सत्यमेव जयते

# REPORT OF THE COMMITTEE

## on Use of Green GIS Technology in Indian Grid

केविप्रा
cea

Government of India
Ministry of Power
Central Electricity Authority

April, 2026

घनश्याम प्रसाद
अध्यक्ष तथा पदेन सचिव भारत सरकार
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सत्यमेव जयते

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# FOREWORD

Green Gas Insulated Substation (Green GIS) is emerging as a sustainable alternative to conventional GIS, aligning with global efforts to reduce environmental impact while maintaining the reliability and efficiency of power systems. Although the contribution of conventional insulating gas to overall global emissions is relatively limited, there is a growing emphasis on adopting cleaner technologies as part of a broader commitment to sustainability. In this context, Green GIS technologies offer promising solutions by utilizing environmentally friendly insulating mediums without compromising performance. This report has been prepared to present an overview of the evolving Green GIS technologies, along with key considerations related to various technological options available, their technical performance, testing requirement and facilities available, indigenization, suitability for phased adoption and Model Guidelines for deployment of Green GIS technology.

I believe this Report would serve as a Reference document for all stakeholders including policymakers, power utilities, manufacturers, EPC contractors, and regulators, and all qualified OEMs, and in kick-starting Indian Power Sector's journey in adopting SF6-free solutions.

I commend the efforts of Sh. N.R.L.K. Prasad, Chief Engineer (PSE&TD Division), and his dedicated team, in bringing out this Report.

**(Ghanshyam Prasad)**

New Delhi
13 April 2026

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# Foreword

As per Regulation No. 44(3)(A) of Central Electricity Authority (Technical Standards for Construction of Electrical Plants and Electric Lines) Regulations, 2022, Gas Insulated Substation or Switchyard shall be constructed in Seismic prone areas, coastal areas, high altitude areas, very heavily polluted areas and for location where space is major constraint. Conventional GIS primarily uses $SF_6$ gas as the insulating medium, which provides excellent dielectric and arc-quenching properties. However, due to the high global warming potential of $SF_6$, increasing attention is being given to the development and adoption of alternative insulating technologies at the global level. These technologies aim to reduce environmental impact by using alternative insulating media while maintaining comparable performance and reliability.

In this context, the CEA Committee, which has been formed to explore the use of Green GIS in Indian Grid, has considered various aspects relating to the adoption of Green GIS in the Indian Grid, and encapsulated the same in this Report so that it can serve as a Reference Document for use by all concerned.

Considering the present status of technology and ecosystem readiness, a phased and cautious approach is considered appropriate for implementation. Pilot installations at lower voltage levels may be undertaken to gain operational experience, followed by gradual scaling based on performance and field feedback. In parallel, emphasis may be placed on the development of indigenous manufacturing facilities for Green GIS in the country.

**(Vijay Kumar Singh)**

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## Acknowledgements

Even though leakage rates from conventional SF6 based Gas Insulated Stations are not significant compared to emissions of other Green House Gas emissions, considering the high global warming potential (GWP) of SF6, alternative media for its effective replacement which offer similar degree of performance with potential environmental benefits are being developed globally.

In this context, the Technical Committee constituted by CEA has examined in detail the use of Green GIS in Indian Grid covering various aspects such as technical issues in establishing Green GIS, issues relating to their testing, strategy to be adopted for their implementation with focus on indigenization. It is brought out that Green GIS technologies present a promising pathway for reducing environmental impact in the power transmission sector. With a structured implementation approach, supported by technological validation, capacity building, and domestic capability development, a gradual transition from conventional $SF_6$-based GIS to Green GIS can be achieved while maintaining system reliability and operational safety.

I would like to express my sincere thanks to Original Equipment Manufacturers (OEMs), viz., M/s Hitachi Energy, M/s GE Vernova T&D India Limited, M/s Siemens Energy, M/s Toshiba T&D Systems (India) Private Limited, and M/s Hyosung T&D India Private Limited, for providing valuable inputs, product information and insights related to Green GIS technologies. My sincere thanks are also extended to Power Grid Corporation of India Limited for their cooperation and support in sharing practical perspectives on Green GIS.

I gratefully acknowledge the contribution of PSE&TD Division officers - Shri Bhanwar Singh Meena, Director, for smooth conducting of the Committee meetings, and Shri Pankaj Kumar Verma, Deputy Director, and Shri Bhavesh Mahawar, Assistant Director, for their die-hard contribution in enriching various details and in putting painstaking efforts in compiling the Report.

I am also thankful to Shri Ghanshyam Prasad, Chairperson, CEA and Shri V.K. Singh, Member (Power System), CEA for their encouragement, motivation, and invaluable guidance in preparation of this report.

**(N.R.L.K. Prasad)**

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**Foreword- Member (Power System)**
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## List of Abbreviations

| | | |
|---|---|---|
| AIS | : | Air Insulated Substation |
| BIS | : | Bureau of Indian Standards |
| CEA | : | Central Electricity Authority |
| CTUIL | : | Central Transmission Utility of India Limited |
| CAPEX | : | Capital Expenditure |
| CB | : | Circuit Breaker |
| DTB | : | Dead Tank Breaker |
| EMC | : | Electromagnetic Compatibility |
| EPD | : | Environmental Product Declaration |
| EPC | : | Engineering, Procurement and Construction |
| ESG | : | Environmental, Social and Governance |
| GIS | : | Gas Insulated Substation |
| GIB | : | Gas Insulated Bus Duct |
| GIL | : | Gas Insulated Line |
| GWP | : | Global Warming Potential |
| GHG | : | Greenhouse Gas |
| HSE | : | Health, Safety and Environment |
| IEC | : | International Electro-technical Commission |
| IEEE | : | Institute of Electrical and Electronics Engineers |
| LCA | : | Life Cycle Assessment |
| LTB | : | Live Tank Breaker |
| MoP | : | Ministry of Power |
| NCT | : | National Committee on Transmission |
| NEP | : | National Electricity Policy |
| ODP | : | Ozone Depletion Potential |
| OEM | : | Original Equipment Manufacturer |
| OPEX | : | Operational Expenditure |
| PASS | : | Plug and Switch System Hybrid Switchgear |
| PFAS | : | Per- and Polyfluoroalkyl Substances |
| PGCIL | : | Power Grid Corporation of India Limited |
| QCBS | : | Quality and Cost Based Selection |
| $SF_6$ | : | Sulphur Hexafluoride |
| ToR | : | Terms of Reference |

# Executive Summary

Gas Insulated Substation (GIS) is widely used in the power transmission system due to its compact design, high reliability, and suitability for urban and space-constrained areas. Conventional GIS primarily uses $SF_6$ gas as the insulating medium, which provides excellent dielectric and arc-quenching properties. However, due to the high global warming potential of $SF_6$, increasing attention is being given to the development and adoption of alternative insulating technologies at the global level. These technologies aim to reduce environmental impact by using alternative insulating media while maintaining comparable performance and reliability.

In this context, a Technical Committee has been constituted by CEA to examine and explore the use of Green GIS in the Indian Grid. The Committee during their deliberations discussed in detail various technical issues in establishing Green GIS, issues relating to their testing, strategy to be adopted for their implementation with focus on indigenization.

It is observed that multiple $SF_6$-free or Green GIS technologies are being developed and deployed globally. The prominent alternatives include fluoronitrile-based gas mixtures and clean air combined with vacuum interruption. These technologies offer significantly lower environmental impact compared to $SF_6$ while aiming to maintain comparable electrical performance. However, their level of maturity varies across voltage levels. While deployment at lower voltage levels such as 132 kV is feasible, application at higher voltage levels requires further field validation, operational experience, and standardization.

It is observed that alternative insulating media used in Green GIS should possess adequate dielectric strength, arc-quenching capability, thermal stability, and compatibility with materials used in GIS construction to ensure reliable long-term performance. Accordingly, the report details all pertinent aspects for the successful implementation of Green GIS. Various technologies, including fluoro-nitrile based gas mixtures and clean air with vacuum interruption - each having its own advantages and limitations in terms of performance, footprint, and application range - have been considered. In addition, aspects such as long-term performance reliability, material compatibility, leakage monitoring, gas handling practices, availability of testing facilities, and requirement of skilled manpower have also been covered in sufficient detail. The report also notes that hybrid GIS configurations can offer a practical solution for phased adoption and upgradation by combining advantages of both AIS and GIS.

From implementation perspective, it is brought out that a phased and cautious approach would be appropriate. Initial deployment may be taken up through pilot projects at lower voltage levels to gain operational experience and validate performance under Indian conditions. Based on the outcomes, the deployment can be gradually scaled up. The report also notes that execution timelines for Green GIS projects may be longer at present due to limited manufacturing base and dependence on imports.

Development of indigenous manufacturing capability is identified as an important factor for long-term adoption. Strengthening domestic manufacturing would help reduce dependency on imports, improve equipment availability, and optimize costs over time. In addition, development of testing infrastructure and standardization framework would support wider adoption and ensure reliability of the technology.

Overall, Green GIS technologies present a promising pathway for reducing environmental impact in the power transmission sector. With a structured implementation approach, supported by technological validation, capacity building, and domestic capability development, a gradual transition from conventional $SF_6$-based GIS to Green GIS can be achieved while maintaining system reliability and operational safety.

# 1. Introduction

## 1.1 Background

For several decades, sulfur hexafluoride ($SF_6$) has been extensively used as the primary insulating and arc-quenching medium in Gas Insulated Substations (GIS) owing to its exceptional dielectric strength, superior arc-interruption capability, and high thermal and chemical stability under a wide range of operating conditions. The unique physical and electrical properties of $SF_6$ such as its high electronegativity, strong arc-cooling characteristics, and ability to rapidly recombine after electrical discharges—have enabled compact insulation systems and efficient interruption of high short-circuit currents, even at extra-high voltage levels. As a result, $SF_6$-based GIS has facilitated the development of standardized, modular, and highly reliable substation equipment across multiple voltage classes, with proven performance over long service lifetimes. These advantages have played a significant role in supporting grid expansion and densification in locations where land availability, safety considerations, and right-of-way limitations restrict the deployment of conventional air-insulated substations, particularly in urban areas, underground installations, offshore platforms, and critical industrial facilities.

$SF_6$ is a potent Greenhouse gas with an extremely high Global Warming Potential (GWP) of 24300 of $CO_2$ equivalent and a long atmospheric lifetime. As such, even small leakage rates, and any untoward incidents resulting from SF6 based GIS installations are associated with environmental costs. In response to evolving climate objectives and regulatory pressures, manufacturers and utilities across the globe are actively developing and deploying $SF_6$ free switchgear technologies that aim to substantially reduce the carbon footprint of high-voltage installations without compromising on performance, reliability, compactness, or scalability. The availability of a scalable $SF_6$-free technology platform spanning multiple voltage levels is essential for enabling widespread adoption, ensuring seamless integration across transmission networks, and facilitating standardized asset management practices, thereby supporting a sustainable transition of power grid infrastructure.

## 1.2 Committee Constitution

In the 24th NCT meeting held on 23.10.2024, CTUIL informed that the 132 kV Badarpur (Powergrid) switching station had been commissioned in the year 1999 and completed 25 years of operation in 2024. As the owner of the switching station, PGCIL had been experiencing challenges in the operation and maintenance of the facility. In order to improve system reliability, it was considered appropriate to upgrade the switching station from the existing single main and transfer bus configuration to a double main and transfer bus scheme, along with conversion of the switchgear from Air Insulated Switchgear (AIS) to Gas Insulated Switchgear (GIS). During deliberations, it was proposed that the upgradation may be undertaken using Green GIS instead of conventional GIS.

In this context, to examine and explore the use of Green GIS in the Indian Grid (Green GIS Committee), a Committee was constituted vide CEA letter dated 18.12.2024 (**Annexure-I**). The details of the Committee Members are given as under:

| | | |
|---|---|---|
| 1 | Sh. N.R.L.K. Prasad, Chief Engineer (PSE&TD Division), CEA | Chairperson |
| 2 | Director (ET&I Division), CEA | Member |
| 3 | Director (CE&ET Division), CEA | Member |
| 4 | Sh. K.K. Sarkar, Sr GM (Engg), CTUIL | Member |
| 5 | Sh. M.S. Rao, Sr. GM(TD), PGCIL<br>Sh. R.P.S. Rana, GM(AM), PGCIL | Member |
| 6 | Director (PSE&TD Division), CEA | Member Convener |

The Terms of Reference (ToR) of the Committee are as follows:

(a) Survey green GIS literature and SF6 alternatives.
(b) Explore the technical aspects in upgradation of existing substations in Green GIS.
(c) Explore possibility of hybrid GIS S/s.
(d) Explore aspects of availability of Green Gas in India, possibility of manufacturing in India etc.
(e) Cost comparison of normal GIS vs green GIS substations.
(f) Technology transfer
(g) Any other relevant issues.

## 1.3 Proceedings of the Committee

Owing to the evolving nature of the subject matter, the Committee, in their meetings, invited various OEM's in the Green GIS field for gaining valuable insights.

The Committee conducted two meeting to deliberate on the matter. The first meeting was held on 14.07.2025 where the technology available with various OEMs (M/s Hitachi Energy, M/s GE and M/s Siemens) was discussed covering technical, commercial, and other relevant aspect of the available technology. The minutes of the first meeting are enclosed at **Annexure-II.**

The second meeting of the Committee was held on 23.12.2025. In the second meeting, two other OEMs (M/s Toshiba and M/s Hyosung) were invited to brief the technology and Green GIS products available with them. In addition to above, certain general items as well as specific items requested by various members covering various aspects of using Green GIS in the Indian Grid were discussed in detail. The minutes of the second meeting are enclosed at **Annexure-III**. In the meeting, all Committee members, and OEMs were also requested to provide additional details covering regulatory and financial and tendering aspects.

Based on the deliberations held, and all relevant information made available, the Report has been structured to address the following aspects:

- Technical Aspects in Establishing Green GIS
- Testing Requirements
- Push for Indigenization
- Implementation Strategy
- Leakage Monitoring

- Financial Incentives
- GHG mitigation and Carbon Credit
- Global Efforts in Reducing SF6 based GIS
- Model Guidelines for Deployment of Green GIS Technology in India
- Model Tender Evaluation Criteria for Green GIS for the Technologies available

Ensuing sections discuss the above in sufficient detail.

# 2. Technical Aspects in Establishing Green GIS

## 2.1 Requirements of Alternative Medium to SF6 Gas

$SF_6$ is a potent Greenhouse gas with a very high Global Warming Potential (GWP) of 24300 of $CO_2$ equivalent and a long atmospheric lifetime. The driving factor across the Globe to develop an alternative to $SF_6$ is its high impact on the environment. Therefore, it is necessary that alternative to $SF_6$ remains environmentally friendly in addition to meeting stringent technical and environmental criteria to be viable for the Indian Grid. Some of the factors which a potential SF6-free Alternative should meet are detailed under.

### a) Environmental: Zero Ozone Depletion Potential (ODP) and Lower GWP

From an environmental perspective, the insulating medium used in Green GIS should exhibit Zero Ozone Depletion Potential (ODP) and a significantly lower Global Warming Potential (GWP) compared to Sulfur Hexafluoride ($SF_6$). Reduction in GWP is a critical requirement considering the long service life of GIS installations and the cumulative impact of potential gas leakage over time. Adoption of low GWP insulating media directly contributes to minimizing lifecycle greenhouse gas emissions from transmission infrastructure while ensuring environmental compliance without compromising system performance.

### b) Safety: Non-toxic and Non-flammable

From a safety perspective, the insulating medium used in Green GIS should be non-toxic and non-flammable, ensuring safe handling, operation, and maintenance under normal as well as abnormal operating conditions. The gas or gas mixture should not pose health hazards to operating personnel and should not support combustion or explosion, even in the event of internal faults or arcing. Consideration should also be given to the nature and impact of any decomposition of by-products to ensure safe operation over the entire service life of the equipment.

### c) Low Boiling Point and Ability to withstand High Pressures

Switchgear in power systems (like GIS and circuit breakers) operate in wide ambient temperatures, sometimes as low as –25°C to –40°C in cold regions. Further, to increase the insulation levels, high pressures are typically employed for the gases in switchgear.

However, as gas insulation works properly only when the gas remains uniformly in gaseous form, the gas to be used should have low boiling point as well as ability to maintain its gaseous state at the pressures typically employed. This is necessary to avoid liquefaction, which can lower dielectric strength and may lead to insulation failure or flashover. The condensation may also lead to non-uniform dielectric strength which can lead to risk of partial discharge and increase in breakdown.

### d) Performance: Dielectric Strength, Arc Quenching, and Thermal Stability

Similar to SF6 gas, the insulating medium used in Green GIS should provide adequate dielectric strength, effective arc-quenching capability, and stable thermal performance to meet the operational requirements of high-voltage substations. The insulation and interruption system shall comply with applicable IEC standards for power-frequency, lightning impulse, and switching impulse withstand levels, as well as short-circuit interruption duties. The insulating medium shall maintain consistent electrical and thermal characteristics over the full range of operating conditions to ensure reliable long-term performance equivalent to conventional $SF_6$-based GIS.

**e) Reliability: Material Compatibility and Lifecycle Stability**

From a reliability perspective, the insulating medium and associated components used in Green GIS should demonstrate compatibility with enclosure materials, seals, conductors, and internal insulating components to prevent degradation, corrosion, or loss of performance over time. The gas and its decomposition by-products shall not adversely affect material integrity throughout the expected service life of the substation. Ensuring long-term chemical stability and material compatibility is essential to maintain gas tightness, minimize leakage, and achieve reliable operation over the full lifecycle of the equipment.

## 2.2 Technological Options Available

Global Switchgear companies have come out with the following principal technological pathways as viable alternatives to $SF_6$ gas:

- Fluoronitrile-based gas mixtures (C4-FN + CO2 + O2)
- Vacuum interruption combined with clean air insulation (N2 + O2)
- Mixture of CO2, O2, and N2

These technologies claim to provide balancing performance, environmental sustainability, and scalability across voltage levels, and represent the current global developments in $SF_6$ free GIS substation systems. A comparison of these technologies is given in the below Table:

| SN | Parameter | $SF_6$ | C4-FN | $CO_2 + O_2$ | Clean Air |
|---|---|---|---|---|---|
| 1. | Composition | Pure $SF_6$ | Fluoronitrile gas mix | $CO_2$+$O_2$ | N2 + O2 (79.5% + 20.5%) |
| 2. | GWP | Very high (24,300) | 99 % Lower compared to $SF_6$ | GWP<1 | Zero |
| 3. | Atmospheric Lifetime | 3200 years | 35 years | Naturally Occurring | Naturally Occurring |
| 4. | Environmental Impact | High | Low | Negligible | No Harmful Impact |
| 5. | GIS Footprint | Very compact | Approx. same as SF6 GIS | Larger than SF6 GIS | Larger than SF6 GIS |
| 6. | Operating Temp | ---- | -30 °C to 50 °C | ---- | -60 °C to 55 °C |
| 7. | Gas Handling | Strict | Controlled | Simple | Simple |
| 8. | Safety | Non-Toxic | Precautions needed | Safe | Safe |

| | | | | | |
|---|---|---|---|---|---|
| 9. | Retrofilling | Exist | Possible in non-switching components | No | No |
| 10. | Gas Availability | High | Limited in India | Naturally Available | Naturally Available |
| 11. | Maturity | Mature Technology | Developing | Developing | Developing |
| 12. | Testing | As per IEC Standard | As per IEC Standard | As per IEC Standard | As per IEC Standard + X-radiation test |
| 13. | Cost | | 6-8 times of $SF_6$ | 6-8 times of $SF_6$ | 6-8 times of $SF_6$ |

*Table 1: Comparison of Available GIS Technologies*

### a) EconiQ (Hitachi Energy)

Hitachi Energy has come out with their solution named as "EconiQ". The EconiQ technology employs optimized gas mixtures based on fluoronitrile ($C_4$-FN) blended with carrier gases such as $CO_2$, $O_2$, or $N_2$, selected according to application requirements. For metal-enclosed switchgear such as GIS, Dead Tank Breakers (DTB), and hybrid systems, a mixture of $CO_2$ (86.5%), $O_2$(10%) and $C_4$-FN(3.5%) is used to retain compact dimensions and high dielectric strength. In case of retro-filling of Gas Insulated Line (GIL)/ Gas Insulated Busduct (GIB), a mixture of $CO_2$ (85%), $O_2$ (5%) and $C_4$-FN (10%) is used to match the dimension required for $SF_6$. For live-tank circuit breakers, a mixture of $CO_2$ and $O_2$ is used for both insulation and interruption thereby eliminating fluorinated gases altogether in these applications.

