Blue –
Our path to Zero with Clean Air

Dr. Mark Kuschel
Siemens Energy - Grid Technologies

July 2023
Siemens Energy is a global leader in the energy business

~ 1/6 of global electricity generation is based on our technology.

We are present in > 90 countries.

91,000 employees work as a team to energize society.¹

We invest around €1bn annually in research and development.

¹ Number of employees as of September 30, 2021
July 2023
As an integrated energy technology company, we support our customers along the energy value chain.

- **Low- or zero-emission power generation**
  - Gas Services
  - Siemens Gamesa Renewable Energy

- **Transport and storage of energy**
  - Grid Technologies

- **Reducing GHG emissions & energy consumption in industrial processes**
  - Transformation of Industry
Agenda

1. Siemens Energy at glance
2. Background phase-out of F-gases
3. Clean air – Our path to zero in transmission
4. Clean air – Status and Roadmap
5. Conclusion
F-gases in our switchgears and power grids require attention

Today's power grid still relies on the most potent greenhouse gas: $\text{SF}_6$

1 kg of $\text{SF}_6$ is equivalent to 24,300 kg of $\text{CO}_2$.

Source: Final IPCC AR6 Report, 2023
UN Sustainable Development Goals, that encourage Sustainable Products enabling Energy Transition

**Regulatory frameworks**
- Regulations
- Climate protection laws (e.g. EU Net-Zero 2050)
- Green deal

**Enterprises**
- Sustainability part of the corporate strategy

**Society**
- Climate change
- Sustainability
- Environmental protection

- F-Gas ban / restrictions
- PFAS ban / restrictions
- Emission-free products
- Decarbonised operations and supply chains
- Purchasing decisions
- Investment decisions
Natural-origin gases are the only way to achieve a CO₂ neutral and non-toxic environment in all aspects

**Clean Air** (GWP = 0, natural-origin gas)
- if used by everyone it is the most environment-friendly switchgear technology of the world.

**F-gas: Fluoronitrile-mix** (GWP ~ 500)
- 10,000 tons F-gases are needed annually for SF₆ replacement in new installations, which means around 50 tons of leakage (= 20 million kg CO₂).
- It takes 30 years until the nature absorbs it.

**No harm**
- on health & environment

**Health risks**
- Fluoronitrile belongs to PFAS*, its decomposition is toxic

**0 trees**
- No greenhouse or F-gases

**321,600,000 trees**

Latest News
- [https://California Sues 3M and DuPont Over PFAS Chemicals - WSJ](https://California Sues 3M and DuPont Over PFAS Chemicals - WSJ)
- [https://news.3m.com/2022-12-20-3M-to-Exit-PFAS-Manufacturing-by-the-End-of-2025](https://news.3m.com/2022-12-20-3M-to-Exit-PFAS-Manufacturing-by-the-End-of-2025)

*PFAS: Per- and polyfluoroalkyl substances including PFAS-F-Gas C4-FN Fluoronitrile
It is time for action!
EU F-Gas Regulation to reduce harmful F-gases in switchgear

EU F-Gas Regulation - Draft published 5th April

• **EU Commission**: proposal to ban all F-gases with GWP > 10 in switchgear
• **EU Parliament**: proposal to ban all F-gases in switchgear
• **EU Member States**: proposal to ban all F-gases with GWP > 10 in switchgear with exemptions

Siemens Energy welcomes the proposals to phase out F-gas in switchgear as it:

• **Is Consistent** with net zero climate targets and a toxic-free environment ambition
• **Is Affordable** to individual households and society
• **Provides Choice** without creating new dependencies in critical infrastructure
Siemens Energy is part of an alliance of six HV and MV voltage power equipment manufacturers who are committed to phase out F-gases in switchgear and who have joined forces to introduce a switch from F-gas insulation to natural-origin gases with GWP < 1 in the EU F-Gas Regulation.
F-gas free products are available and in reliable use worldwide up to 420 kV, the majority rely on natural-origin gases to ensure safe power grids!

