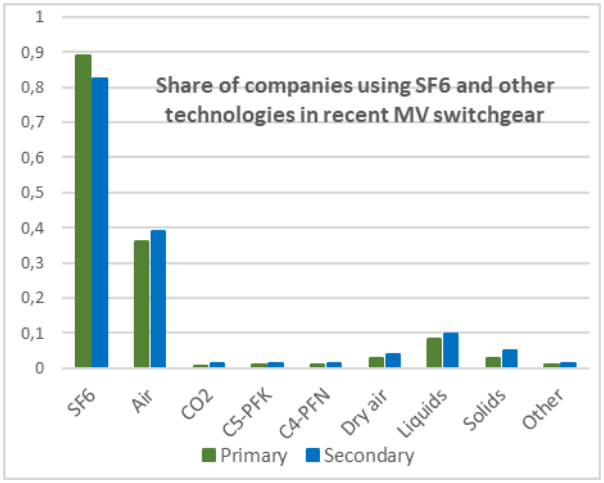
### Fielding and participants

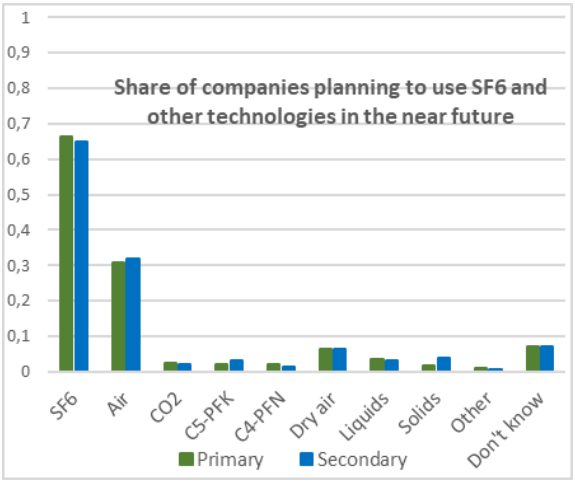
The survey was carried out between November 2019 and February 2020 and targeted at professionals involved in the purchase of MV switchgear. 431 professionals dealing with MV

switchgear completed the questionnaire. The vast majority of participants came from France, Germany and Spain, few participants from the UK and Poland. More than half of them (53%) indicated having a leading role in the switchgear purchasing process in their company, while 39% indicated being involved. 58% of respondents worked for a distribution network operator or an electrical distribution company. 333 professionals, who indicated that they knew the approximate price of switchgear, took part in the SPCE.

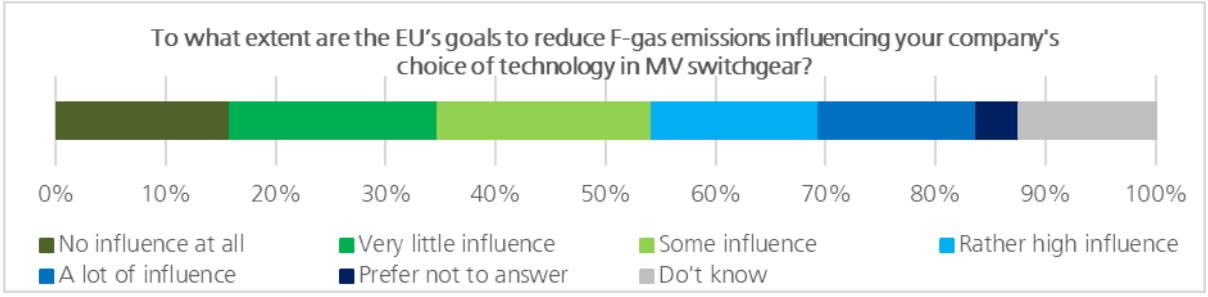
## Preliminary results

Preliminary results from the survey analysis show that more than 20% of respondents expect that their company will not continue to purchase MV switchgear containing SF6 in the near future. At the same time, respondents remain uncertain which technology will most likely replace SF6. The expected decline in SF6 is mainly driven by policies and regulation, though 20% of respondents also indicate better performance as a reason to purchase SF6-free alternatives. The principal barriers to replacing SF6 by other technologies are need for more space, higher purchasing price as well as lack of reliable suppliers for SF6-free alternatives.




Regarding EU policies on F-gas emission, 58% of respondents describe themselves as completely or rather unfamiliar with these policies. At the same time, half of the participants believe that their company's choice of technology in MV switchgear is substantially influenced by the EU's goals to reduce F-gas emissions. Looking at respondents' perception of different policy tools, we observe that financial incentives (e.g., subsidies) and a complete ban on SF6 are considered the two most useful policies to promote SF6-free MV switchgear. (These results are most likely driven by a combination of both desirability of policies and their expected effectiveness.)




Preliminary results from the SPCE show that the propensity to purchase a particular switchgear option declines as price and size increase. At the same time - and as to be expected – the propensity to purchase a specific switchgear option increases if the option has a longer warranty

period, a lower global warming impact, and no leak of F-gases is possible. In particular, respondents answering on behalf of their companies are on average willing to pay 20% more for an option with a low global warming impact compared to an option with a high global warming impact. Moreover, they are on average willing to pay 15% more for an option with no possible leak of F-gases compared to an option where a leak of F-gases is possible. (The cited values for average willingness to pay are based on a large variety of different users and MV switchgear products.)

### Availability of final results

Detailed final results from analysis of the survey and the SPCE will be available by the end of April. Results will notably include detailed information on choice of technologies for primary and secondary MV switchgear by companies in the past three years and over the next three years. Results on technology acceptance, perception of policies and willingness to pay for different switchgear attributes will be presented by country, by industry, and by primary and secondary switchgear, whenever relevant differences exist.

## Short profile of study partners

The Fraunhofer Institute for Energy Economics and Energy System Technology IEE in Kassel researches for the national and international transformation of energy supply systems.

We develop solutions for technical and economic challenges in order to further reduce the costs of renewable energies, to secure the supply despite volatile generation, to ensure grid stability at the usual high level and to make the business model of the energy transition a success.

With the help of our scientific, technical and operational offerings and solutions, we support our customers and partners from politics and industry.

Established by Grenoble's Chamber of Commerce and Industry in 1984, Grenoble Ecole de Management (GEM) is a higher education institution in Management. It delivers 40 national and international programs from the undergraduate to the Doctoral level for about 6000 students. It is accredited by EQUIS, AACSB and AMBA, and a member of the Conférence des Grandes Ecoles. GEM ranks among the 20 best European Business Schools (latest Financial Times Ranking), and typically among the top 4 to 6 business schools in France.

The GEM Energy Management team combines research on strategic management, technology innovation and energy policy to create and share knowledge that will help businesses and society move towards a low-carbon future.