From an environmental and safety perspective, the gas mixtures used in EconiQ solutions exhibit zero ozone depletion potential, 99 % Lower GWP potential compared to $SF_6$, and favorable health and safety characteristics. The mixtures are non-flammable, non-toxic in their applied concentrations and decompose naturally without accumulating in the environment. They do not accumulate in soil, water, or vegetation, and have an atmospheric lifetime of approximately 30 years.

The EconiQ is a scalable technological solution for eliminating $SF_6$ from high-voltage gas-insulated substations while maintaining the performance, reliability, and compactness of conventional GIS. The technology is designed to match conventional GIS in terms of dielectric performance, short-circuit capability, operational reliability, and footprint, making it suitable for deployment across a wide range of voltage levels, including extra-high-voltage applications up to 420 kV and beyond.

Hitachi Energy's EconiQ portfolio is as under:

| High-voltage portfolio | Presently Available | Future Expansion |
|---|---|---|
| Live Tank Circuit Breaker (LTB) | 72.5 kV-31.5 kA<br>145 kV-40 kA<br>420 kV-63 kA<br>420 kV-80 | 245 kV-63 kA<br>170 kV-40 kA<br>(2028 and beyond) |
| Dead Tank Circuit Breaker (DTB) | 72.5 kV,145 kV- 40 kA<br>420 kV-63 kA<br>550 kV-63 kA<br>420 kV-80 kA | 245 kV-63 kA (2026)<br>800 kV-63 kA (2027) |
| Plug and Switch System Hybrid Switchgear (PASS) | 420 kV- 63 kA,<br>72.5 kV, 145 kV- 40 kA | |
| Gas Insulated Switchgear (GIS) | 72.5 kV,145 kV- 40 kA<br>420 kV-63 kA<br>550 kV-63 kA<br>420 kV-80 kA | 245 kV-63 kA (2026)<br>145 kV-63 kA (2027)<br>170 kV-50 kA (2028 and beyond) |
| Gas Insulated Line (GIL) | 420 kV, 550 kV | 245 kV (2026) |
| Retrofill for GIL (Service) | 420 kV, 550 kV | |

*Table 2: Hitachi Energy's EconiQ Portfolio*

### b) g3 (GE Vernova)

GE Vernova has developed "$g^3$" technology as an eco-efficient alternative to $SF_6$ for high-voltage power equipment. The $g^3$ gas mixture consists primarily of $CO_2$ (>82%), $O_2$ (5–13%), and fluoronitrile ($C_4F_7N$: 3.5–6%), which together reduce the global warming potential by approximately 99% compared to $SF_6$, while delivering equivalent electrical performance. GE Vernova uses the mixture of just $CO_2$ and $O_2$ in case of Live Tank Circuit Breaker. In case of Metal enclosed Equipment, GE Vernova solution uses mixture of $CO_2$, $O_2$, and fluoronitrile ($C_4F_7N$), the mixture is called as "$g^3$".

In the $g^3$ gas mixture, $CO_2$ improves arc-extinction capability, $O_2$ stabilizes the gas during arcing and limits decomposition, and $C_4F_7N$ enhances insulation strength and arc-quenching performance. This optimized combination ensures reliable operation under all electrical parameters as defined in IEC 62271-1 (2021), with performance identical to conventional $SF_6$-based GIS.

The size of the GIS remains the same as that of GIS with $SF_6$ for similar voltage and bay configurations. Moreover, design of GIS bay and Busduct with g3 as gas mixture is scalable and can be made available up to the maximum voltage levels (of 800 kV), operating current and short time current (STC).

From an operational perspective, $g^3$ equipment uses standard gas monitoring, pressure gauges, and handling practices, similar to those used for $SF_6$. Premixed gas will be supplied by established industrial gas manufacturers. Utilities can easily adopt $g^3$ for operation and maintenance throughout the equipment lifecycle with minimal training to its personnel. $g^3$ technology offers the low lifecycle environmental footprint, without compromising safety, reliability, or performance.

GE Vernova's $g^3$ portfolio is as under:

| High-voltage portfolio | Presently Available | Future Expansion |
|---|---|---|
| Live Tank Circuit Breaker (LTB) | 72.5 kV, 145 kV | 420 kV (2026)<br>170 kV (2028)<br>245 kV (2029)<br>Up to 800 kV-80 kA (2030+) |
| Dead Tank Circuit Breaker (DTB) | 72.5 kV, 145 kV | HYpact 72.5 / 145 kV (2026)<br>245 kV (2027)<br>362 kV (2028)<br>550 kV (2029) |
| Gas Insulated Substation (GIS) | 72.5 kV, 145 kV, 245 kV, 362 kV, 420 kV | 170 kV (2026)<br>145 kV-63 kA (2027)<br>420 kV-80 kA (2028)<br>550 kV (2029) |

*Table 3: GE Vernova's $g^3$ Portfolio*

Over 1,000 g3-equipped bays are operational across the world at 145 kV and 420 kV gas-insulated substations (GIS), including more than 30 km of gas-insulated lines (GIL), and more than 150 live tank circuit breakers (LTB). Utilities in more than ten countries have adopted g3 for new installations and retrofits.

### c) Blue GIS (Siemens Energy)

Siemens Energy's Blue portfolio is based on a combination of Vacuum Interruption and Clean Air Insulation, i.e., mixture of $N_2$ (80%) and $O_2$ (20%) as a complete replacement for $SF_6$ in high-voltage switchgear. This technology eliminates the use of fluorinated greenhouse gases and provides an insulating medium with zero global warming potential, zero ozone depletion potential, and non-toxic, non-flammable characteristics. The clean air insulation and vacuum switching concept is inherently stable and capable of reliable operation over a wide temperature range, making it suitable for diverse climatic and environmental conditions.

From a technical and operational perspective, the Blue technology offers excellent short-circuit switching performance without degradation, high reliability, and stable operation over a wide temperature range (-60 ºC to +55 ºC). The system is sealed-for-life, maintenance-free, and does not require special gas handling systems. Since the gas mixture is of Nitrogen and Oxygen which are naturally available in the atmosphere, therefore no ventilation, $CO_2$ monitoring, or complex safety infrastructure is required in GIS Hall. Gas leakage levels are below 0.1% per annum per compartment, comparable to conventional GIS, while eliminating environmental risk. The technology of Clean Air Insulation has no patent dependency, therefore, allowing multiple supply chains and long-term supply security.

The vacuum and clean air configuration provides lowest lifecycle environmental and economic cost, as it requires no special end-of-life (EOL) treatment, no gas recovery, and no regulated disposal processes. The absence of hazardous gases simplifies installation, operation, and decommissioning, making the system maintenance and regulation-free over its full lifecycle. The technology offers unmatched advantages in terms of sustainability, safety, lifecycle cost, and regulatory resilience. However, the footprint of Clean Air Insulation based equipment is comparatively larger than that of conventional $SF_6$ GIS, Hitachi Energy's EconiQ and GE Vernova's g3.

The Siemens Blue portfolio is already deployed globally across GIS, Circuit Breakers, and Gas Insulated Busduct systems, demonstrating technical maturity, scalability, and operational reliability. This technology provides a fully fluorine-free, climate-neutral solution for future power transmission infrastructure and represents a long-term sustainable pathway for Green GIS implementation in India. Siemens has delivered first HV vacuum CB with clean air 145 kV in 2017, first HV vacuum GIS with clean air 145 kV in 2018 and first GIB with clean air 420 kV in 2022.

Siemens's Blue portfolio is as under:

| High-voltage portfolio | Presently Available | Future Expansion |
|---|---|---|
| GIS | 72.5 kV-25 kA<br>72.5 kV-31.5 kA<br>145 kV-40 kA<br>145 kV-50 kA | 72.5 kV-50 kA (2027)<br>145 kV-63 kA (2026)<br>145 kV-31.5 kA (2030)<br>245 kV-63 kA (2029)<br>420 kV-80 kA (2029)<br>550 kV-80 kA (2032) |
| 420/ 550 kV GIS | BP, 420 kV/ 63 kA | CB, 420 kV-63 kA (2027) |
| Live Tank Circuit Breaker (LTB) | FG, 145 kV-40 kA (1G) | FI/FG, 145 kV-40 kA (2G) (2026)<br>420 kV-63 kA (2026)<br>420 kV-80 kA (2028)<br>FI, 245 kV-63 kA (2029)<br>550 kV-63 kA (2029)<br>800 kV-63 kA (2030) |
| Dead Tank Circuit Breaker (DTB) | 145 kV-40 kA<br>145 kV-63 kA | 72.5 kV-40 kA (2026)<br>245 kV-63 kA (2029)<br>362 kV-63 kA (2029)<br>550 kV-63 kA (2031) |
| DC GIS | - | BP, DC 550 kV (2027)<br>HSS, DC 550 kV (2031) |
| DC Live Tank | indoor commutation and high-speed switches | outdoor and multiterminal switches (2028) |
| GIB/GIL | GIB 145 kV-63 kA<br>GIB, 420 kV-63 kA | |

*BP-Back parts i.e. other than CB, CB-Circuit Breaker, GIB-Gas Insulated Busbar
**FI-Single Pole Drive, FG-Common Drive

*Table 4: Siemens's Blue Portfolio*

### d) AEROXIA (Toshiba)

Toshiba's "AEROXIA" Green GIS solution is based on natural origin gas mixtures comprising Nitrogen ($N_2$), Carbon Dioxide ($CO_2$) and Oxygen ($O_2$). The technology is positioned as an alternative gas-insulated solution utilizing gases that are free from fluorinated compounds and PFAS substances. The gas solution has Global Warming Potential close to unity and zero Ozone Depletion Potential. The approach emphasizes environmental compatibility, non-toxicity, non-flammability, stable supply chain, and simplified gas handling without the need for specialized gas recovery infrastructure. The AEROXIA natural origin gas solution is based on mature SF6 design technologies. It is therefore potentially scalable to cover the existing high voltage and large capacity ratings.

Since AEROXIA uses carbon-neutral natural origin gas mixtures, negligible impact on climate change and ozone layer depletion will be caused even if the gas is accidentally emitted to the atmosphere. Since AEROXIA gases do not condense down to -50 $^{o}$C even under high gas pressure, they are a perfect fit for low temperature outdoor applications. The AEROXIA natural origin gas solution enables simplified gas handling processes where special gas handling gear is not necessary and even gas recovery may not be required.

The AEROXIA solution has already achieved replaceable equipment size of the 72/84 kV GIS, and will realize compatible equipment size to those of existing SF- products by continuous technical innovations. F-Free High Voltage Switchgears Technology and Product Development Road maps are given below:

| **High-voltage portfolio** | **Presently Available** | **Future Expansion** |
|---|---|---|
| Solid Insulated Switchgear | Up to 72 kV | |
| Gas Insulated Switchgear (GIS) | 72 kV-31.5 kA | 220 kV-50 kA: FY 35 -39<br>400 kV-63 kA: FY 35 -36 |
| Gas Insulated Bus Ducts (GIB) | 145 kV-40 kA<br>145 kV-63 kA | 400 kV-63 kA: FY 26 -27<br>220 kV-50 kA: FY 35 -39 |

*Table 5: Toshiba (AEROXIA) Portfolio*

### e) Hyosung Green GIS

Hyosung is developing their Green GIS product in Korea. As of now, Hyosung has developed Gas Insulated Switchgear upto Voltage level 170 kV, 50 kA. Hyosung is using C4-FN" gas mixture for their alternate to $SF_6$ gas. C4-FN gas mixture enables Hyosung to maintain the same performance level as $SF_6$ while reducing climate impact by approximately 98%. They are also using the same gas composition based on fluoronitrile. As informed by Hyosung, 132 kV Green GIS product has already been type tested, 400 kV Green GIS product has been developed and is currently undergoing type testing, and 220 kV Green GIS product is planned to be completed in the second half of 2026.

Hysoung is planning to begin developing export-oriented products in 2026 and to gradually expand the application of this technology across its entire GIS portfolio—from small to large-scale switchgear—by 2030.

| **High-voltage portfolio** | **Presently Available** | **Future Expansion** |
|---|---|---|
| Gas Insulated Switchgear (GIS) | 170 kV-50 kA | 145 kV-40 kA: 2026<br>245 kV-50 kA: 2026<br>420 kV-63 kA: 2026<br>145 kV-63 kA: 2028 |

| | | |
|---|---|---|
| | | 245 kV-63 kA: 2028<br>420 kV-80 kA: 2028<br>550 kV-63 kA: 2030<br>800 kV-50 kA: 2030 |

*Table 6: Hyosung Green GIS Portfolio*

## 2.3 Interoperability

Interoperability between conventional $SF_6$ based GIS supplied by different OEMs is achieved through the use of custom-designed interface adaptor modules. Such interfaces incorporate gas-tight barrier insulators, ensuring that the existing and newly installed GIS sections operate as independent gas compartments. This arrangement prevents intermixing of $SF_6$ gas and allows each section to be maintained at its respective operating pressure, thereby ensuring electrical integrity and operational safety. The governing design parameter for such interconnections is the permissible gas pressure difference between adjacent compartments, which is typically maintained within the range of 2.5 to 3 bar. In cases where a higher pressure differential is anticipated, additional design measures, such as dual barrier arrangements with an intermediate dummy isolator are adopted to safely accommodate the pressure difference. These established engineering solutions provide a reliable framework for interoperability in conventional GIS/ hybrid GIS configurations.

However, Interoperability between GIS systems employing different insulating media i.e. solution used by different OEMs is a complex technical issue. At present, it is noted that practical field installations demonstrating direct interoperability between different $SF_6$ free technologies, or between $SF_6$ free GIS and $SF_6$ GIS within the same GIS are not present. Consequently, such interoperability arrangements are still at an exploratory stage and require further validation through detailed engineering studies and controlled pilot implementations.

It is recognized that interoperability between GIS systems using different insulating gases may introduce operational risks. In case of SF6 based GIS, mixing of SF6 gas between GIS of two different OEMs does not compromise the purity of the insulating medium as single gas i.e. SF6 is used in the GIS of all the OEMs. However, in case of Green GIS as the OEMs are using different mixtures as insulating medium, even after using interfaces or gas barriers seals, or pressure boundaries, there is a possibility of unintended intermixing of different gases. Such intermixing may adversely affect dielectric strength, arc-quenching capability, and thermal performance, as the resulting gas composition would deviate from the design specifications of the respective systems. This could compromise equipment reliability and operational safety. Accordingly, any consideration of interoperability would require robust gas separation designs, fail-safe sealing arrangements, and clearly defined operational and maintenance guidelines. Until such measures are proven through experience and testing, the use of mixed-gas interoperability within a single GIS system may be avoided in favor of clearly segregated configurations.

## 2.4 Green Retro-filling and Green Retro-fitting (Upgradation)

Among the technologies available as on date, EconiQ solution is claimed to have the technical capability of being used for retro-filling of existing conventional GIS. Hitachi Energy is using a mixture of $CO_2$ (85%), $O_2$ (5%) and $C_4$-FN (10%) to match the dimension required for $SF_6$ Switchgear. However, the solution for retro-filling is available only for Gas Insulated Line (GIL)/ Gas Insulated Busduct (GIB). Retro-filling of switching components like Circuit Breakers, Disconnectors is not feasible, as the interrupting chambers are specifically designed for a defined insulating and arc-quenching medium and are subjected to high thermal and dielectric stresses during switching operations. Any deviation from the original gas design may adversely affect interruption capability, dielectric strength, and overall equipment reliability.

With respect to retro-fitting/ upgradation of existing substations to Green GIS technology, conversion from AIS to Green GIS, or from conventional $SF_6$ based GIS to Green GIS, it generally requires complete replacement of the primary equipment. Partial modification of the installed GIS is not practical due to differences in gas systems, sealing arrangements, design pressures, and internal construction. Consequently, such conversions would effectively involve dismantling of the existing primary infrastructure and installation of new equipment. However, in the case of fluoronitrile-based Green GIS solutions, where equipment dimensions are comparable to conventional GIS, reuse of the existing GIS building and associated civil structures may be feasible, subject to detailed engineering assessment and layout verification.

## 2.5 Green Hybrid GIS Configurations

Hybrid Gas Insulated Substation (Hybrid GIS) is a substation configuration that combines the main components of gas-insulated technology—such as circuit breakers, disconnectors, and earthing switches—within compact, metal-enclosed, gas-filled modules, while using air/ solid-insulated busbars and external connections. This conventional hybrid arrangement typically results in a 50–70% reduction in substation footprint compared to traditional Air Insulated Switchgear (AIS), making it well suited for urban substations, brownfield expansions, and sites with limited land availability. The entire installation is outdoor, with suitable modification in the paint and surface coating of equipment to meet environment and site conditions. The encapsulated GIS components provide high reliability and require minimal maintenance, while the air-insulated portions simplify construction, reduce overall cost, and allow easier future extension. As a result, Hybrid GIS offers a practical and flexible solution that balances compactness, operational reliability, and ease of installation and expansion.

During the deliberations, Hybrid GIS was examined as a practical configuration for the upgradation and phased modernization of existing substations. It was observed that such configurations allow retention of existing busbars and gantries, thereby reducing the extent of civil works, construction duration, and associated system outages. The suitability of outdoor Hybrid GIS installations was noted with emphasis on the need for appropriate paint systems, surface coatings, and corrosion protection to meet environmental and site conditions.

In Indian Grid, there are a few substations which are near to end of their life. Further, there are also few substations where due to increase in the demand, requirement of a greater number of bays has arisen. In these substations, deployment of Green Hybrid GIS may be explored which shall has the lesser footprint in addition lesser Global Warming Potential, therefore, may be accommodated in the existing Substation.

## 3. Testing Requirements

The reliability of conventional GIS in the Indian power system is underpinned by rigorous Type Testing and Routine Testing as mandated by international standards such as IEC 62271-203. During the deliberations by the Committee, it was noted that the basic testing framework for Green GIS remains largely the same as that applied to conventional $SF_6$-based GIS. This ensures that key performance aspects, including dielectric insulation strength, temperature rise under continuous loading, and the ability to safely withstand & interrupt short-circuit currents, continue to meet established grid safety and reliability benchmarks.

However, since Green GIS uses alternative insulating media and, in some cases, modified equipment designs, it may be necessary to identify and carry out additional tests beyond those prescribed for conventional $SF_6$ based GIS. Such tests, if required, should be aimed at confirming the performance, operational safety, and long-term reliability of the equipment under Indian grid conditions. The need for any additional testing is to be assessed, depending on the specific technology adopted, and those tests shall be carried out in accordance with relevant international standards or established technical practices to ensure that Green GIS meets the same level of reliability and safety as conventional GIS. As informed by Siemens Energy, in case of Clean Air Technology, X radiation test is additionally required.