1. F-gas free alternative technology & products already available
2. Manufacturers are committed to close the portfolio gaps
3. The proposed transition time is sufficient to close and develop F-gas-free portfolio
Agenda

1. Siemens Energy at glance
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July 2023
Clean air - Benefits for grid operators and society

Clean air \( (\text{N}_2 + \text{O}_2) \) insulation

- Zero \( \text{CO}_2 \) emissions, lowest \( \text{CO}_2 \) footprint, GWP = 0
- Zero toxicity, highest stability, easiest gas handling
- Zero liquefaction at low temperatures -60 °C
- Zero patent dependencies, multiple suppliers

Vacuum interruption

- Zero toxic decomposition products, hermetically tight
- Highest switching performance w/o degradation, scalable short-circuit current capabilities
- Zero maintenance (sealed for life)

\[ \begin{align*}
\text{Clean, Safe and Future-proof regarding F-gas and PFAS regulation!}
\end{align*} \]
Clean air - Proven technology

Order intake of clean air units
Circuit breaker (LT, DT), Instrument Transformer, GIS, GIB

- more than 3000 units contracted worldwide in all climate zones
- nearly 1500 units & over 20 Mio hours successfully in operation
- 2.6 Mio t CO₂ emissions saved through banked and leakages from SF₆ over the lifetime

AIS & GIS clean air installation examples

Status March 2023
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Roadmap from Zero to Zero: Offering a fully F-gas-free, climate-neutral Blue portfolio by 2030

Gas-insulated switchgear
- 72.5 kV
- 145 kV
- 420 kV (GIB)
- 420 kV (back parts)
- 245 kV
- 550 kV

Live tank circuit breaker
- 72.5 kV
- 145 kV
- 420 kV
- 245 kV
- 550 kV

Dead tank circuit breaker
- 145 kV
- 72.5 kV
- 245 kV
- 362 kV
- 550 kV

Instrument transformer
- 72.5 kV
- 145 kV
- 245 kV
- 420 kV

GIB = gas-insulated busducts
back = disconnecter, earthing switch, voltage transformer, busbar...
CB = circuit breaker

July 2023
Agenda

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Conclusion – Clean air fits perfectly for customer switchgear requirements

Environmental impact
Zero greenhouse gases and Zero global warming potential

Health & safety
Zero toxicity and Zero hazard

Performance
Highest switching capability with Zero degradation and a wide temperature range (down to lowest temperatures)

Gas handling & costs
Zero maintenance vacuum technology. Zero training, reporting, or special EOL treatment needed. Lowest lifecycle costs

Manufacturer competence
Rich experience:
> 50 years in switchgear,
> 40 years in vacuum and air insulation
Grid technologies for clean energy:

Environmentally friendly, safe, reliable and economical over the entire service life

Thank you for your attention!
Contact

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mark.kuschel@siemens-energy.com

Head of International Standardization for Grid Technologies

Personal involvement
1) Secretary IEC SC17C & Cenelec TC17AC
2) Vice Chair IEC TC99
3) Area Advisor Cigre SC B3 AA2 GIS Substations
4) Associations T&D Europe, VDE FNN, ZVEI
Backup
F-gas free products enable zero emission in all aspects

Space Footprint, Example 145 kV GIS*

<table>
<thead>
<tr>
<th></th>
<th>1st SF₆ GIS</th>
<th>Current SF₆ GIS</th>
<th>1st Blue GIS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reduction:</td>
<td>SF₆-Vol. - 80 %</td>
<td>Weight - 60 %</td>
<td>Footprint: - 80 %</td>
</tr>
<tr>
<td>Leakage rate per year in %</td>
<td>1</td>
<td>0.1</td>
<td>0.1</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>Bay W x H x D in m</th>
<th>Bay weight in t</th>
<th>Gas amount in kg</th>
<th>Banked GWP in t CO₂-eq.</th>
</tr>
</thead>
<tbody>
<tr>
<td>1st SF₆ GIS</td>
<td>2.4 x 3.7 x 5.0</td>
<td>12</td>
<td>230</td>
<td>5,405</td>
</tr>
<tr>
<td>Current SF₆ GIS</td>
<td>0.8 x 2.5 x 4.1</td>
<td>4.5</td>
<td>85</td>
<td>2,000</td>
</tr>
<tr>
<td>1st Blue GIS</td>
<td>1.0 + 2.9 x 3.7</td>
<td>4.7</td>
<td>32</td>
<td>0</td>
</tr>
</tbody>
</table>