The list of necessary Type tests required to be conducted on Green GIS is as below**:**

| SN | Name of the Type Test | Test Facility Availability in India (Yes/No) | Name of Testing Lab/ Organization having the Test Facility in India |
|---|---|---|---|
| 1 | Dielectric tests | Yes.<br>Upto 420kV rating | CPRI, Bengaluru |
| 2 | Radio interference voltage (R.I.V.) test | Yes. | CPRI, Hyderabad |
| 3 | Measurement of the resistance of circuits | Yes. | CPRI, Hyderabad<br>CPRI, Bengaluru |
| 4 | Gas tightness tests | No. | Proposed to be established in CPRI, Hyderabad |
| 5 | Temperature-rise tests | Yes. | CPRI, Hyderabad<br>CPRI, Bengaluru |
| 6 | Short-time withstand current and peak withstand current tests | Yes.<br>Up to 170kA 3sec up to 800kV class | CPRI, Bengaluru |
| 7 | Verification of the protection | Yes.<br>Degree of protection (upto IP65) | CPRI, Bengaluru<br>CPRI, Bhopal |
| 8 | Electromagnetic compatibility tests (EMC) | No. | Proposed to be established in CPRI, Hyderabad |
| 9 | Mechanical and environmental tests | No. | -- |
| 10 | Partial Discharge Test | Yes. | CPRI, Hyderabad |

| | | | |
|---|---|---|---|
| 11 | Pressure Withstand Test on Enclosure | No. | -- |
| 12 | Additional tests on auxiliary and control circuits | Yes. | CPRI, Bengaluru |
| 13 | X-radiation test procedure for vacuum interrupters | No. | -- |
| 14 | Verification of making and breaking capacities | Yes.<br>Up to 36kV rating | CPRI, Bengaluru<br>CPRI, Bhopal |

*Table 7: Type tests for Green GIS as per IEC 62271-203 & IEC 62271-1*

In addition to above, Routine test shall also be carried out as per IEC 62271-203. IEC 62271-203: 2022 clearly mentions that if the GIS is designed to use any other gas than $SF_6$, the necessary technical grade and the characteristics of the gas/ gas mixture used for the type testing shall be defined and documented by the manufacturer of the GIS and documented in the type test reports.

IEC 60376:2018 defines the quality for technical grade sulphur hexafluoride (SF6) and complementary gases such as nitrogen (N2) and carbon tetra-fluoride (CF4), for use in electrical equipment. For quality of alternate to $SF_6$ gases, IEC has come out with IEC 63360-2025 which specifies the quality of gases alternative to SF6 for use in electrical power equipment. Further, IEC has incorporated gases alternative to SF6 in the standard IEC 62271-4 which deals with Handling Procedures for gases for insulation and/or switching. IEC 60480:2019 provides criteria for the re-use of sulphur hexafluoride (SF6) and its mixtures after recovery and reclaiming from electrical equipment (e.g. for maintenance, at the end-of-life). However, no such international standard exists which provides criteria for the re-use of gases alternative to $SF_6$.

## 4. Push for Indigenization

As of now, all the major OEMs, viz., GE Vernova, Hyosung, Siemens Energy, Toshiba, Hitachi Energy and CG Power have developed facilities in India for manufacturing the conventional $SF_6$ based GIS up to the Voltage level of 420 kV. Additionally, Toshiba T&D India (TTDI), GE Vernova and Hyosung are also manufacturing conventional $SF_6$ based GIS at the Voltage level of 800 kV in India. Location of the conventional GIS manufacturing facilities of various OEMs in India is given in the below table:

| SN | OEM | Factory Location | Voltage Level |
|---|---|---|---|
| 1. | GE Vernova T&D India Ltd. | - Hosur, Tamil Nadu<br>- Chennai (assembly & components) | up to 765 kV |
| 2. | Hyosung T&D India Pvt. Ltd. | Pune, Maharashtra | 66 kV to 800 kV |
| 3. | Siemens Energy India Ltd | Aurangabad, Maharashtra | up to 420 kV |
| 4. | Toshiba T&D Systems (India) Pvt. Ltd. | Rudraram (near Hyderabad), Telangana | 66 kV to 800 kV |
| 5. | Hitachi Energy India Ltd. | Vadodara, Gujarat | 72.5 kV to 420 kV |
| 6. | CG Power and Industrial Solutions Ltd. | Nashik, Maharashtra | up to 420 kV |

*Table 8: Locations of the Conventional GIS Manufacturing Facilities of various OEMs in India*

As per MoP Order dated 16.11.2021 regarding Public Procurement (Preference to make in India), the MLC content in the Gas Insulated Switchgear (up to 400 kV AC) has been stipulated as 60%. For the GIS of the Voltage level above 400 kV, the MLC content has been stipulated as 50%.

During the Committee deliberations, it is observed that although global manufacturers have developed Green GIS solutions, the manufacturing and type testing for these products currently takes place outside India. As a result, Green GIS equipment is presently much more expensive than conventional $SF_6$ based GIS, with indicative costs estimated to be 6 to 8 times higher than the conventional $SF_6$ based GIS because entire quantum need to be imported from overseas factories of concerned OEMs. It is also noted that the execution timeline for Green GIS projects is presently expected to be around 20–25% longer than that of conventional $SF_6$-based GIS projects, mainly due to the current dependence on the imported equipment. The overall procurement process for Green GIS remains similar to conventional GIS projects, with the primary equipment being supplied by Green GIS manufacturers, while gas handling systems and associated testing equipment are arranged by EPC contractors. It is recognized that increased indigenization and development of local manufacturing facilities would be key factors in reducing project costs, timelines, and improving execution efficiency in the future.

The Indigenization of Green GIS technology is a critical aspect for its sustainable and large-scale adoption in the Indian grid. Given the strategic importance of transmission infrastructure and the long service life of GIS installations, developing domestic manufacturing capability for Green GIS equipment, associated components, and insulating media is essential to ensure supply security, cost competitiveness, and long-term operability. Indigenization is not only a matter of cost reduction but also a strategic necessity to ensure the long-term sustainability of the Indian Power Sector under the "Aatmanirbhar Bharat" initiative.

Green GIS technologies currently rely on alternative insulating media such as Fluoronitrile-based gas mixtures or clean air insulation systems, which may involve materials and processes not yet widely available within the country. Indigenization efforts would therefore need to address both the manufacturing of primary GIS equipment and the sourcing, handling, and quality assurance of alternative insulating gases. This includes assessment of existing industrial capabilities for manufacturing of gas and compliance with environmental and safety regulations applicable to these gases. In this connection, it is noted that M/s Laxmi Organic Industries Ltd, which manufactures Fluoronitrile (C4FN) gases in India, has an installed annual capacity of 60T, with the possibility of adding an additional 60T. And its capacity is sufficient for 3,000–3,500 bays of 132 kV Class Green GIS bays.

During the deliberations, the possibility of utilizing and expanding existing $SF_6$ based GIS manufacturing facilities for the production of Green GIS equipment has been examined. It is noted that, with suitable modifications and upgrades to accommodate alternative insulating media and revised manufacturing processes, the same facilities may be leveraged for manufacturing Green GIS, thereby supporting faster indigenization, reducing initial capital investment, and enabling a smooth transition from conventional GIS to Green GIS technology.

It is also observed that OEMs have indicated their willingness to establish manufacturing facilities in India, subject to the availability of sufficient and sustained demand. In this context, the need for a clear and time-bound roadmap for gradual reduction in the use of $SF_6$, similar to international practices, has been noted as a potential enabler for market development. It is further noted that the training requirements for installation and handling of Green GIS equipment are expected to be largely similar to those for conventional $SF_6$-based GIS, which would facilitate easy adoption by utilities and EPC contractors.

# 5. Implementation Strategy

As per Regulation No. 44(3)(A) of Central Electricity Authority (Technical Standards for Construction of Electrical Plants and Electric Lines) Regulations, 2022, Gas Insulated Substation or Switchyard shall be constructed in Seismic prone areas, coastal areas, high altitude areas, very heavily polluted areas and for location where space is major constraint. Accordingly, while planning a Transmission Scheme, these factors are considered and accordingly a Substation is planned as AIS or GIS. So far, all the GIS based Substation at all the voltage levels are being considered based on the conventional $SF_6$ based GIS technology.

As of now, Alternative to SF6 technology for the Voltage level of 145 kV has been developed by four OEMs. No OEMs has developed the technology at 245 kV till date. A Table showing the Green GIS technology available till date is given below:

| **Equipment Voltage Class (kV)** | **OEM who has developed Green GIS Technology** | | | | |
|---|---|---|---|---|---|
| | **Live Tank Circuit Breaker (LTB)** | **Dead Tank Circuit Breaker (DTB)** | **Hybrid GIS** | **Gas Insulated Switchgear (GIS)** | **Gas Insulated Bus Ducts (GIB)** |
| 72.5 | Hitachi Energy, GE Vernova | Hitachi Energy, GE Vernova | Hitachi Energy | Hitachi Energy, GE Vernova, Siemens, Toshiba, | - |
| 145 | Hitachi Energy, GE Vernova, Siemens | Hitachi Energy, GE Vernova, Siemens | - | Hitachi Energy, GE Vernova, Siemens, Toshiba | Siemens, Toshiba |
| 245 | - | - | - | GE Vernova | - |
| 420 | Hitachi Energy | Hitachi Energy | Hitachi Energy | Hitachi Energy, GE Vernova | Hitachi Energy, Siemens Toshiba |
| 550 | - | Hitachi Energy | - | Hitachi Energy | Hitachi Energy |

*Table 9: Green GIS Technolgy available till date*

From the above Table, it may be highlighted that availability of SF6-free solutions at 220 kV (230 kV) voltage level is not adequate. Even though SF6 based SF6 solutions at 220 kV are limited, due to availability of huge no. of AIS substations at 220 kV level, efforts must be made to leverage their large base for deploying technologies pertaining to Retrofitting and Retrofilling.

It is seen from the above Table that Green Circuit Breaker, Green GIS, and Green Gas Insulated Bus duct (GIB) are available with multiple OEMs for 132 kV (110 kV)voltage level. As such, it is proposed that a pilot project may be carried out for a full 132 kV (110 kV) Green Gas Insulated Substation. **(Commencement Timeline: 2027-28)**

It is also seen that Green Gas Insulated Bus duct (GIB) is available with multiple OEMs for 400 kV voltage class. As such, it is also prudent to carry out a pilot for the same at a suitable GIS substation. **(Commencement Timeline: 2027-28)**

Further, a couple of existing AIS Substations may be selected at 400 kV or 220 kV **to retrofit** selected components, viz., Green CB/ Green GIS, Green GIB for assessing Retrofitting. **(Commencement Timeline: 2027-28)**

A couple of existing SF6 based GIS Substations may also be selected at 400 kV or 220 kV to **retro-fill** selected components, viz., Green CB/ Green GIS, Green GIB, for assessing Retro-filling. **(Commencement Timeline: 2027-28)**

Based on the experience gained from above pilots, and after establishing their field proven-ness, $SF_6$-free solutions may be progressively introduced for 132 kV and above Substations (preferably for new stations and for the existing stations reaching their end of life) starting with **10%** of the total new Projects based on GIS planned as part of the next 5-year National Electricity Plan (2027-28 to 2031-32). **Commencement Timeline for the same may preferably be from 2029-30/ 2030-31 onwards**. This percentage of SF6-free solutions may be further increased in steps of 10 for succeeding 5-year NEPs thereafter. Further, due consideration may also be given to implementation of Green GIS in the cases of upgradation of AIS Substations.

To ensure that the SF6-free solutions commence their journey in Indian Power Sector as per above outlined timelines, it is proposed that implementation of SF6 free solutions at suitable locations shall be captured, and appropriately incorporated in National Electricity Plans.

# 6. Leakage Monitoring

The environmental impact associated with $SF_6$-based equipment primarily arises due to leakage of the gas during operation or in rare cases due to equipment explosion. Such leakage may occur not only during the service life of the equipment at substations but also at manufacturing, testing, and handling stages.

As per IEC standards, the maximum allowable leakage limit for SF6 gas is 0.1% and for non-SF6 gas is 0.5% of the total gas quantity per annum under normal operating conditions. However, the leakage rate may increase with ageing of equipment, deterioration of sealing systems, and inadequate maintenance practices.

Clean air-based Green GIS solutions utilize atmospheric air as the insulating medium have zero global warming potential, and do not pose any environmental concern in the event of leakage. This eliminates the need for specialized gas recovery and environmental compliance measures associated with $SF_6$. However, the operational performance of clean air GIS is dependent on maintaining adequate internal pressure and purity of the gas. Leakage of air from the sealed compartments may result in a drop in pressure, which can adversely affect dielectric strength, potentially leading to mal-operation or reduced reliability of the equipment. Therefore, despite the absence of environmental concerns, emphasis must be placed on maintaining enclosure integrity, ensuring proper sealing, and incorporating reliable pressure monitoring and alarm systems.

In Green GIS solutions utilizing fluoronitrile based gas mixtures, although the global warming potential has been significantly reduced, typically by about 99% compared to conventional $SF_6$ based GIS, it still possesses a finite environmental impact. Consequently, any leakage, even at low levels, should be minimized. In addition, maintaining the required gas pressure is again essential for ensuring proper insulation and interruption performance.

Accordingly, it is important that all types of GIS, irrespective of the insulating medium used, should be equipped with robust sealing systems, continuous leakage monitoring mechanisms, and appropriate alarm provisions to detect and limit leakage within acceptable levels, thereby ensuring both environmental compliance and operational reliability.

## 7. Financial Incentives

The push for development of a technology comes through two ways. One is demand of the technology and the other is incentive to develop the technology. In case of development of Green GIS, some countries are providing the incentive to develop the technology to replace $SF_6$. Globally there are two examples where such initiative of financial incentive is being given to promote F-Free Switchgear. These examples are "Green Innovation Fund" in Japan and "EU Life Fund" in European Union. These, along with other incentives being extended to R&D, Proto-Typing etc. in countries like Japan and EU, have to be studied, and similar or better mechanisms may be developed & provided to ensure early Catch-Up and sooner adoption of Green GIS Solutions in Indian Power Sector also.

### 7.1 Green Innovation Fund

Towards the goal of achieving carbon neutrality by 2050, Japan has established a comprehensive policy framework to promote low-emission technologies through the Green Innovation Fund administered by the Ministry of Economy, Trade and Industry (METI) and implemented by the New Energy and Industrial Technology Development Organization (NEDO). Under this fund, the government provides long-term support of up to 10 years to companies and Organizations undertaking projects with clearly defined performance targets, covering the entire spectrum from research and development to demonstration and social implementation. Through this Fund, the Organisation/ Companies may get the funding to develop a new technology which can replace the $SF_6$ based GIS.

### 7.2 European Union's Life Fund

The European Union (EU), through its LIFE Programme for Climate Action, supports the development and deployment of $SF_6$-free switchgear by funding projects focused on design, demonstration, and validation of alternative insulating technologies under real operating conditions. These initiatives promote the transition from $SF_6$-based systems by enabling development of equipment suited to alternative gas properties. LIFE-funded projects involve collaboration among manufacturers, transmission system operators, and research institutions to validate $SF_6$-free switchgear, including high-voltage circuit breakers and GIS, in practical grid applications. The outcomes indicate that such technologies can achieve comparable performance and reliability while substantially reducing environmental impact, thereby supporting a technology-neutral and competitive pathway for gradual transition towards $SF_6$-free electrical infrastructure in Europe.

### 7.3 Financial Incentive approach in Indian Context

Even though Green GIS solutions hold promise in providing similar operational performance as that of conventional SF6 based GIS with much reduced environmental impacts, owing to their high initial cost (6-8 times of conventional $SF_6$ based GIS), they may not compete with conventional SF6 based GIS on their own strengths. Therefore, it is appropriate that suitable incentives may need to be given for their development as well as deployment in Indian Grid. In case of SF6 based GIS also, the cost of the technology was quite high when it was deployed in India. However, with time and with increase in local content, the cost of the technology has come down. Similarly, as the Green GIS technology gets mature and the demand increases, the cost of the technology will also come down. Once the pace of deployment of the technology increases alongside tis maturation, the incentive may be withdrawn.

Developmental incentives may be provided to Organizations such as CPRI, and Manufacturers committing to develop on Indian soil. It may also be extended to facilitating requisite Transfer of Technology (TOT) for Indian Entities. This will reduce, if not eliminate, the dependence on foreign countries for import of Green GIS products, apart from making the technology cheaper. Coming to deployment of the technology, suitable financial incentives may also need to be provided to cope with high initial costs, and to ensure the technology adoption takes off.

There is also another mechanism, viz., Climate Finance Taxonomy which is a tool to identify activities consistent with India's climate action goals and transition pathway, by which financing of the deployment of Green GIS may be done. The objective is to facilitate greater resource flow to climate-friendly technologies and activities, enabling achievement of the country's vision to be Net Zero by 2070 while also ensuring long-term access to reliable and affordable energy. The taxonomy will adopt a graded approach, classifying activities at various levels. In this respect, SF6-free/ Green GIS and SF6-free/ Green Switchgear (used in AIS) may be got included under the Climate Finance Taxonomy under the "Substation" under the Transmission Sub sector in the broader Sector as "Power" which includes Technologies and advanced materials and innovations that support the performance of grid and transmission systems in a low-carbon power sector.

## 8. GHG Mitigation and Carbon Credits

Paris Agreement under the United Nations Framework Convention on Climate Change sets a global objective to limit the rise in average global temperature to well below 2°C above pre-industrial levels, with efforts to limit warming to 1.5°C, recognizing the significant risk that climate change poses to sustainable development and human well-being.

Under NDC pledges for 2030 in the Paris Agreement, India aims to enhance its share of non-fossil in its Installed Capacity mix, reducing Emissions Intensity of its GDP and creating carbon sink through increased forest & tree cover, enhancing the country's ambition under the UNFCCC and its Paris Agreement. These targets reflect a strategic balance between economic development goals and environmental sustainability, and they underscore the importance of transitioning key energy and infrastructure sectors — including the power transmission network — towards low-emission technologies to align with national and international climate objectives. In this connection, India has already achieved 50% of its installed electric power capacity from non-fossil fuel sources five years ahead of its 2030 target.

In a significant step towards strengthening India's action, the Indian Cabinet has also approved India's Nationally Determined Contribution for period 2031-2035 (NDC 3.0) on. India's NDC 3.0 targets aim to accelerate the nation's transition to a net-zero future by 2070, emphasizing high-growth, low-carbon development. Key goals include reducing GDP emission intensity by 47% below 2005 levels by 2035, achieving 60% non-fossil fuel electricity capacity, and creating 3.5–4.0 billion tonnes of $CO_2$ equivalent in carbon sinks.

Though, the contribution of $SF_6$ gases in total greenhouse gases is very minute. Nonetheless, $SF_6$-free / Green GIS and Green Switchgear used in AIS will help reduce Greenhouse Gas (GHG) emissions by eliminating or significantly reducing the use of $SF_6$ gas, which has a very high Global Warming Potential. Since these technologies directly contribute to lowering emissions from the power transmission sector, they are suitable for consideration under Articles 6.2 and 6.4 of the Paris Agreement.

Articles 6.2 and 6.4 of the Paris Agreement are mechanisms designed to facilitate international cooperation and carbon trading to achieve climate targets (NDCs). Article 6.2 allows decentralized, bilateral trading of emission reductions (ITMOs), while Article 6.4 establishes a centralized UN-supervised market for high-quality carbon credits. Therefore, if carbon trading w.r.t. Green GIS is included under these mechanisms, projects adopting Green GIS may become eligible to generate carbon credits for the avoided $SF_6$ emissions, which can improve the financial attractiveness of such projects.

Accordingly, $SF_6$-free / Green GIS and $SF_6$-free / Green Switchgear (used in AIS) may be proposed for inclusion under the GHG Mitigation Activities framework of Articles 6.2 and 6.4 of the Paris Agreement. This would support India's climate goals and provide an additional incentive for utilities to adopt environmentally friendly switchgear technologies. Necessary steps may be taken to examine eligibility, define emission reduction methodologies, and coordinate with the appropriate national authorities for participation in the carbon market mechanism.

# 9. Global Efforts in Reducing SF6 based GIS

## 9.1 USA – California

USA (California) has come out with Regulation for Reducing Sulfur Hexafluoride Emissions from Gas Insulated Switchgear (2011, amended in 2022). As per this regulation, the following are Phase-out dates for new SF6 switchgear (order intake date):

(a) ≤145 kV & <63 kA : 1.1.2025
(b) ≤145 kV & ≥63 kA : 1.1.2028
(c) ≤245 kV & <63 kA : 1.1.2027
(d) ≤245 kV & ≥63 kA : 1.1.2031
(e) >245 kV : 1.1.2033

Responsibility for compliant installation of the switchgear lies with the operator.

## 9.2 USA - New York State

USA (New York) has come out with the SF6 Standards and Reporting rules (6 NYCRR Part 495) (2024). Under these rules, the following are the Phase-out dates for the order of new SF6 insulated equipment (order intake date):

(a) Up to 145 kV & <63 kA: 1.1.2027
(b) Up to 145 kV & >63 kA: 1.1.2028
(c) Up to 245 kV & <63 kA: 1.1.2027
(d) Up to 245 kV & >63 kA: 1.1.2031
(e) >245 kV: 1.1.2033

Responsibility for compliant installation of the switchgear lies with the supplier/ manufacturer.

## 9.3 European Union

European Union has come out with (EU) Regulation 2024/574 ("revised F-Gas Regulation"). Under this regulation, EU is phasing out the installation of new SF6 switchgear. The phasing out of new SF6 switchgear (putting into operation date) are as below:

(a) Up to 145 kV & up to 50 kA: 1.1.2028
(b) >145 kV & >50 kA: 1.1.2032

Responsibility for compliant installation of the switchgear lies with the operator. The use of alternatives to SF6 is regulated as per below:

- Either GWP of the gas is below 1, or, by derogation, below 1000 if there's no or only one bidder with GWP below 1, **Or**
- The global carbon footprint of the equipment is lower than this with GWP below 1, subject to the adoption by the legislator of a delegated act under ESPR (Ecodesign for Sustainable Products Regulation)

## 9.4 Switzerland

Switzerland has come out with ChemRVV Anhang 2.19 & Stand der Technik. Under these, Phasing out dates for the installation of new SF6 switchgear (putting into operation date) have been set as below:

(a) Up to 145 kV & up to 50 kA : 1.1.2028
(b) >145 kV & >50 kA : 1.1.2032

All alternatives can be used according to the Standing of Technics document, which is to be reviewed every 3 years considering the available technologies and their environmental impact (lifecycle and GWP). Responsibility for compliant installation of the switchgear lies with the operator.

### 9.5 United Kingdom

UK has the mechanism named as Insulation and Interruptions Gas (IIG) Incentive (2007)-RIIO-2 and RIIO-3. The regulator (OFGEM) set up financial incentives to reduce SF6 leakage, in the form of rewards and penalties corresponding to the actual SF6 leakage rates of operators compared to a baseline set by OFGEM. This baseline is updated every five years under the RIIO framework (RIIO are price regulation frameworks (Revenue = Incentives + Innovation + Outputs). RIIO-3 for Electricity Transmission was published on December 4, 2025, and will cover the time period from 1 April 2026 to 31 March 2031). Exemptions exist to resolve a failure or in the absence of alternatives to SF6.

### 9.6 Norway

Norway has the mechanism as Norwegian Tax on Sulphur Hexafluoride Tax on SF6 imported and used during operation of the switchgear: 580 EUR / kg of SF6 (except for first fill of the switchgear, so actually corresponds only to SF6 for refilling).

### 9.7 Denmark

Denmark apart from being part of EU F Gas regulation, also imposes Tax on SF6 imported and used during operation of the switchgear: 480 EUR / kg of SF6 (except for first fill of the switchgear, so actually corresponds only to SF6 for refilling) as part of Denmark's national environmental tax law.

### 9.8 Spain

Spain apart from being part of EU F Gas regulation, Tax on SF6 imported and used during operation of the switchgear: 100 EUR / kg of SF6 under Law 16/2013 on environmental taxes and amendments via Law 14/2022 and implementing regulations (e.g., Royal Decree 712/2022).

### 9.9 Canada

Canada under their Greenhouse Gas Pollution Pricing Act (GGPPA), S.C. 2018, c. 12, cover SF6 by carbon pricing in two situations:

- Under the federal Output-Based Pricing System (OBPS) which applies to large industrial facilities (ex TSOs, electricity producers) in case of leaks above emission limits;
- In Québec, cap-and-trade system includes SF6.

### 9.10 Australia

In Australia, under Ozone Protection and Synthetic Greenhouse Gas Management Act 1989, License is mandatory to import, export and manufacture SF6 and SF6-containing equipment to/in/from Australia. Cost is 3000$ for a 2-year importing license fee. Additionally, an Import/Manufacture Levy of $165 per metric tonne is to be paid twice a year.

# 10. Model Guidelines for Deployment of Green GIS Technology in India

In view of the availability of multiple $SF_6$-free / Green GIS technologies employing different insulation and interruption principles, it is necessary to establish a uniform and technology-neutral framework to facilitate their orderly deployment in the Indian power system. Such framework should support utilities and transmission developers in adopting Green GIS solutions in a reliable, safe, and transparent manner without restricting competition or favoring any specific insulation medium or design approach.

The Model Guidelines for deployment of Green GIS technology detailed hereunder provide a structured and technology-neutral framework for the adoption of SF6-free GIS technologies in India, irrespective of used insulating medium, interruption principle, or proprietary design, provided the functional, safety, environmental, and performance requirements are met. The guidelines also define a systematic pathway for the phased elimination of Sulphur Hexafluoride (SF6)-based equipment.

The model guidelines may be appropriately adopted by

## 10.1 Scope

The Guidelines cover:

(a) New installations across HV, EHV applications.
(b) Brownfield replacement and life-extension projects
(c) Manufacturing, procurement, installation, operation, and end-of-life management

## 10.2 Background and Rationale

Alternative insulation and interruption technologies with significantly lower environmental impact compared to $SF_6$ are under development and deployment globally. Adoption of such technologies shall be evaluated based on lifecycle environmental performance, operational reliability, safety, and suitability for Indian power system conditions, without preference for any specific insulating medium or technology principle.

## 10.3 Policy Alignment

Deployment of Green GIS solution, shall align with:

(a) National Electricity Policy (NEP)
(b) Central Electricity Authority (CEA) technical regulations
(c) Bureau of Indian Standards (BIS)/IEC/IEEE standards as applicable for switchgear

## 10.4 Technology Definition and Classification

Green GIS refers to Gas insulated Substation utilizing alternative insulation and/or interruption technologies (other than $SF_6$) with significantly lower GWP, meeting applicable electrical, mechanical, safety, and operational performance requirements. Green GIS is defined as gas-insulated switchgear with a suitable alternative to SF6 gas with

(a) Significantly lower lifecycle greenhouse gas emissions compared to $SF_6$-based systems.
(b) No compromise on electrical, mechanical, safety, or lifecycle performance

## 10.5 Guiding Principles

Deployment of Green GIS shall be governed by the following principles.

### a) Technology Neutrality

These guidelines are strictly technology neutral. No insulating medium, proprietary gas mixture, interruption technology, or manufacturer shall be mandated or excluded, provided the equipment meets functional, technical, safety, and environmental requirements.

### b) Performance-Based Qualification

Qualification and evaluation shall be based on demonstrated electrical performance, operational reliability, safety, and lifecycle suitability.

### c) Grid Reliability and Safety

Adoption of Green GIS shall not compromise:

(a) System Reliability
(b) Short Circuit Performance
(c) Operational Safety
(d) Availability and Maintainability

Tender specifications and qualification criteria shall not include conditions that directly or indirectly restrict participation of qualified technologies or manufacturers.

## 10.6 Technical and Performance Requirements

All Green GIS installations shall meet the following minimum requirements, irrespective of manufacturer:

(a) Electrical ratings and short-circuit performance equivalent to legacy SF6 GIS
(b) No electrical, thermal, or dielectric derating
(c) Insulation system suitable for Indian climatic, seismic, and pollution conditions
(d) Environmental and site Suitability
(e) Switching function shall be performed using proven interruption technology suitable for the intended voltage level and application.
(f) Insulating media shall eliminate or significantly reduce $SF_6$ usage and comply with applicable environmental and safety requirements.
(g) Equipment shall be designed to operate reliably under Indian environmental conditions including temperature variation, humidity, pollution, and altitude.

## 10.7 Procurement and Tendering Guidelines

### a) Need for a Technology-Neutral Evaluation Framework

In the absence of a single, universally adopted Green GIS technology across all manufacturers, conventional L1 (lowest price)–based tendering may not be suitable for SF6-free GIS procurement. Differences in the following parameters necessitate introduction of a structured, transparent, and technology-neutral evaluation scale applicable to all manufacturers.

- Insulation philosophy

- Switching technology maturity
- Environmental footprint
- Lifecycle risk and service philosophy

### b) Transitional Tendering and Multi-Criteria Evaluation

Until Green GIS technologies reach convergence across manufacturers, utilities may adopt appropriate (Quality and Cost based Selection (QCBS) type evaluation.

Utilities and transmission owners shall introduce a weighted evaluation model for Green GIS tenders, covering various factors as per enclosed **Annexure-IV**. Price shall be evaluated only after minimum qualifying scores are achieved in technical and environmental categories.

### c) Transparency and Auditability

The evaluation scale, scoring methodology, and weightages shall be:

- Declared upfront in tender documents
- Uniformly applied to all bidders
- Auditable and traceable for regulatory review

This approach ensures fair competition while enabling informed decision-making in a rapidly evolving technology landscape.

## 10.8 Manufacturing, Localization, and Supply Chain

- Preference shall be given to OEMs with local manufacturing.
- Localization of testing, commissioning, and service capability shall be promoted under Make in India
- Technology transfer and indigenous capability development may be encouraged.

## 10.9 Implementation Approach

Deployment of Green GIS may be implemented through:

- Pilot Installations
- New Substations
- Substation Augmentation Projects
- Suitable Replacements in the existing Installations

Adoption shall be gradual and aligned with system planning and operational requirements. Utilities shall retain flexibility to select appropriate technologies based on technical and operational suitability.

## 10.10 Approach for Phasing out SF6 based GIS

a) This shall be made applicable to all new procurement and major augmentation of EHV switchgear at 132 kV (110 kV) and above voltage levels covering the following equipment:

- Gas Insulated Switchgear (GIS)
- Circuit breakers (Dead-tank / Live-tank)
- Gas insulated Bus ducts, Bays, and Line modules

### b) Rationale for $SF_6$ Phase-Out

- $SF_6$ is an extremely potent greenhouse gas with very high Global Warming Potential and long atmospheric lifetime.
- Continued addition of $SF_6$-filled equipment increases the long-term emissions liability of the Indian power system.
- International markets have demonstrated technical viability of $SF_6$-free EHV switchgear using alternative interruption and insulation concepts.
- Globally there is a trend to shift to $SF_6$ free gases in Switchgears
- Early transition enables Indian utilities and manufacturers to avoid technology lock-in and stranded assets.

### c) Requirements for New EHV Switchgear

#### ➢ Immediate Actions

- Mandatory $SF_6$ inventory and reporting for all EHV substations.
- All new tenders shall include environmental evaluation criteria in addition to technical and commercial evaluation.

#### ➢ Progressive Restrictions on New $SF_6$ Procurement

For the Voltage class of 132 kV and above, $SF_6$-free solutions to be progressively introduced through pilot projects, followed by scaled deployment. Once the field proven-ness of the $SF_6$ free Switchgear is established through Pilot Projects, 10% of the total new Project based on GIS may be installed based on $SF_6$ free, which gradually may be increased.

Selection shall be based on transparent and technology-neutral evaluation criteria without mandating any specific alternative insulating medium or technology

### d) Requirements for Installed Base

Focus shall be on leakage reduction, improved monitoring, and assured recovery at end-of-life.

#### ➢ Inventory and Reporting

- Asset-wise $SF_6$ register including nameplate quantity, refilling events, leakage alarms, and recovered quantities.
- Annual reporting at utility and regulator level.

#### ➢ Leak Detection and Maintenance

- Continuous gas density monitoring with event logging.
- Periodic leak surveys using calibrated instruments.
- Mandatory corrective action for repeated leakage.

#### ➢ End-of-Life Management

- Mandatory recovery of insulating medium during dismantling, where applicable.
- Prohibition of venting under all circumstances.
- Submission of recovery and processing certificates with mass balance, where applicable.

### 10.11 Compliance and Review

Utilities deploying Green GIS shall maintain relevant technical and operational records. These guidelines may be periodically reviewed and updated based on technological advancements, operational experience, and industry feedback.

# 11. Model Tender Evaluation Criteria for Green GIS Technologies

With the emergence of multiple $SF_6$-free / Green GIS technologies employing different insulation media and switching principles, it is essential that procurement provisions ensure a level playing field while maintaining system reliability, safety, and environmental performance. Tender requirements should be defined in a technology-neutral manner, focusing on functional performance, environmental impact, operational safety, and lifecycle considerations rather than prescribing any specific gas mixture or design. This approach will enable participation from all qualified technologies that meet the performance and environmental objectives of the Indian power system.

The evaluation framework should take into account key aspects such as environmental benefits in terms of greenhouse gas emission reduction, safety and ease of handling, installation and maintenance requirements, availability of service and support infrastructure, and overall lifecycle cost etc., in addition to its Operational as well as Capital Cost. Consideration of availability of gas handling systems, training requirements, and indigenous manufacturing potential, is also important to ensure sustainable deployment. Such an approach will promote competition, encourage technological advancement, and facilitate gradual transition towards environmentally sustainable substation technologies.

However, the Green GIS technology must meet the electrical and mechanical performance. OEMs must have type test performance to validate these. There should not be any relaxation on certain aspects such as smooth operation in the ambient temperature of the Substation, switching capabilities i.e. short circuit current & nominal current, dielectric performance etc.

As available OEMs in the field of Green GIS are having different technologies, a comparative analysis should be carried out by Utilities to give the fair consideration to each of the technology. For this purpose, a model tender evaluation Criteria has been developed, and is given at **Annexure-IV.** In the Model tender evaluation Criteria, the Evaluation Points have been categorized into four major Categories. These are as follows.

(a) Technology & Reliability
(b) Operation & Maintenance
(c) Sustainability, Environmental Protection & HSE
(d) CAPEX & OPEX

These major categories have been further divided into sub categories. Appropriateness of each of these Categories/ subcategories is explained in the following paras.

## 11.1 Technology & Reliability

### a) Product maturity & references

It is important that the Green GIS Technology has sufficient field experience. Considering this factor in the evaluation criteria minimizes project risk by relying on technology with an established operational track record, resulting in fewer unexpected issues and more predictable outcomes. For this OEMs have to provide evidence of reliable, field-proven performance.

### b) Lifetime of the Product

A longer product lifetime reduces the need for replacements, minimizes lifecycle costs, and supports sustainability goals. The Substations in India are constructed for operation of 35 years. Therefore, high lifetime expectations are especially important for Power Sector, where outages are costly and disruptive.

### c) Footprint / Dimensions

One of the major uses of the GIS is to reduce the requirement of the land. Therefore, it is appropriate that the technology is also compared in terms of its footprint. A compact footprint reduces land and civil engineering costs, simplifies retrofits, and enables installation in space-constrained environments. This is important where the land is not easily available.

### d) Gas Tightness / Leakage Rate

Low leakage rates are critical for environmental protection, regulatory compliance, and minimizing operational costs, especially w.r.t. gases that still have GWP. Further, Gas losses can lead to safety risks, increased maintenance, and regulatory penalties.

## 11.2 Operation & Maintenance

### a) Maintainability and Lifetime Support

It is important that less dependability remains on the OEM for the maintenance. Therefore, Independence from the supplier is often a formal requirement in tenders. This factor shall enable maintenance by in-house staff, reducing operational expenditure and dependency on external service providers. It will increase flexibility and responsiveness, especially for remote or critical sites. In case there is dependability on OEM, the Lifetime Support may be ensured for proper O&M.

### b) Inspection & Revision Intervals

(In-service) Availability of a Substation is important in the Indian Context. Therefore, it is necessary that frequent inspection/ maintenance are avoided. This also becomes important in the context of unmanned Substation which necessitates the requirement of less maintenance.

Longer intervals between inspections and revisions reduce downtime, lower maintenance costs, and increase asset availability. Predictable, infrequent maintenance is highly valued for critical infrastructure.

### c) Gas Handling and Maintainability

Evaluation should also consider the safety of gas handling procedures, availability of handling equipment, and compliance with applicable safety standards. Standardization of gas handling processes and availability of trained manpower shall be considered to ensure safe and reliable operation. Availability of established gas handling procedures, lifecycle support infrastructure, and service facilities within India shall be taken into account to avoid operational delays and hidden lifecycle costs.

### d) Special Training of Maintenance Personnel for Insulation Gas

Special training of Maintenance Personnel for Insulation gas not only increases the overall cost of the Project, but also makes the maintenance of the GIS dependent on the trained manpower. Therefore, in case of the absence of a mandatory requirement for special training of maintenance personnel, training costs and operational risk get reduces. It also simplifies the on-boarding of new staff and ensures compliance with safety regulations.

### e) Gas Availability

For the smooth Operation and Maintenance of the Substation, the availability of gas is crucial. Giving weightage to this factor, will ensure security of supply, reduce risk of project delays or operational interruptions. Further, it will avoid dependency on single-source suppliers or vulnerable supply chains.

## 11.3 Sustainability, Environmental Protection & HSE

### a) Global Warming Impact Reduction

The major factor behind the development of the Green GIS is to reduce the GWP of $SF_6$ gas. Lower GWP reduces the carbon footprint and supports compliance with climate-related regulations and sustainability goals. Therefore, it is important that technologies are compared at the tender stage in terms of their Global Warming Potential (GWP).

### b) Toxicity and Health Risks

The toxicity of insulating gases and their by-products impacts occupational safety and environmental protection. Non-toxic solutions reduce risk for personnel and simplify safety procedures. Therefore, weightage should be given to the toxicity of the Gas being used.

### c) End-of-Life Gas Handling (After Decommissioning)

Safe, simple end-of-life handling reduces costs and environmental risk. It also avoids hidden costs and regulatory hurdles at the end of the asset's life.

### d) Environmental Product Declaration (EPD) / Life Cycle Assessment (LCA)

EPDs and LCAs are increasingly required in tenders and for sustainability reporting. Transparent environmental data supports ESG goals and customer sustainability strategies.

## 11.4 Invest & Expenses (TOTEX)

### a) Capital Expense (CAPEX)

Initial investment is a key decision factor in project planning and tender evaluation. Lower CAPEX can improve project feasibility and competitiveness. Therefore, the CAPEX of the Product should be given major weightage.

### b) Operational Expenditure (OPEX)

Ongoing operational costs significantly impact the total cost of ownership (TCO). Lower OPEX improves long-term profitability and budget predictability. Therefore, at the tender stage, the Operational Expenditure should be taken into consideration.