Total LCA (40 years) CO₂ Emission Footprint, Example 145 kV GIS*

- ~ 5% Material, Production, Logistic
- ~ 16% AC Losses Operation
- ~ 79% Gas Production & Emissions

Produced 2022

- SF₆: 100%
- Clean Air: 21%
- F-Gas-Mix (C4FN): 25%

Produced 2050**

- Emissions 50 t CO₂-eq
- Clean Air
- F-Gas-Mix (C4FN)

Grid operators do not require infrastructure changes, replacement is easily possible within the given footprint

F-gas free enables net zero without any CO₂ compensation

* LPIT (Low-Power Instrument Transformer) is an excellent countermeasure to optimize footprint and enable digitalisation
* own evaluation. Produced 2022 European power-mix, around 400 g CO₂/kWh & 2050 0 CO₂ emission from power generation
** Typical substation with 7 Bays
Life Cycle Cost Analysis for 145 kV GIS (40 years life assumption)
Gas and Gas-Handlings costs of F-gases are considerable

1) Grid operator & end consumer perspective: Lowest life cycle costs with Clean Air
2) Society perspective: No costs for climate and environment with Clean Air
Our financial performance in Fiscal Year 2021

- **Revenue**: €28.5bn
- **Orders**: €33.0bn
- **Order backlog**: €84bn
- **Basic earnings per share**: €(0.63)
- **Adjusted EBITA before Special Items**: €661m
- **Adjusted EBITA margin before Special Items**: 2.3%

**Revenues by region**:
- **EMEA (Europe, Middle East, Africa)**: €14.1bn (of which Germany: €2.4bn)
- **Americas**: €8.1bn (of which USA: €4.9bn)
- **Asia, Australia**: €6.4bn (of which China: €1.6bn)
We enable a reliable, sustainable and digital grid through a leading portfolio

Our grid technology portfolio

**Digital Grid**
- Grid Consulting
- IoT and Edge
- Grid Automation

**Grid Solutions**
- High-Voltage Direct Current (HVDC) – onshore & offshore
- Flexible AC Transmission System (FACTS)
- Substations – onshore & offshore
- Medium-Voltage Direct Current (MVDC)

**Products**
- Power and Distribution Transformers
- Bushings, Instrument Transformers & Coils
- Renewables & Traction
- Switchgears
- Product bundles and systems

**Storage**
- Turnkey battery energy storage solutions (grid connected and off-grid)

**Service**
- Product services
- Modernization and upgrades
- Long-term service concepts and grid integration
East Anglia ONE: the world’s largest order for an offshore wind power plant

Gas-insulated switchgear
- Installation of 102 bays of SF$_6$-free 8VM1 Blue GIS™ for 72.5 kV with a total capacity of 714 MV to power around 500,000 British households with clean energy
- Vacuum interrupter technology
- Clean air insulation technology

Customer benefits
- Zero direct CO2 emissions
- Easiest gas handling process
- Reduced quantities of cable
- Reduced cable installation times
- Improved efficiencies in power transmission

Key facts
- Customer: Siemens Gamesa Renewable Energy for Scottish Power Renewables
- Offshore wind farm located off the east coast of England
- Operation of GIS requires no SF$_6$ or any other greenhouse gas
- Year of order: 2018
- Energization: 2020

January 2023
Key facts

- Customer: Netze BW GmbH, Germany
- Modernization of a 110 kV substation in Noerdlingen
- Operation requires no SF₆ or any other greenhouse gas
- Year of order: 2017
- Energization: 2018