### c) End-of-Life Costs (Disposal, Decommissioning)

Disposal and decommissioning costs can be high, especially for hazardous or regulated materials. Therefore, End-of-life costs should be taken into consideration while evaluating the tender.

### d) Gas Costs (Procurement, Lifetime, Disposal)

Gas procurement and management costs affect the Operational Cost. Volatility in gas prices or supply can introduce financial risk. Therefore, the cost of the gas should also be taken into consideration while evaluating the tender.

## 12. Way-Forward

The Committee has considered various aspects relating to the adoption of Green GIS in the Indian Grid. It is observed that multiple $SF_6$-free or Green GIS technologies, including fluoronitrile-based mixtures and clean air with vacuum interruption, are being developed and deployed globally across different voltage levels. These technologies offer potential environmental benefits while maintaining performance comparable to conventional systems. However, their level of maturity varies, particularly at higher voltage levels, where further field validation and operational experience are required.

It is noted that while initial deployment of Green GIS is feasible at lower voltage levels such as 132 kV, large-scale implementation at higher voltage levels would require additional efforts in terms of standardization, testing, and development of supporting infrastructure. Key aspects such as long-term performance reliability, material compatibility, leakage monitoring, gas handling practices, and availability of testing facilities assume significant importance for ensuring reliable operation. Addressing these aspects would be essential to build confidence among utilities and stakeholders for wider adoption of Green GIS technologies.

Considering the present status of technology and ecosystem readiness, a phased and cautious approach is considered appropriate for implementation. Pilot installations at lower voltage levels may be undertaken to gain operational experience, followed by gradual scaling based on performance and field feedback. In parallel, emphasis may be placed on the development of indigenous manufacturing facilities for Green GIS in the country. Strengthening domestic manufacturing capabilities would help reduce dependency on imports, improve availability of equipment, and lower overall costs over time, thereby supporting a smooth and sustainable transition from conventional $SF_6$-based GIS to Green GIS while maintaining system reliability and operational safety.

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सत्यमेव जयते
भारत सरकार
Government of India
विद्युत मंत्रालय
Ministry of Power
केंद्रीय विद्युत प्राधिकरण
Central Electricity Authority
विद्युत प्रणाली योजना एवं मूल्यांकन प्रभाग-II
Power System Planning & Appraisal Division-II

Date: 18.12.2024

## Office Order

**विषय / Subject: Constitution of committee regarding use of Green GIS technology in the Indian Grid– reg.**

National Committee on Transmission (NCT) in its 24th meeting held on 23.10.2024 decided to constitute a committee for exploring use of Green GIS in Indian Grid.

2. Accordingly, a committee is hereby constituted with following composition:-

| | | |
|---|---|---|
| 1. | Chief Engineer (PSE&TD Division), CEA | Chairperson |
| 2. | Director (ET&I Division), CEA | Member |
| 3. | Director (CE&ET Division), CEA | Member |
| 4. | Representative from CTUIL | Member |
| 5. | Representative from POWERGRID | Member |
| 6. | Director (PSETD Division), CEA | Member Convener |

3. The Committee may co-opt other members as may be considered necessary.

4. The Terms of reference (ToR) of the committee are:
   a) Survey green GIS literature and $SF_6$ alternatives.
   b) Explore the technical aspects in upgradation of existing substations in Green GIS.
   c) Explore possibility of hybrid GIS S/s.
   d) Explore aspects of availability of Green Gas in India, possibility of manufacturing in India etc.
   e) Cost comparison of normal GIS vs green GIS substations.
   f) Technology transfer
   g) Any other relevant issues.

5. The committee shall submit its recommendations to Member (PS) within 06 months.

This issues with the approval of competent authority

भवदीय/Yours faithfully,

18/12/2024

(राहुल राज / Rahul Raj)
निदेशक/ Director

Annexure-I



To

1. Chief Engineer (PSE&TD Division), CEA
2. Chief Engineer (CE&ET Division), CEA
3. Chief Engineer (ET&I Division), CEA
4. Chief Operating Officer, CTUIL
5. CMD, POWERGRID

Copy to:

1. Member (Power Systems), CEA
2. Chief Engineer (PSPA-I Division), CEA
3. Chief Engineer (PSPA-II Division), CEA

**भारत सरकार/ Government of India**
**विद्युत मंत्रालय/ Ministry of Power**
**केन्द्रीय विद्युत प्राधिकरण/ Central Electricity Authority**
**विद्युत प्रणाली अभियांत्रिकी एवं प्रौद्योगिकी विकास प्रभाग**
**Power System Engineering & Technology Development Division**

**Date: 31.07.2025**

सेवा में,

<As per attached list>

विषय: **Minutes of the first meeting of the committee regarding use of Green GIS in Indian Grid– reg.**

महोदया/ महोदय,

A meeting was held under the chairmanship of Chief Engineer (PSE&TD Division), CEA on 14.07.2025 at 15:00 hrs at Manthan Conference Hall, CEA, Sewa Bhawan, R K Puram Sector-I, New Delhi regarding use of Green GIS in Indian Grid.

The minutes of the meeting is attached for your information and necessary action.

Encl.: As above

**भवदीय,**

भंवर 31/7/2025

**(भंवर सिंह मीना /Bhanwar Singh Meena)**

**निदेशक/ Director**

**To**

1. Director, ET&I Division, CEA
2. Director, CE&ET Division, CEA
3. Shri K K Sarkar (CGM-Engg.), M/s CTUIL, 2nd Floor, Corporate Centre, Plot No:2, "Saudamini",Sec-29, Near IFFCO Chowk, Gurgaon Email: kksarkar@powergrid.in CC: coo-ctu@ctuil.in
4. Shri M. S. Rao, Sr. GM(TD) & Shri RPS Rana (General Manager), M/s Powergrid Corporation of India Ltd Saudamini, Plot No. 2, Sector-29 Gurgaon-122001 (Haryana) Email id: msrao@powergrid.in , rpsrana@powergrid.in CC: cmd@powergrid.in
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**Copy to,**

1. SA to Chairperson, CEA
2. SA to Member (PS)

# Power System Engineering & Technology Development Division
## Central Electricity Authority

**Minutes of the First Meeting of the Committee regarding Use of Green GIS in Indian Grid**

1. A meeting was convened on 14.07.2025 at 15:00 Hrs at Manthan Conference Hall, 2nd Floor, Sewa Bhawan, R.K. Puram Sector-1, New Delhi under the chairmanship of Chief Engineer (PSE&TD Division), CEA regarding use of Green GIS in Indian Grid. List of participants is given at **Annexure-I.**

2. At the outset, CE (PSE&TD Division), CEA welcomed all the participants and briefed about the agenda of the meeting. He mentioned that CTUIL informed in the 24th NCT meeting that the existing 132 kV Badarpur (POWERGRID) switching station was commissioned in 1999 and completed 25 years of service in 2024. POWERGRID, the owner of the substation is facing issues in O&M of the switching station. To improve reliability, it would be prudent to upgrade the switching station from single main and transfer bus scheme to double main transfer bus scheme by converting from Air Insulated Switchgear (AIS) to Gas Insulated Switchgear (GIS). Further, it was proposed in the 24th NCT meeting that upgradation could be carried out as Green GIS instead of conventional GIS. In this regard, a Committee was constituted vide CEA letter dated 18.12.2024 to explore the use of Green GIS in Indian Grid. Formation and ToR of the Committee was issued vide CEA letter dated 07.07.2025 (copy enclosed).

3. Thereafter, CE (PSE&TD Division), CEA requested manufactures to give presentation on the technology available covering technical, commercial, and other relevant aspects.

4. Representative from M/s Hitachi Energy gave a brief presentation **(Annexure-II).** The salient points of the presentation are as follows:
   (i) The Paris Agreement aims to limit global temperature rise well below 2°C and pursue efforts to limit it to 1.5°C above pre-industrial levels. To limit global warming to 1.5°C, greenhouse gas emissions must peak before 2025 at the latest and decline 43% by 2030. Under NDC pledges for 2030 in the Paris Agreement, India aims to reduce the emissions intensity of its GDP by 45% from 2005 levels, achieve 50% of its installed electric power capacity from non-fossil fuel sources, and create an additional carbon sink of 2.5 to 3 billion tonnes of $CO_2$ equivalent through increased forest and tree cover.
   (ii) Sulfur Hexafluoride ($SF_6$) is an excellent gas in terms of dielectric insulating properties and arc extinguishing properties. It is used in all voltage transmission applications. For decades, SF6 has been the norm in the electrical industry due to its excellent insulation capabilities but its emission remains a major concern. It is one of the most potent greenhouse gases, with a global warming potential (GWP) 24,300 times higher than $CO_2$, contributing to 0.6% of global emissions.
   (iii) A green alternative to $SF_6$ gas should have zero ozone depletion potential, low global warming potential, be non-toxic, non-flammable, stable, and have a low boiling point, high dielectric strength, effective arc quenching, good thermal performance, and compatibility with materials.

(iv) Hitachi Energy offers "EconiQ" as a rapid shift to eco-efficient solutions by eliminating $SF_6$, thereby cutting $CO_2$-equivalent emissions from insulation gas. It matches the reliability and scalability of conventional systems while ensuring the lower carbon footprint across its lifecycle. As an industry-standard alternative, it helps utilities and industries move away from $SF_6$, with a wide range of switchgear and breakers scalable up to ultra-high-voltage, all these while maintaining the same compact size as traditional $SF_6$-based solutions.

(v) The gas mixtures used in EconiQ are non-toxic, non-flammable, and decompose naturally without accumulating in the environment. It does not accumulate in water, plants, or soil and has atmospheric lifetime around 30 years.

(vi) Hitachi Energy's EconiQ portfolio replaces conventional $SF_6$ gas with eco-efficient gas mixtures $CO_2$+$O_2$+C4-FN, in all metal-enclosed switchgear (GIS, DTB, PASS) for insulation and switching. In metal-enclosed breakers, the size is determined by the insulating gas used inside. 3.5% C4-FN is needed to keep them compact. A gas mixture of $CO_2$ + $O_2$ replaces conventional $SF_6$ gas in all Live Tank Circuit Breaker (LTB) applications for insulation and switching. A gas mixture of $N_2$+$O_2$+C4-FN is used in retro-filling of Gas Insulated lines. This gas mixture of N2+O2+C4-FN can be used in retro-filling of non-switching equipment such as Gas Insulated Bus-duct (GIB); however, it does not offer same performance as $SF_6$ in switching equipment such as Circuit Breakers.

(vii) Hitachi Energy has deployed over 2,000 EconiQ units worldwide, including the world's first $SF_6$-free 420 kV and 550 kV circuit breakers, as well as retrofill solutions for existing gas-insulated lines (GIL). Hitachi Energy has delivered the world's first $SF_6$-free 420 kV dead-tank circuit breaker in the US and the world's first $SF_6$-free 420 kV gas-insulated switchgear in Germany.

(viii) Hitachi Energy EconiQ portfolio is as under:

| **High-voltage portfolio** | **Available now** | **Future Expansion** |
|---|---|---|
| Live tank circuit breaker (LTB) | 72.5 kV-31.5 kA<br>145 kV-40 kA<br>420 kV-63 kA<br>420 kV-80 | 245 kV-63 kA<br>170 kV-40 kA<br>(2028 and beyond) |
| Dead tank circuit breaker (DTB) | 72.5 kV,145 kV- 40 kA<br>420 kV-63 kA<br>550 kV-63 kA<br>420 kV-80 kA | 245 kV-63 kA (2026)<br>800 kV-63 kA (2027) |
| Plug and Switch System hybrid switchgear (PASS) | 420 kV- 63 kA,<br>72.5 kV, 145 kV- 40 kA | |
| Gas-Insulated Switchgear (GIS) | 72.5 kV,145 kV- 40 kA<br>420 kV-63 kA<br>550 kV-63 kA<br>420 kV-80 kA | 245 kV-63 kA (2026)<br>145 kV-63 kA (2027)<br>170 kV-50 kA (2028 and beyond) |
| Gas-insulated line (GIL) | 420 kV, 550 kV | 245 kV (2026) |
| Retrofill for GIL (Service) | 420 kV, 550 kV | |

5. Representative from M/s Hitachi Energy stated that cost of EconiQ GIS is around 5 to 8 times of conventional $SF_6$ gas based GIS in Europe. He further mentioned that both GE and Hitachi use the same fluorinated gas as a $SF_6$ free solution for GIS.

Annexure-II



6. Representative from M/s GE gave a brief presentation (**Annexure-III**). The salient points of the presentation are as follows:
   - (i) SF6, while excellent for electrical insulation, is an extremely potent greenhouse gas with a global warming potential 24,300 times greater than $CO_2$. $SF_6$ is the main contributor to the carbon footprint over 40 yrs.
   - (ii) GE's $g^3$ gas mixture ($C_4F_7N+CO_2+O_2$) delivers comparable performance to $SF_6$ while reducing greenhouse gas emissions by 99%. It maintains the same compact equipment footprint and is scalable across all voltage levels and applications, including GIS, GIL, and Circuit Breakers.
   - (iii) In the gas mixture ($C_4F_7N+CO_2+O_2$), $CO_2$ is used to improve the arc extinction capability, $O_2$ is used to stabilize the gas against decomposition in arcing and $C_4F_7N$ is used to boost insulation and arc quenching performances.
   - (iv) g3 products offer the lowest environmental footprint over the full product life cycle.
   - (v) C4F7N mixtures demonstrate high insulation properties. g3 metal-enclosed switchgear is as compact as $SF_6$ ones with same performance and it is possible to design dual-gas compatible concepts.
   - (vi) Over 1,000 g3-equipped bays are operational across the world at 145 kV and 420 kV gas-insulated substations (GIS), including 30+ km of gas-insulated lines (GIL), and 150+ live tank circuit breakers (LTB). Utilities in 10+ countries have adopted g3 for new installations and retrofits.
   - (vii) g3 based GIS at 72.5 kV, 145 kV, 245 kV and 420 kV level, LTB at 72.5 kV and 145 kV level and DTB at 145 kV level is available for the temperature down to -25/30°C. GE is planning to develop the g3 based GIS and DTB upto 550 kV by 2029.

7. Representative from M/s Siemens gave a brief presentation **(Annexure-IV)**. The salient points of the presentation are as follows.
   - (i) Siemens Energy's Blue portfolio replaces $SF_6$ with a combination of vacuum interruption and clean air insulation ($N_2$ + $O_2$), having zero global warming potential, zero toxicity, and operation in extreme temperatures.
   - (ii) This technology has zero patent dependencies and simplifies gas handling. Vacuum / clean air does not require special safety systems such as ventilation or $CO_2$-monitoring.
   - (iii) Gas leakage < 0.1% p.a./compartment.
   - (iv) The vacuum and clean air technologies provide excellent short-circuit switching performance without degradation. This technology is maintenance and regulation free and requires no special EOL treatment. Over all it has the lowest lifecycle costs.
   - (v) Siemens Energy has over 60 years of experience in switchgear with global production of 48,000+ GIS bays and 165,000+ CBs as well as more than 50 years of experience in vacuum and air insulation technology.
   - (vi) Siemens has delivered first HV vacuum CB with clean air 145 kV in 2017, first HV vacuum GIS with clean air 145 kV in 2018 and first GIB with clean air 420 kV in 2022.
   - (vii) The vacuum and clean air technology based equipment has comparatively arger footprint than the conventional $SF_6$ gas based equipment.

8. CE (PSE&TD), CEA, inquired about the permissible $SF_6$ gas leakage limits and the power sector's contribution to global warming due to $SF_6$ emissions. He emphasized that the environmental impact of $SF_6$ arises mainly from gas leakage or equipment explosions. In response, the representative from M/s GE stated that, as per IEC standards, the maximum allowable $SF_6$ leakage limit is 0.5% of the total volume, though leakage may increase with equipment ageing. Representative from M/s Siemens stated that there is no mechanism to monitor the leakage. However, representative from PGCIL replied that they are monitoring the leakage of $SF_6$ gas.

9. CE (PSE&TD), CEA also inquired about the operating temperature range of Green GIS technologies. The representative from GE stated that g3-based equipment is suitable for temperatures ranging from -30°C to +50°C, while the representative from Siemens mentioned that Blue gas-based equipment can operate between -60°C and +55°C. On this CE (PSE&TD), CEA said that in certain regions of India, such as western Rajasthan, temperatures can exceed 50°C. Therefore, it is suggested that Green GIS based equipment should be designed considering Indian operating conditions.

10. In this connection, Director (CE&ET), CEA suggested that SF6-free/ Green GIS is a fit case for including under GHG Mitigations Activities covered under Articles 6.2 & 6.4 of Paris Agreement for trading of carbon credits, which will facilitate in their adoption. On this, it was agreed that SF6-free/ Green GIS as well as SF6-free/ Green Switchgear (used in AIS) may be got included under GHG Mitigation Activities covered under Articles 6.2 & 6.4 of Paris Agreement, and requested Director (CE&ET), CEA to take necessary action in this regard.

11. Director (PSE&TD), CEA suggested that interoperability of different Green GIS technology based equipment shall be ensured while designing for uniformity and for allowing bay extension in future using another technology. Representative from PGCIL suggested that the pilot project may be done using more than one Green GIS technologies to gain overall operational experience.

12. CE (PSE&TD Division), CEA stated that in order for a Green GIS technology to be truly green, not only when the gas used has minimal environmental impact but also the process behind manufacturing should also has less carbon footprint. He requested manufacturers to share the cost comparison between the conventional $SF_6$ based equipment and Green GIS technology-based equipment.

The meeting ended with thanks to the Chair.

**Annexure-I**

## List of Participants

**CEA**

1. Sh. N.R.L.K. Prasad, Chief Engineer (PSE&TD)
2. Sh. Bhanwar Singh Meena, Director (PSE&TD)
3. Sh. Sachin K. Bhise, Director (CE&ET)
4. Sh. Pankaj Kumar Verma, Deputy Directory (PSE&TD)
5. Sh. Pankaj Kumar Sangwan, Deputy Director (PSE&TD)
6. Sh. Bhavesh Mahawar, Assistant Director (PSE&TD)

**POWERGRID**

1. Sh. M. Srinivas rao, Chief GM (TD)
2. Sh. R.P.S. Rana, General Manager (A.M.)

**GE VERNOVA**

1. Sh. Amit Narway, Regional leader Sales
2. Sh. Anjan Banerjee, Head of Marketing
3. Sh. Sushant Singh, Sr. Manager Sales

**SIEMENS ENERGY**

1. Sh. Rajeev Virdi, Chief Manager
2. Sh.Vaibhav Aaradhi, Sr. Manager
3. Sh. Harsh Trivedi, Manager

**HITACHI ENERGY**

1. Sh. Dheeraj Jain, Head GIR India
2. Sh. Dhiraj Fanish, Head Renewables
3. Sh. Mohit Chhabra, Legal Counsel Regulatory
4. Sh. Rajdeepak Pandey, PGSV S&M
5. Sh. Shafali Asthana, Head Business Development & Marketing

Annexure-II


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Hitachi Energy
EconiQ® high-voltage technology and innovation
Our promise towards a sustainable energy future for all
Public for external selected customers
Public
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Annexure-II

# Paris Agreement 2015 – COP 21 of UN Climate Change Conference

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The Paris Agreement is a **legally binding international treaty on climate change**. It was adopted by 196 Parties at the UN Climate Change Conference (COP21) in Paris, France, on 12 December 2015. It entered into force on 4 November 2016.

Its overarching goal is to hold “the increase in the global average temperature to well below 2°C above pre-industrial levels” and pursue efforts “to limit the temperature increase to 1.5°C above pre-industrial levels.”

However, in recent years, world leaders have stressed the need to limit global warming to 1.5°C by the end of this century.

That’s because the UN’s Intergovernmental Panel on Climate Change indicates that crossing the 1.5°C threshold risks unleashing far more severe climate change impacts, including more frequent and severe droughts, heatwaves and rainfall.

To limit global warming to 1.5°C, greenhouse gas emissions must peak before 2025 at the latest and decline 43% by 2030

**To Hold the increase in the global average temperature to 1.5 °C above pre-industrial levels**

Annexure-II

# Paris 2015 - India NDC pledges for 2030

- India's greenhouse gas (GHG) emission intensity of its GDP will be reduced by 45% below 2005 levels by 2030.
- 50% cumulative electric power installed capacity from non-fossil fuel-based energy resources by 2030
- India will create an additional 'carbon sink' of 2.5 to 3 billion tones of Co2 equivalent through additional forest and tree cover by 2030

**"India targets to achieve Net Carbon Zero by 2070 "**

Annexure-II

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# $SF_6$ has been dominant for Electrical Switchgear Industry….

- SF6 is an excellent gas in terms of dielectric insulating properties and arc extinguishing properties.
- SF6 represents the latest technology in modern high-voltage switchgear technology.
- Used in all voltage transmission applications up to 1200 kV level.
- More than 50 years of experience


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# Sulfur hexafluoride ($SF_6$) – a greenhouse gas

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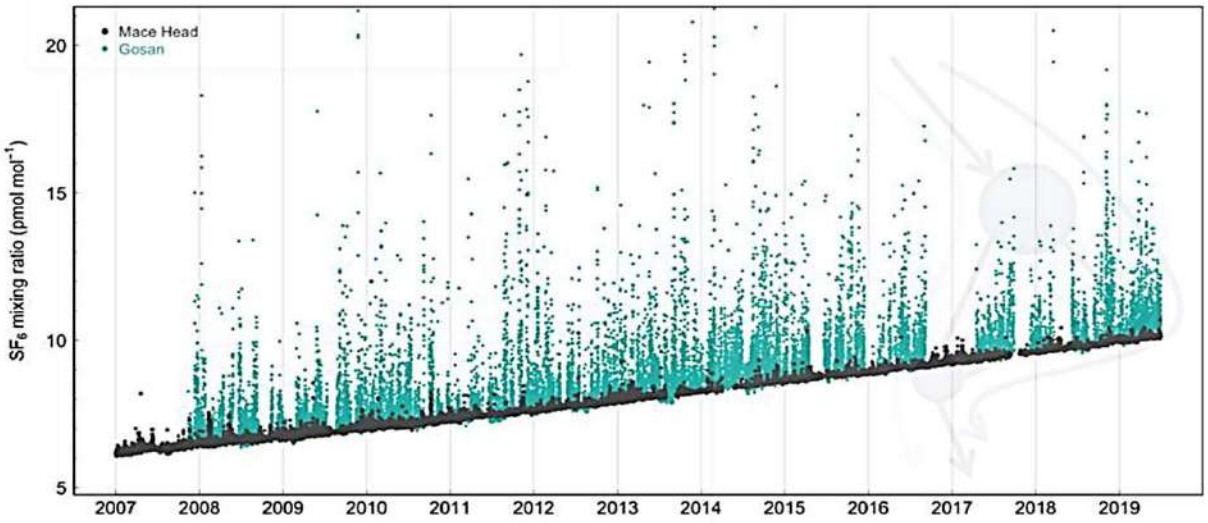
$SF_6$ is needed in switchgear but has some **global environmental impact**

Photo: NASA




Sources: IPCC AR6 (2021), Simmonds (2020)

**0.6%** Contribution to emissions today

**10 parts per trillion** (260,000 tons) Atmospheric concentration



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Annexure-II

Selection criteria for an insulation gas

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# Potential $SF_6$ alternatives – Key Requirements

- Zero ozone depletion potential (ODP)
- Lower Global Warming Potential (GWP)
- Non-toxicity
- Non-flammability
- Low boiling point
- High dielectric strength
- Arc quenching capabilities
- Thermal performance
- Stability and material compatibility

Annexure-II

# EconiQ® – our promise towards a carbon neutral future


## 01
**Reducing environmental impact**

Through eco-efficient products and solutions that reduce waste, carbon footprint and improve society

## 02
**Enabling energy and resource efficiency**

Reducing operational costs and environmental risks, while improving safety

## 03
**Future-proofing life cycle investments**

Technologies that are designed to meet existing and future energy demands


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Annexure-II

# EconiQ high-voltage products

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## Eco-portfolio for reducing environmental impact, increasing energy efficiency, and future-proofing technology investments

**01** The EconiQ portfolio offers exceptional environmental performance compared to conventional solutions

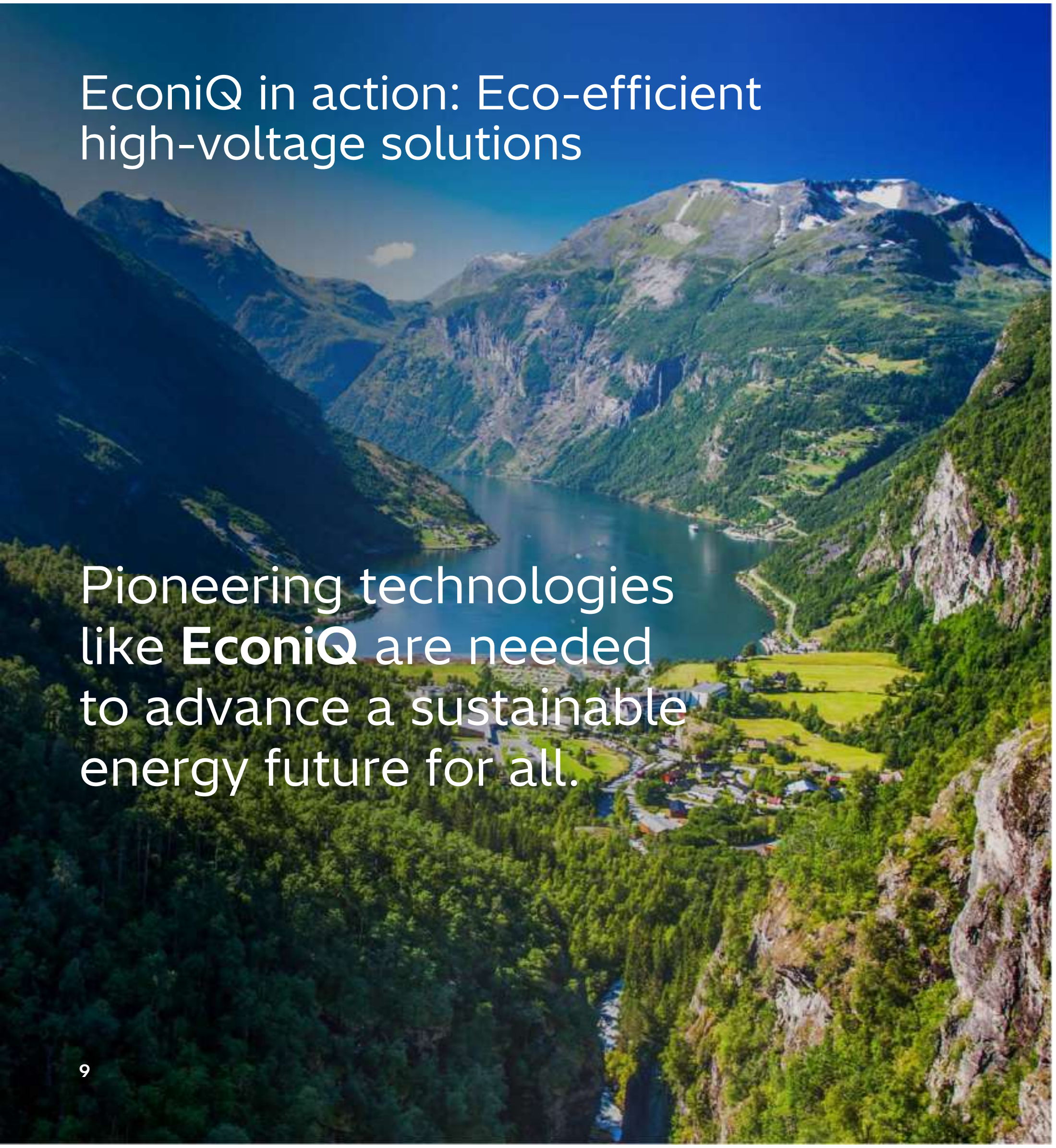
**02** The $SF_6$-free gas mixtures for high-voltage switchgear is the first big step in the EconiQ portfolio

**03** EconiQ $SF_6$-free solutions create significant customer value

### Creating value for our customers towards a carbon-neutral future

- Collaborating with our customers & partners to reduce carbon footprint
- Working towards a standard and scalable solution for the industry
- Ensuring future-proof lifecycle investments
- Enabling more efficient use of energy and resources

Annexure-II

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## EconiQ enables the rapid transition to eco-efficient solutions today!

**01** **Contains no $SF_6$, essentially eliminating $CO_2$ equivalent emissions** related to the insulation gas

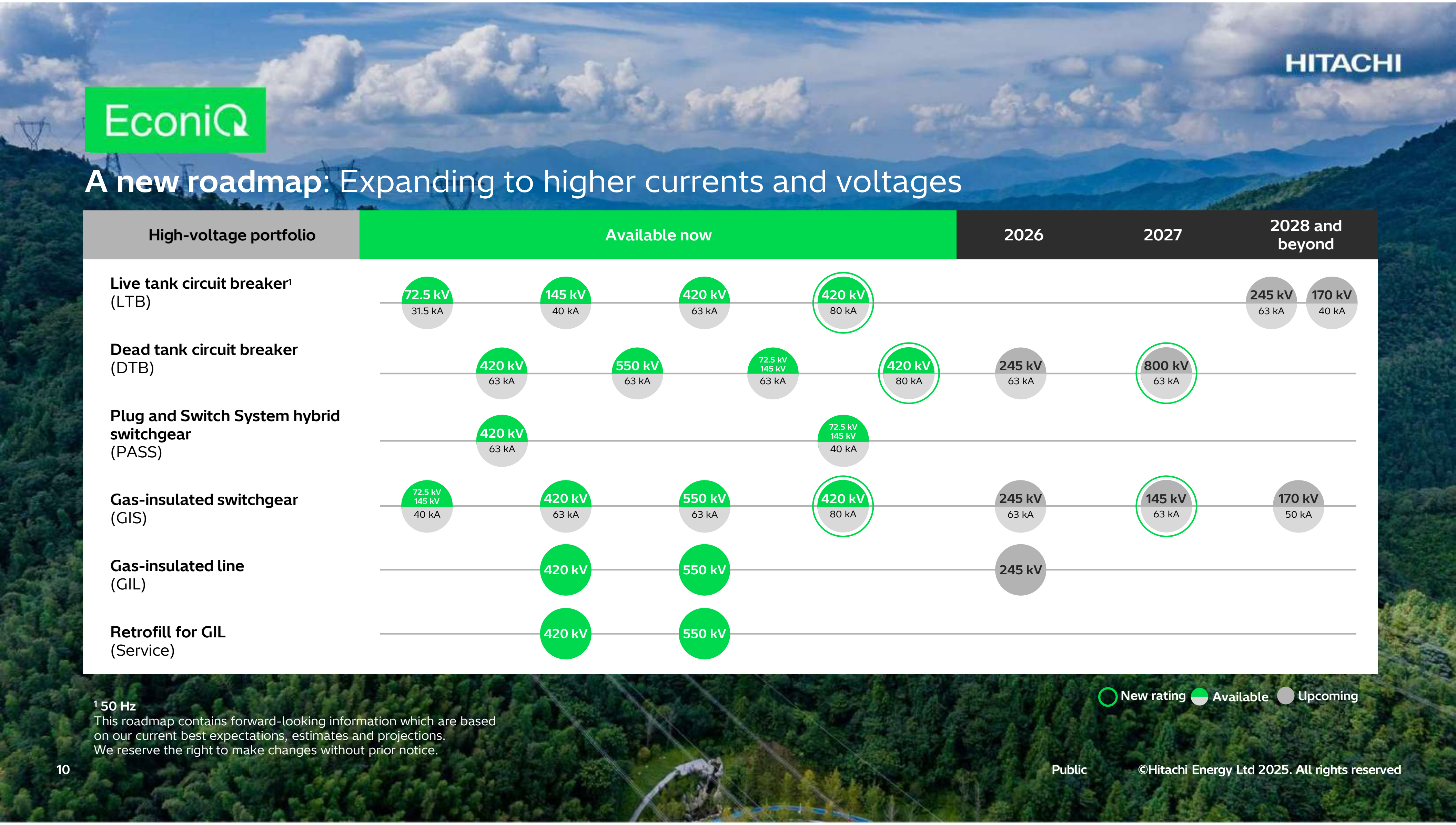
**02** **100% as reliable and scalable as the conventional solution** while delivering the lowest carbon footprint throughout the total lifecycle

**03** **An industry standard solution** to enable utilities and industries to break free of $SF_6$

**04** **Extensive portfolio of switchgear and breakers** scalable to ultra-high-voltage

**05** **Remains as compact** as the conventional $SF_6$ solution.

Annexure-II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EconiQ
A new roadmap: Expanding to higher currents and voltages
High-voltage portfolio
Available now
2026
2027
2028 and beyond
Live tank circuit breaker¹ (LTB)
72.5 kV 31.5 kA
145 kV 40 kA
420 kV 63 kA
420 kV 80 kA
245 kV 63 kA
170 kV 40 kA
Dead tank circuit breaker (DTB)
420 kV 63 kA
550 kV 63 kA
72.5 kV 145 kV 63 kA
420 kV 80 kA
245 kV 63 kA
800 kV 63 kA
Plug and Switch System hybrid switchgear (PASS)
420 kV 63 kA
72.5 kV 145 kV 40 kA
Gas-insulated switchgear (GIS)
72.5 kV 145 kV 40 kA
420 kV 63 kA
550 kV 63 kA
420 kV 80 kA
245 kV 63 kA
145 kV 63 kA
170 kV 50 kA
Gas-insulated line (GIL)
420 kV
550 kV
245 kV
Retrofill for GIL (Service)
420 kV
550 kV
New rating
Available
Upcoming
¹ 50 Hz
This roadmap contains forward-looking information which are based on our current best expectations, estimates and projections.
We reserve the right to make changes without prior notice.
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# EconiQ gas circuit breaker technology

*Based on **well-proven** gas circuit breaker technology*

The EconiQ gas circuit breaker remains as compact as the conventional $SF_6$ solution.



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## LTA

A gas mixture of $CO_2$ + $O_2$ replaces $SF_6$ in all LTB applications for insulation and switching.

**Eco-efficient gas mixture**

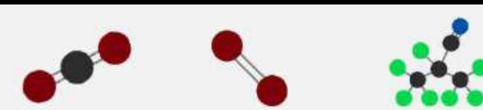
**$CO_2$** Carbon dioxide

**$O_2$** Oxygen

## Metal Enclosed (MEB)

A gas mixture of $CO_2$ + $O_2$ + C4-FN* replaces $SF_6$ in all our metal-enclosed switchgear (GIS, DTB, PASS) for insulation and switching.

**Eco-efficient gas mixture**



**$CO_2$** Carbon dioxide

**$O_2$** Oxygen

**C4-FN** Fluorinated nitrile

* C4-FN is a synthetic gas

Annexure-II

# Electrical field distribution – LTB and GIS

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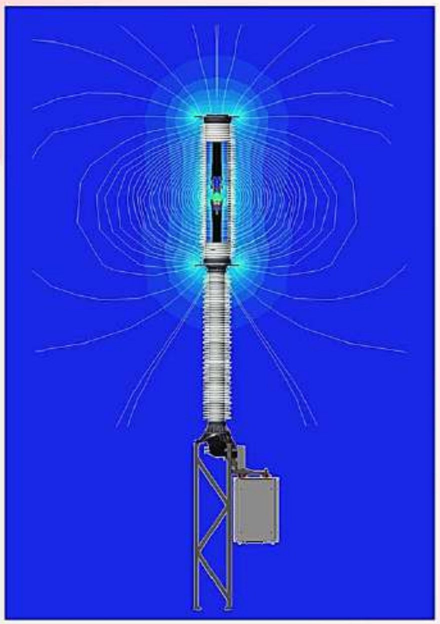
The EconiQ high-voltage portfolio **retains the size, performance, and reliability** of a conventional $SF_6$-based solution. **It is as safe and compact.**

## Live Tank Circuit Breaker (LTB)

LTBs stand high up in the air, with its size determined by the properties of the surrounding atmosphere

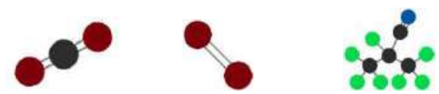
**$CO_2$** Carbon dioxide

**$O_2$** Oxygen



## Gas-Insulated Switchgear (GIS)

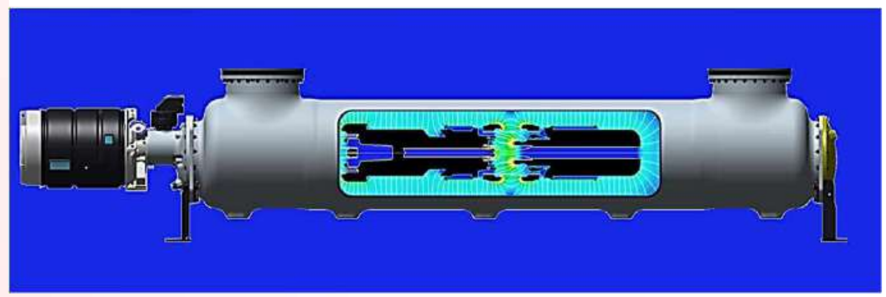
In metal-enclosed breakers, the size is determined by the insulating gas used inside. 3.5% C4-FN is needed to keep them compact.