The world’s first SF₆-free high-voltage switchgear with clean air insulation

Circuit breakers

- Installation of two SF₆-free 3AV1 Blue Circuit Breakers™ for 145 kV
- Vacuum interrupter technology
- Clean air insulation technology

Instrument transformers

- Six SVAA voltage and current transformers with clean air insulation
Success Story

- Customer: BKK Net, Norway
- Modernization of a 145 kV Koengen S/s in Bergen- Norway’s largest cruise port.
- Operation requires no SF₆ or other greenhouse gas anymore
- Year of order: 2018
- Energization: 2020

The world's first F-gas-free GIS with clean air & vacuum technology

Gas-insulated switchgear

- Installation of 3 bays of the 8VN1 Blue GIS™ for 145 kV
- Vacuum interrupter technology
- Clean air insulation technology

Low power instrument transformers

- GIS includes low power instrument transformers (LPIT) to ensure a compact design

“We anticipate that SF₆ will eventually be banned or burdened by restrictions and penalty fees, so when making investments in capacity and substations in and around Bergen, we opted to eliminate SF₆ from the equation- because we want to move towards sustainability, and we didn’t want to make a decision today that would embarrass us two years down the line.”

- Jens Skår, Division Manager, BKK Nett- Norway

### Stakeholders, legislation and regulations – Details Europe

Natural-origin gases with GWP < 1 are 100 % future-proof with no risk for regulatory exposure!

#### F-gas regulation
- **Trialogue negation started**
- **Decision and Adoption expected July 2023**

<table>
<thead>
<tr>
<th>Voltage Range</th>
<th>Decision / Publication</th>
<th>Preferred alternative</th>
</tr>
</thead>
<tbody>
<tr>
<td>(a) kV ≤ 24</td>
<td>Commission 05.04.2022</td>
<td>GWP &lt; 10</td>
</tr>
<tr>
<td>(b) 24 &lt; kV ≤ 52</td>
<td>Parliament 30.03.2023</td>
<td>F-gas-free</td>
</tr>
<tr>
<td>(c) 52 &lt; kV ≤ 145</td>
<td>Council 05.04.2023</td>
<td>GWP &lt; 10</td>
</tr>
<tr>
<td>(d) kV &gt; 145</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

#### PFAS* Restrictions
- **Decision and Adoption expected 2025**

- **PFAS* Restrictions started**
- **Decision and Adoption expected 2025**

**Report** from 07.02.2023 includes a restriction proposal for PFAS-F*-Gases in switchgears starting:

- 2026 / 2027 ≤ 145 kV, > 145 kV in 2033

* Per- and polyfluoroalkyl substances (forever chemicals) including C4-FN and C5-FK

### Table of Obligations

<table>
<thead>
<tr>
<th>Obligations F-Gases*</th>
<th>Reporting</th>
<th>Certification</th>
</tr>
</thead>
<tbody>
<tr>
<td>C4-FN, C5-FK</td>
<td>Same as SF₆</td>
<td>Reporting &amp; Certification</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Ban of Export</th>
<th>No</th>
<th>Yes</th>
<th>No</th>
</tr>
</thead>
<tbody>
<tr>
<td>Service exemptions</td>
<td>No</td>
<td>Repair</td>
<td>Repair, Expansion</td>
</tr>
</tbody>
</table>
Stakeholders, legislation and regulations – Details USA

Natural-origin gases with GWP < 1 are 100% future-proof with no risk for regulatory exposure!