**$CO_2$** Carbon dioxide

**$O_2$** Oxygen

**C4-FN** Fluorinated nitrile





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# Life cycle assessment for environmental performance

## Assessing the impact on the environment

- **Quantifies** the environmental impact of a product or a system from cradle to grave
- Includes the **whole life cycle**
- **Standardized** methodology (ISO 14040 14044), databases, and expertise
- **Shows environmental hot spots –** phase of life and materials that have the highest environmental impact



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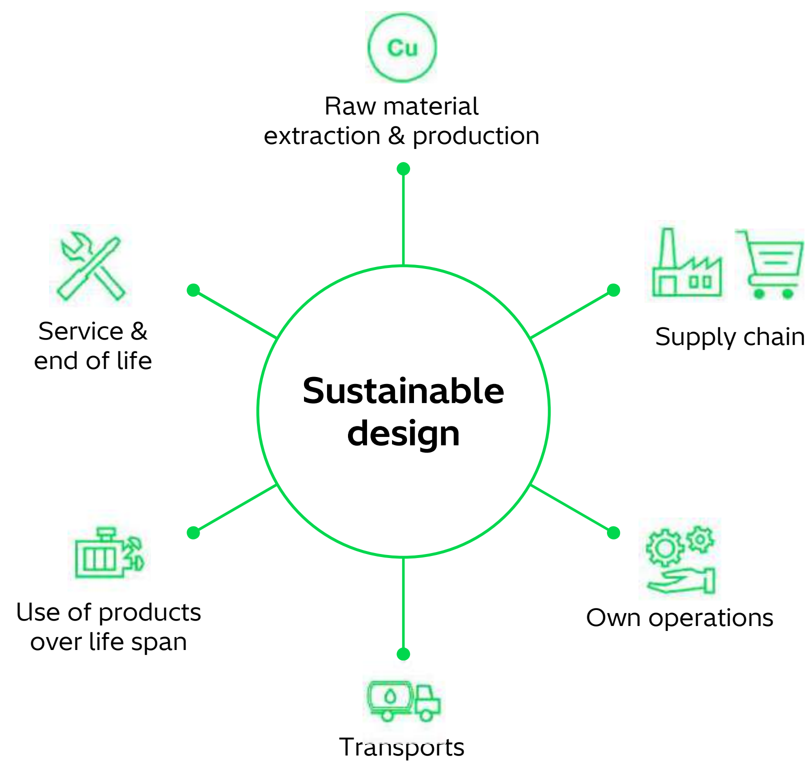
**LCA is the accepted state-of-the-art method to measure environmental performance**



Annexure-II

# The gas mixtures for EconiQ metal-enclosed portfolio

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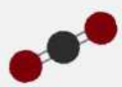
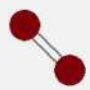
## New products – all modules

### $CO_2$ / $O_2$ / C4-FN


86.5 mol%
$CO_2$

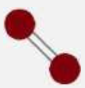

10 mol%
$O_2$


3.5 mol%
C4-FN

## Retrofill gas-insulated lines

### $N_2$ / $O_2$ / C4-FN


85 mol%
$N_2$


5 mol%
$O_2$


10 mol%
C4-FN



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# Solutions with GWP < 10 of the gas do not have the lowest carbon footprint

- Larger size and more material use result in a larger total $CO_2$ footprint if only the GWP of the gas is minimized.
- Even with 100% renewable electricity production, the material production is not carbon neutral.
- Although air has a GWP of zero, the total $CO_2$ equivalent emissions are higher for the air+vacuum GIS compared to that with $CO_2$ / $O_2$ / C4-FN mixture.



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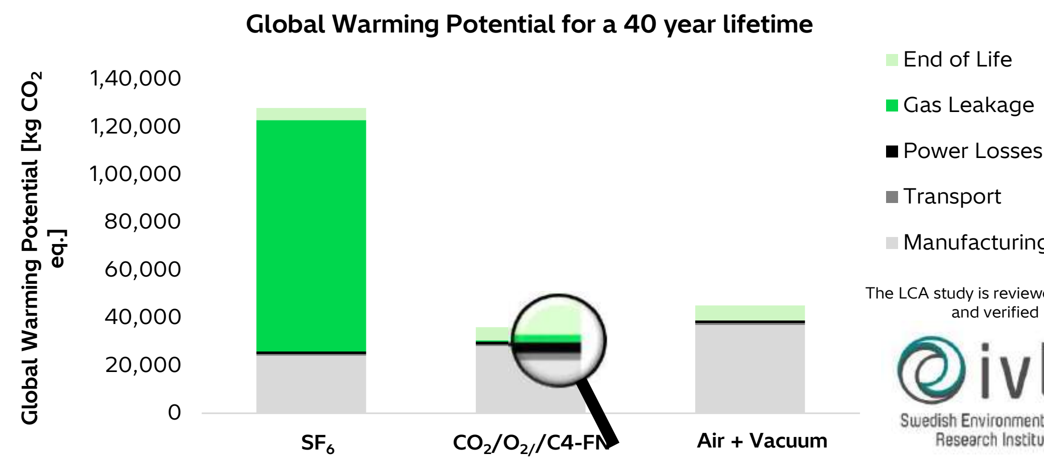
## Why are we using the C4-FN gas mixture?

Compact size, best reliability, scalability to all high-voltage levels

Elimination of $SF_6$ results in the lowest carbon footprint

**Carbon footprint of 145 kV gas-insulated switchgear per life cycle assessment (LCA)[1]**




The LCA study is reviewed and verified by

ivl Swedish Environmental Research Institute

[1] The full study report can be found in Life Cycle Assessment of Different Concepts of $SF_6$-free Gas Insulated Switchgear, 202206_2665472. The Study is approved and verified by the external independent institute, the Swedish Environmental Research Institute.

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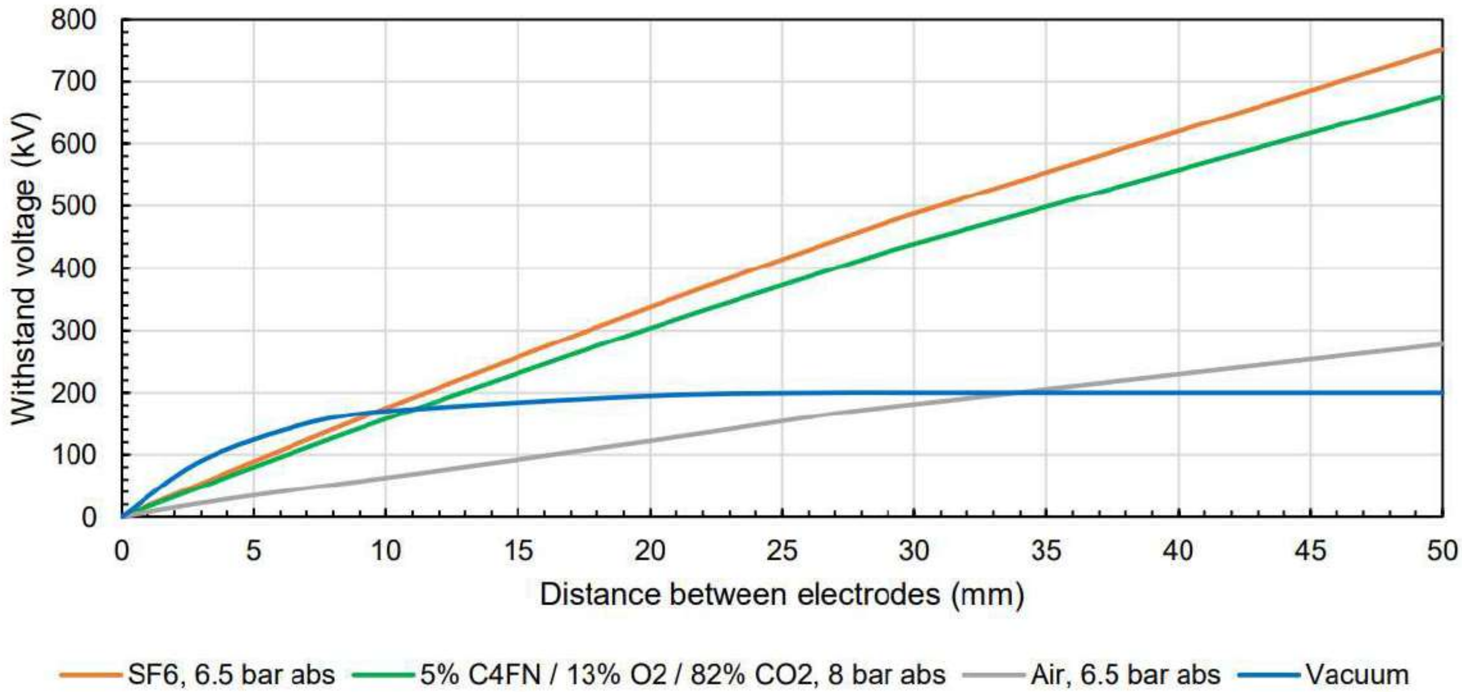
# Why Gas Mixture with C4FN?




**99 % Lower GWP potential than SF6 , C4FN mixture has Strong Di-Electric & Interruption performance that enables lowest LCA (life cycle impact) on the environment**


Source of Graph : GE-HE Handbook on the Gas Mixtures

Annexure-II

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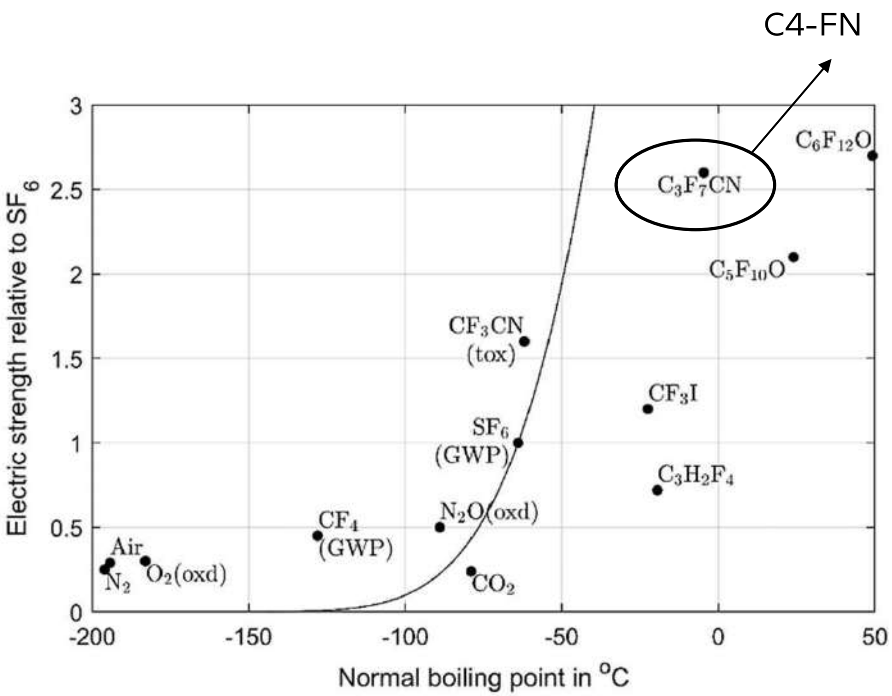
# Dielectric strength, boiling point




Source: https://www.research-collection.ethz.ch/bitstream/handle/20.500.11850/458505/3/author_version.pdf

**Natural gases have a poor dielectric performance compared to $SF_6$**

Source: Cigré Brochure 730



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Annexure-II

# Environment, Health & Safety assessment of C4-FN

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## Robust health and safety features for use in high-voltage

- Eco-efficient gas mixture is not classified as toxic
- Pure C4-FN has the lowest EU CLP* classification and is in the same category as many household cleaning products
- Pure C4-FN classified as “harmful if inhaled” at a high concentration, which is unlikely to happen because it is only used as a strongly diluted mixture and access is limited to trained personnel following safety procedures

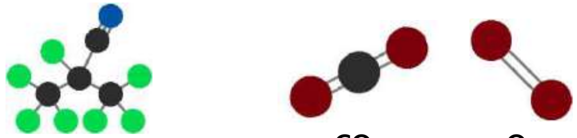
## Sustainable and environmentally responsible technology

- Does not accumulate in water, plants, or soil
- If it would accidentally escape from its tight enclosure, it would distribute evenly in the atmosphere
- Atmospheric lifetime around 30 years
- Decomposes into substances that already exist in nature

**Eco-efficient gas mixture**

C4-FN
**3.5%**

Carbon dioxide and Oxygen
**96.5%**



**C4-FN** **$CO_2$** **$O_2$**

* The CLP Regulation is a European Union regulation from 2008, which aligns the European Union system of classification, labelling and packaging of chemical substances and mixtures to the Globally Harmonized System

Annexure-II

# Gas handling equipment from multiple established suppliers

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## MONITOR
Sensor

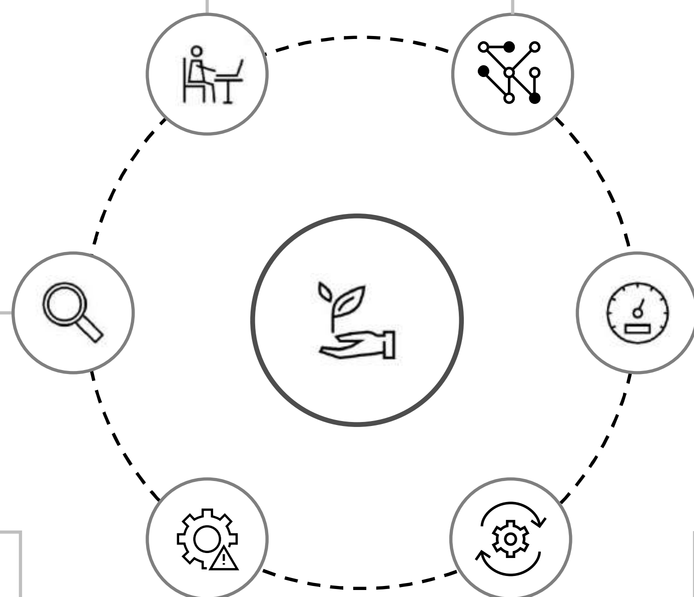
© WIKA © KELLER © TRAFAG

## ANALYZE
C4-FN mixture analyzer

© WIKA © EMT © DILO

## DETECT
Leakage detector

© BACHARACH © ISM © DILO © Dräger



## INITIAL FILLING
Mixture prepared from single gases or taken from premixed bottles and then filled into the equipment

© DILO © AIR LIQUIDE © AIR LIQUIDE / Laurent Lelon © DILO

## SERVICE
**Fill, recover, refill**
Gas is handled with service cart

© DILO © AIR LIQUIDE

## DISPOSE
Recycling or incineration

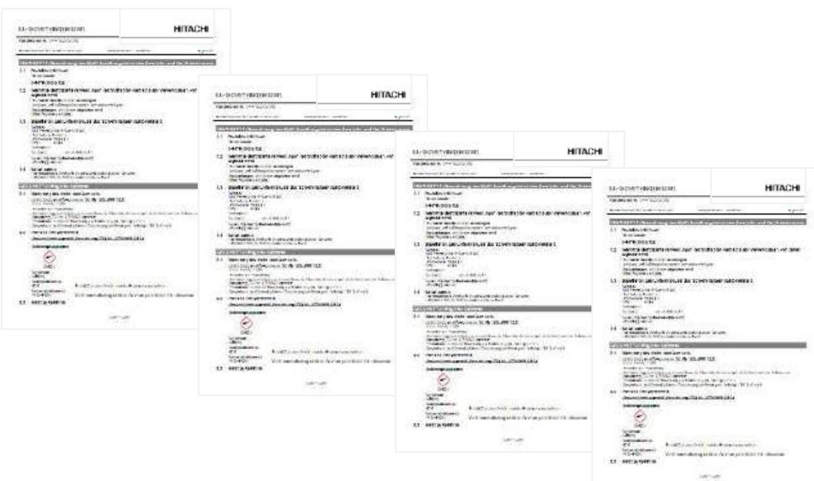
Annexure-II

# Gas handling: Highest safety standards and clear procedures

HITACHI

## Safety data sheets

- Safety data sheets for the gas mixture used are provided by Hitachi Energy
- Country-specific versions, according to national specifications and in the respective national language



## Gas handling instructions

- All gas handling procedures for safe handling of the gas are described in the gas handling instructions.
- In line with IEC 62271-4 Ed. 2.0

Annexure-II

# EconiQ

high-voltage global footprint

HITACHI


## At the forefront of **eco-efficient innovation**

- Unveiled the world's first $SF_6$-free 420 kV and 550 kV circuit breaker
- Delivered the world's first $SF_6$-free 420 kV dead tank circuit breaker in the US
- Delivered the world's first $SF_6$-free 420 kV gas-insulated switchgear in Germany

**2,000+**
EconiQ units worldwide

**>10 years**
experience in eco-efficient high-voltage technology

More than
**15 km**
EconiQ gas-insulated lines

**30 countries**
Adopted EconiQ high-voltage technology to achieve carbon-neutrality targets

Annexure-II

HITACHI

# Technology breakthrough

**World's first** fully type-tested $SF_6$-free 420 kV circuit breaker enabling our customers to transition to net zero

**450+** EconiQ breakers ordered

Annexure-II

HITACHI

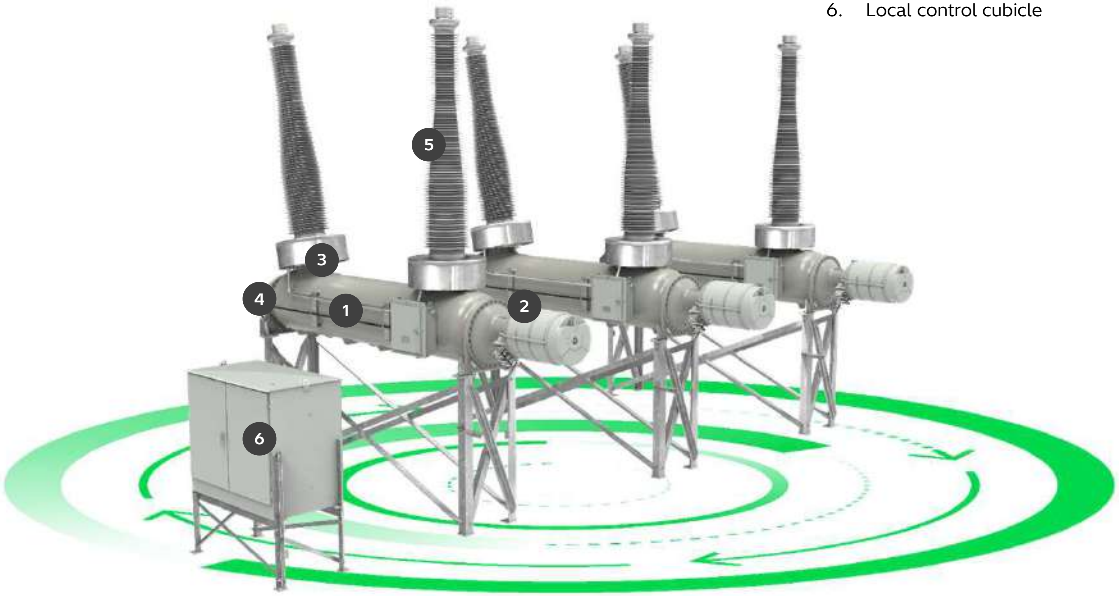
# Type EconiQ 420PM63-HA

**Target ratings and features**

| **EconiQ 420PM63-HA** | | |
|---|---|---|
| Rated voltage | kV | 362-420 |
| Rated frequency | Hz | 50 / 60 |
| Rated continuous (nominal) current | A | 3000 / 4000 / 5000 |
| Rated short-circuit (interrupting) current | kA | 63 |
| Rated first-pole-to-clear factor ($k_{pp}$) | | 1.3 & 1.5 |
| Rated capacitive switching Class | | C2 |
| Rated capacitive switching voltage factor ($k_c$)<br>• Line and cable charging | | 1.4 |
| Minimum operating temperature, no tank heaters | °C | -30 |
| Rated mechanical endurance class | | M2 |
| Extended electrical endurance class | | E2 |
| Independent (single-) pole operation | | HMB-8 |

Easy operation at high performance ratings – 63 kA / 3 second short circuit rating, up to 5000 A, 100% $SF_6$-free, E2 class

1. Circuit breaker
2. Operating mechanism
3. Current transformer
4. Pressure relief device
5. Bushing
6. Local control cubicle





Public

Annexure-II


HITACHI
World first $SF_6$-free 420 kV DTB
– Picture after successful routine tests
– Handed over to the customer in June 2023
– In operation since December 2023
HITACHI
24
Public
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Annexure-II

HITACHI

# Hitachi Energy installs the world's first EconiQ 420 kV DTB in the US

*The EconiQ DTB aligns with our mission to replace $SF_6$ with better alternatives that reduce greenhouse gas emissions.*

**Aftab Khan**
Senior Vice President of Engineering at Eversource

## Challenge

Eversource aims to build a cleaner energy future for its customers and become carbon-neutral in its operations by 2030.

## Solution

Hitachi Energy installed the EconiQ 420 kV Dead Tank Circuit Breaker (DTB) at an Eversource 345 kV substation in December 2023.

## Impact

The breakthrough technology will enable Eversource to reduce its carbon footprint and achieve sustainability goals.