SF6-gas regulation – In place in CA and being implemented by other states

- **January 2022 CARB SF6 regulation becomes effective** No reporting of Clean Air as GWP is zero

<table>
<thead>
<tr>
<th>Voltage Capacity (kV)</th>
<th>Short-Circuit Current Rating (kA)</th>
<th>Phase-Out Date</th>
</tr>
</thead>
<tbody>
<tr>
<td>38 ≤ kV ≤ 145</td>
<td>≤ 63</td>
<td>January 1, 2025</td>
</tr>
<tr>
<td></td>
<td>≥ 63</td>
<td>January 1, 2028</td>
</tr>
<tr>
<td>145 &lt; kV ≤ 245</td>
<td>&lt; 63</td>
<td>January 1, 2027</td>
</tr>
<tr>
<td></td>
<td>≥ 63</td>
<td>January 1, 2031</td>
</tr>
<tr>
<td>&gt; 245</td>
<td>All</td>
<td>January 1, 2033</td>
</tr>
</tbody>
</table>

- **July 2021 state of Maine** ‘Effective January 1, 2030, any product containing intentionally added PFAS may not be sold in Maine unless the use of PFAS in the product is specifically designated as a currently unavoidable use by the Department’.

- **3M** to stop production of PFAS from end 2025 (letter Dec 20, 2022) Including F gases used in switchgear

- **The Environmental Protection Agency (EPA) has established a PFAS* Council**

- **Many states restricting us of PFAS in fire fighting and food packaging**

PFAS* Restrictions started and manufacturing being stopped by 3M in 2025

- **New York state working on regulation to ban SF6**

- **Maryland commits to Net Zero GWP by 2045**

*Per-und polyfluoroalkyl Substances including F-Gases C4-FN
75 % of today’s SF₆-free High Voltage portfolio > 52 kV manufactured in Europe uses gases with GWP < 1

<table>
<thead>
<tr>
<th>Global OEMs manufacturing in Europe*</th>
<th>AIS CB</th>
<th>AIS IT</th>
<th>GIS / GIL***</th>
<th>Bushings</th>
</tr>
</thead>
<tbody>
<tr>
<td>Siemens Energy</td>
<td>NOG</td>
<td>-</td>
<td>NOG</td>
<td>-</td>
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<tr>
<td>Trench</td>
<td>-</td>
<td>NOG</td>
<td>-</td>
<td>NOG</td>
</tr>
<tr>
<td>HSP</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>NOG</td>
</tr>
<tr>
<td>Hitachi Energy</td>
<td>NOG (CO2/O2)</td>
<td>-</td>
<td>C5-FK, C4-FN</td>
<td>-</td>
</tr>
<tr>
<td>General Electric</td>
<td>C4-FN**</td>
<td>-</td>
<td>C4-FN</td>
<td>-</td>
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<tr>
<td>Pfifner</td>
<td>NOG</td>
<td>NOG</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Arteche</td>
<td>-</td>
<td>Open</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

Yearly new unit installations in Europe

- > 10.000
- > 20.000
- > 4.000
- > 25.000

*Global sales with complete portfolio, not limited to local country markets as e.g. Koncar and ELBUD; AIS Air-insulated switchgear, GIS Gas-insulated switchgear, GIL Gas-insulated line; CB Circuit-breaker, IT Instrument transformer; NOG Natural-origin gases (N₂/O₂ or CO₂/O₂) GWP < 1, **C4-FN Fluoronitrile (PFAS)-CO₂-O₂-Mixture GWP ~ 500, IP protected by 3M C5-FK Fluoroketone (PFAS)-CO₂-O₂-Mixture GWP < 1; **C4-FN can easily be moved to NOG (CO₂/O₂) -> slide 6

***Additional global OEMs manufacturing worldwide (Production outside Europe)
- All Japanese OEMs incl. Meiden, Toshiba, Mitsubishi & Hitachi use NOG; South Korea use partly NOG and C4-FN; China – 4 x NOG, 1 x C4-FN, most of OEMs in China are still open regarding alternative SF₆ technology
- Asian manufacturers successfully supply High Voltage CB & GIS with NOG to Europe with GWP < 1

Clear regulatory framework in EU with F-gas bans and sufficient transition time enables globally electric zero emission grids.

Global OEMs Europe > 52 kV
- GWP < 1
- C4-FN
- Open

Global OEMs World > 52 kV
- GWP < 1
- C4-FN
- Open

July 2023