Annexure-II


HITACHI
World's first
$SF_6$-free 420 kV
DTB in operation
Operational since
December 2023
26
Public
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Annexure-II

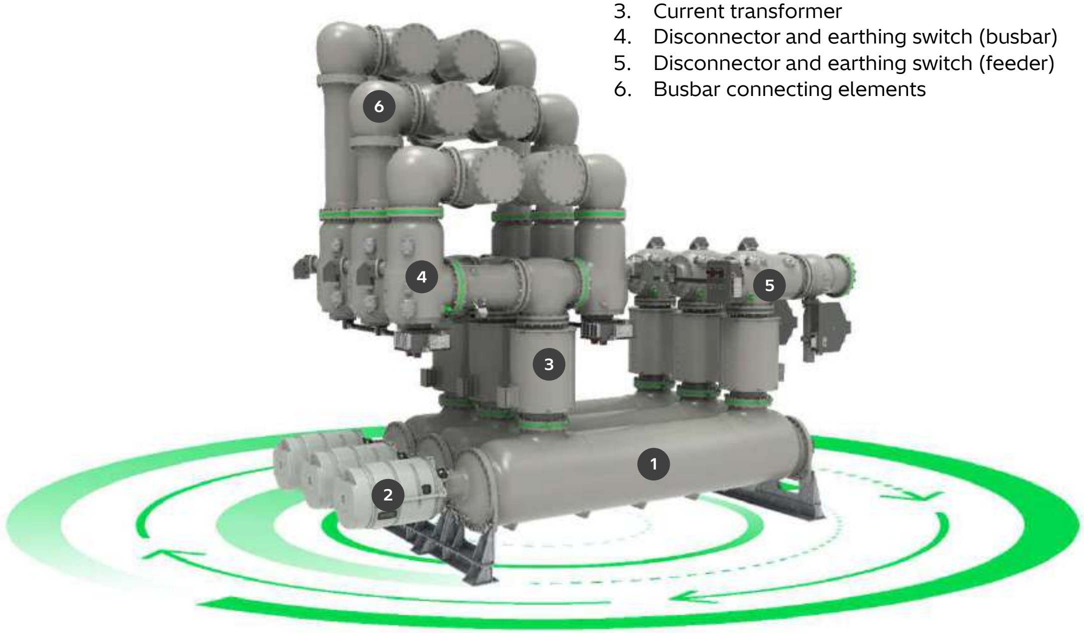
HITACHI

# 420 kV eco-efficient Gas-Insulated Substation

### Target ratings and features

| EconiQ GIS ELK-3, 420 kV | | |
|---|---|---|
| Rated voltage | kV | 420 |
| Rated frequency | Hz | 50 / 60 |
| Rated short-duration power-frequency withstand voltage (1 min) | kV | 650 |
| Rated lightning impulse withstand voltage (1.2 / 50 µs) | kV | 1425 |
| Rated switching impulse withstand voltage (250 / 2500 µs) | kV | 1050 |
| Rated normal current (at 40 °C) | A | 5000 |
| Rated short-circuit breaking current | kA | 63 |
| Rated short-time withstand current (up to 3 s) | kA | 63 |
| Rated peak withstand current | kA | 171 |
| Circuit breaker mechanical endurance class | | M2 (10,000 CO) |
| Circuit breaker electrical endurance class | | E2 |
| Circuit breaker capacitive switching class (k=1.4) | | C2 |
| Ambient temperature range | °C | -30...+50 |
| Installation | | Indoor / outdoor |

63 kA / 3 second short circuit rating, up to 5000 A, 100% $SF_6$-free, E2 class




1. Circuit breaker
2. Operating mechanism
3. Current transformer
4. Disconnector and earthing switch (busbar)
5. Disconnector and earthing switch (feeder)
6. Busbar connecting elements

Annexure-II

HITACHI

# World's first $SF_6$-free GIS implemented at TenneT

*We are proud to collaborate with TenneT in their efforts to accelerate the energy transition and strengthen the power infrastructure in Germany.*

## Challenge

Upgrading substations with an eco-efficient $SF_6$ alternative to meet the growing electricity demand and support Germany's decarbonization plans.

## Solution

The world's first $SF_6$-free 420 kilovolt (kV) gas-insulated switchgear (GIS) and a state-of-the-art modular prefabricated grid connection solution contributes to TenneT's carbon neutrality goals to build a sustainable and resilient grid in Germany.

## Impact

Major grid connection upgrade which significantly extends the operating life of existing power assets to ensure the longevity and continued efficiency of the existing power infrastructure.

Annexure-II

HITACHI

# Handover of world's first $SF_6$-free 420 kV GIS to TenneT, Germany


Symbolic handover held during EconiQ High Voltage Day, June 11, 2024, in Zurich, Switzerland



Public

Annexure-II

HITACHI

# An iconic milestone in 2024: EconiQ 550 kV circuit breaker

## The world's first eco-efficient 550 kV circuit breaker


**Scalable to the highest voltage ratings and unlocks the widest range** of EconiQ high-voltage applications like GIS and DTB

**Fully tested** according to the IEC and IEEE standards

**As reliable and compact** as the conventional $SF_6$ breaker technology

**Practically eliminates the carbon footprint** of the insulation gas

**Lifetime of 40 years**

**Accelerates the energy transition toward a carbon-neutral future.**


Public

Annexure-II

HITACHI

# Applications of the EconiQ 550 kV circuit breaker

## Applications

- Line & cable switching
- Transformer switching
- Reactor switching
- Capacitor bank switching

## Superior quality and robustness

- Single operating mechanism for each phase
- Tested according to IEEE and IEC standards
- with mechanical endurance class M2, capacitive switching class C2, and high seismic performance
- Extended electrical endurance class E2
- Quality system providing traceability on component level

Annexure-II

HITACHI

# EconiQ 550 kV circuit breaker

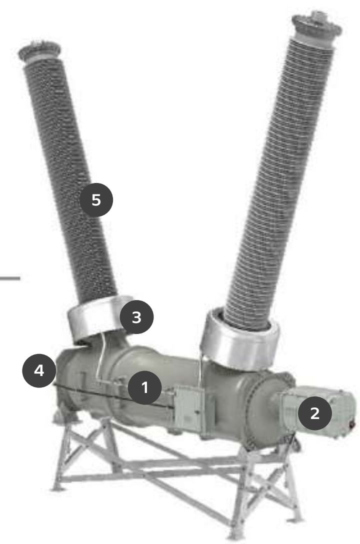
### Target ratings and features

| Performance data – EconiQ 550 kV circuit breaker | | GIS | DTB |
|---|---|---|---|
| Rated voltage | kV | 550 | 550 |
| Rated frequency | Hz | 50/60 | 50/60 |
| Rated lightning impulse withstand voltage (1.2 / 50 µs) | kV | 1675* | 1800 |
| Rated switching impulse withstand voltage (250 / 2500 µs) | kV | 1300* | 1300 |
| Rated power frequency withstand voltage | kV | 740* | 860 |
| Rated chopped wave impulse withstand voltage | kV | - | 2320 |
| Rated continuous current | A | 5000 | 5000 |
| Rated short-circuit breaking current | kA | 63 | 63 |
| Rated short-time withstand current (3s) | kA | 63 | 63 |
| Mechanical endurance class | | M2 | M2 |
| Electrical endurance class | | E2 | E2 |
| Capacitive switching class | | C2 | C2 |
| Capacitive voltage factor for line and cable switching | | 1.4 | 1.4 |
| Ambient air temperature | °C | -30...+40 | -30**...+40 |
| Gas mixture | | $CO_2$ / $O_2$ / C4-FN | |

**63 kA / 3 second short circuit rating, up to 5000 A, 100% $SF_6$-free**


**Gas-insulated switchgear**

1. Circuit breaker
2. Operating mechanism
3. Current transformer
4. Disconnector
5. Pressure relief device




**Dead tank circuit breaker**

1. Circuit breaker
2. Operating mechanism
3. Current transformer
4. Pressure relief device
5. Bushing

* Higher ratings than IEC according to GB standard | ** Below -30 °C with tank heaters



Public

Annexure-II


**Handover of the world's first $SF_6$-free 550 kV circuit breaker to Wesco and launch of the new EconiQ 145 kV DTB**

Handover held during Sustainable Energy Day, April 8, 2025, in Mount Pleasant, Pennsylvania, US


Public

Annexure-II

HITACHI

# EconiQ 550 kV DTB supports Hydro One to achieve net zero

## Challenge

Hydro One is Ontario's largest electricity transmission and distribution service provider. It strives to minimize the installation of new $SF_6$ assets to the grid.

## Solution

EconiQ Dead Tank Circuit Breaker (DTB) 550 kV satisfies the most stringent performance requirements. The newly ordered DTB will be located at the existing 525 kV substation connecting to the Lennox Generating Station between Toronto and Ottawa.

## Impact

The EconiQ DTB will support Hydro One in its goal to minimize the installation of new $SF_6$ assets while retaining its current high technical performance standard in the 525 kV grid.

Annexure-II

HITACHI

# EconiQ 550 kV DTB supports Wesco to achieve net zero

## Challenge

WesCo, based in Pittsburg, Pennsylvania, is committed to powering progress. It has the ambition to fulfil ambitious sustainability goals while realizing renewables projects moving at fast pace.

## Solution

Hitachi Energy's EconiQ 550 kV DTB is free of $SF_6$ and available with suitable lead time. The pilot installation is likely to be in the 1,200 MWh energy storage facility in Maricopa County, Arizona developed by Recurrent Energy.

## Impact

An important step toward contributing to the US Net-Zero Greenhouse Gas Emissions by 2050 was possible with Hitachi Energy's breakthrough technology that reduces substation greenhouse gases on high voltage equipment.



Public

Annexure-II

# EconiQ gas circuit breaker technology: live tank circuit breaker LTA

## Based on well-proven gas circuit breaker technology

A gas mixture of $CO_2$ + $O_2$ replaces $SF_6$ in all LTB applications for insulation and switching.

**Eco-efficient gas mixture**

**$CO_2$**
Carbon dioxide

**$O_2$**
Oxygen

Annexure-II

HITACHI

# EconiQ Live Tank Circuit Breaker – LTA

## Scalable eco-efficient Live Tank Circuit Breakers

Combining the reliability and experience from gas type circuit breakers with the use of carbon dioxide ($CO_2$) and oxygen ($O_2$) as an eco-efficient insulation gas mixture.

| Type | LTA 72.5D1 | LTA 145D1 | DCB-LTA 72.5D1 |
|---|---|---|---|
| Rated voltage | 72.5 kV | 145 kV | 72.5 kV |
| Rated current | 2750 A | 3150 A | 2750 A |
| Rated short-time withstand current | 31.5 kA | 40 kA | 31.5 kA |
| Rated frequency | 50 Hz | 50 Hz | 50 Hz |
| Ambient temperature | -50/+40 °C | -50/+50 °C | -50/+40 °C |
| Gas-mixture | $CO_2 + O_2$ | $CO_2 + O_2$ | $CO_2 + O_2$ |

Annexure-II

HITACHI

# The EconiQ LTA portfolio continues to grow with new products

Game-changing $SF_6$-free high-voltage live tank circuit breaker



Disconnecting circuit breaker LTA up to 145 kV

Annexure-II

HITACHI

# New EconiQ 420 kV breaker application: LTA

## The world's first eco-efficient 420 kV live tank circuit breaker LTA

**Fully tested as described in** the IEC standards

**Based on well-proven** gas circuit breaker technology

**Same footprint and reliability** as the conventional $SF_6$ solution

**Easy retrofit** in existing substations

**Designed to operate** in temperatures as low as -50° C

**Suitable for shunt reactor switching**

Annexure-II

HITACHI

# EconiQ 420 kV Live Tank Circuit Breaker – LTA

## Applications

- Line & cable switching
- Transformer switching
- Reactor switching
- Capacitor bank switching

## Superior quality and robustness

- Tested according to IEC standards with mechanical endurance class M2 and capacitive switching class C2
- Extended electrical endurance class E2
- Quality system providing traceability on component level

Annexure-II

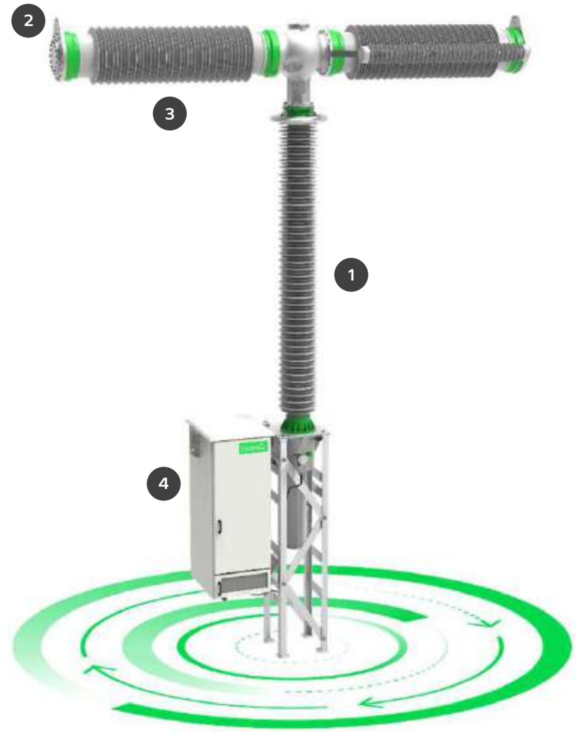
HITACHI

# EconiQ 420 kV Live Tank Circuit Breaker – LTA

**Target ratings and features**

| Performance data – EconiQ Live Tank Circuit Breaker – LTA | | |
|---|---|---|
| Rated voltage | kV | 420 |
| Rated frequency | Hz | 50 |
| Rated lightning impulse withstand voltage (1.2 / 50 μs) | kV | 1425 |
| Rated switching impulse withstand voltage (250 / 2500 μs) | kV | 1050 |
| Rated power frequency withstand voltage | kV | 610 |
| Rated continuous current | A | up to 5000 |
| Rated short-circuit breaking current | kA | 63 |
| Rated short-time withstand current (3s) | kA | 63 |
| Mechanical endurance class | | M2 |
| Electrical endurance class | | E2 |
| Capacitive switching class | | C2 |
| Capacitive voltage factor for line and cable switching | | 1.4 |
| Ambient air temperature | °C | -50...+40 |
| Gas mixture | | $CO_2$ / $O_2$ |

63 kA / 3 second short circuit rating, up to 5000 A, 100% $SF_6$-free




1. Post insulator
2. Terminals
3. Breaking unit
4. Operating mechanism

**100%**

as reliable and compact as the conventional $SF_6$-based solution

Annexure-II

HITACHI

# Breakthrough EconiQ 420 kV LTA support SSEN to achieve net zero

*We are delighted to collaborate with Hitachi Energy and order some of the world's first $SF_6$-free 420 kV AIS circuit breakers, which is a testament to our position as a leader in the adoption of $SF_6$ alternatives.*

**Rob McDonald**
Managing Director of SSEN

## Challenge

SSEN, the UK-based international energy company supplies 10,200 GWh of renewable energy per year. It requires pioneering sustainable energy solutions to fulfil their aim to be net zero by 2030.

## Solution

Hitachi Energy will deliver the new generation EconiQ 420 kV LTA that will eliminate 100% of the $CO_2$ equivalent emissions related to the insulation gas and strengthen the network.

## Impact

The new order supports SSEN's plans to phase out $SF_6$ entirely and cut its carbon intensity by 80% by 2030, while also enabling at least 20GW of renewable energy, 2 million EVs and 1 million heat pumps to be connected to its electricity network.



Public

Annexure-II

HITACHI

# Breakthrough EconiQ 420 kV LTA support TenneT to achieve net zero

## Challenge

Rebuilding a substation with an eco-efficient $SF_6$ alternative to meet the growing electricity demand and support Germany's and The Netherland's decarbonization plans.

## Solution

The EconiQ Live Tank Circuit Breaker LTA 420 kV is a reliable solution to eliminate 100% of the $CO_2$ equivalent emissions related to the insulation gas and strengthen the German and Dutch grids. The innovative breaker will be installed in an existing 380 kV AIS substation.

## Impact

Contributing to TenneT's plan to cut at least 30 percent of its scope 3 upstream emissions by 2030 with the target to achieve carbon-neutrality by 2050.

Annexure-II

HITACHI

# EconiQ technology contributes to Fingrid's environmental goals

## Fingrid is decarbonizing its outdoor breaker installations


The 46 year-old Heinola substation is Fingrid's first substation to install the $SF_6$-free EconiQ LTA, 145 kV

## Things you need to know about EconiQ LTA

- ~ 200 installations worldwide
- LTA is as 100% reliable as the $SF_6$ breaker
- Eco-efficient $CO_2$-based gas mixture
- Future-proof to environmental regulations


Public

Annexure-II

HITACHI

# EconiQ® breaker contributes to Norway's journey towards net-zero

*We are excited to join forces with Hitachi Energy to bring new and innovative EconiQ technology that reinforces our strategy for sustainable operations.*

**Atle Isaksen**
Head of Grid Development, BKK Nett

## Challenge

Rebuilding a substation with an eco-efficient sulfur hexafluoride ($SF_6$) alternative to meet the growing electricity demand and support Norway's decarbonization plans.

## Solution

The EconiQ Live Circuit Tank Breaker LTA is a reliable solution that eliminates 100 percent of the $CO_2$-equivalent emissions related to the insulation gas and strengthens the Norwegian grids.

## Impact

It contributes to Norway's plans to cut at least 50 percent of its greenhouse gases by 2030 with the target to achieve carbon-neutrality by 2050.

Annexure-II

HITACHI

GE VERNOVA

# SF6-FREE UPDATES FOR HV SWITCHGEAR

# What is $SF_6$ and why does the industry need to replace it?

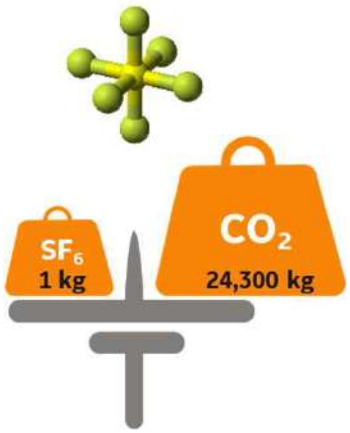
GE VERNOVA

## What is $SF_6$?

- Excellent gas for electrical **insulation**
- **Industrial standard** used in switchgear for insulation and switching
- Over the last 50 years, has met the high **reliability** needs of TSOs/DSOs (i.e., blackout avoidance)

*Typical GIS Switchgear filled with $SF_6$ gas*

## Why does the industry need to replace $SF_6$?




$SF_6$ is a greenhouse gas with a GWP over 100 years that is 24,300[(a)] times greater than that of $CO_2$

nationalgrid quotes:

*"When excluding transmission losses, $SF_6$ makes up **92% of scope 1 & 2 emissions**"*

*"All new assets should be **$SF_6$-free where possible**"*

*"Need to be early technology adopters **working with OEMs** to field test non-$SF_6$ alternatives"*

**$SF_6$ emissions are the 2nd contributor to scope 1[(b)] GHG emissions for our customers**

- (a) Based on the Sixth Assessment Report adopted by the Intergovernmental Panel on Climate Change
- (b) scope 1 are those direct emissions that are owned or controlled by a company

**Alternatives to $SF_6$ will help TSOs/DSOs to achieve their Net Zero targets**

# Our Journey towards $SF_6$-Free HV equipment

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GRiDEA
Innovations to
Decarbonize the Electrical Grid
4

# $SF_6$-Free Solutions for High-Voltage Switchgear

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## METAL-ENCLOSED EQUIPMENT



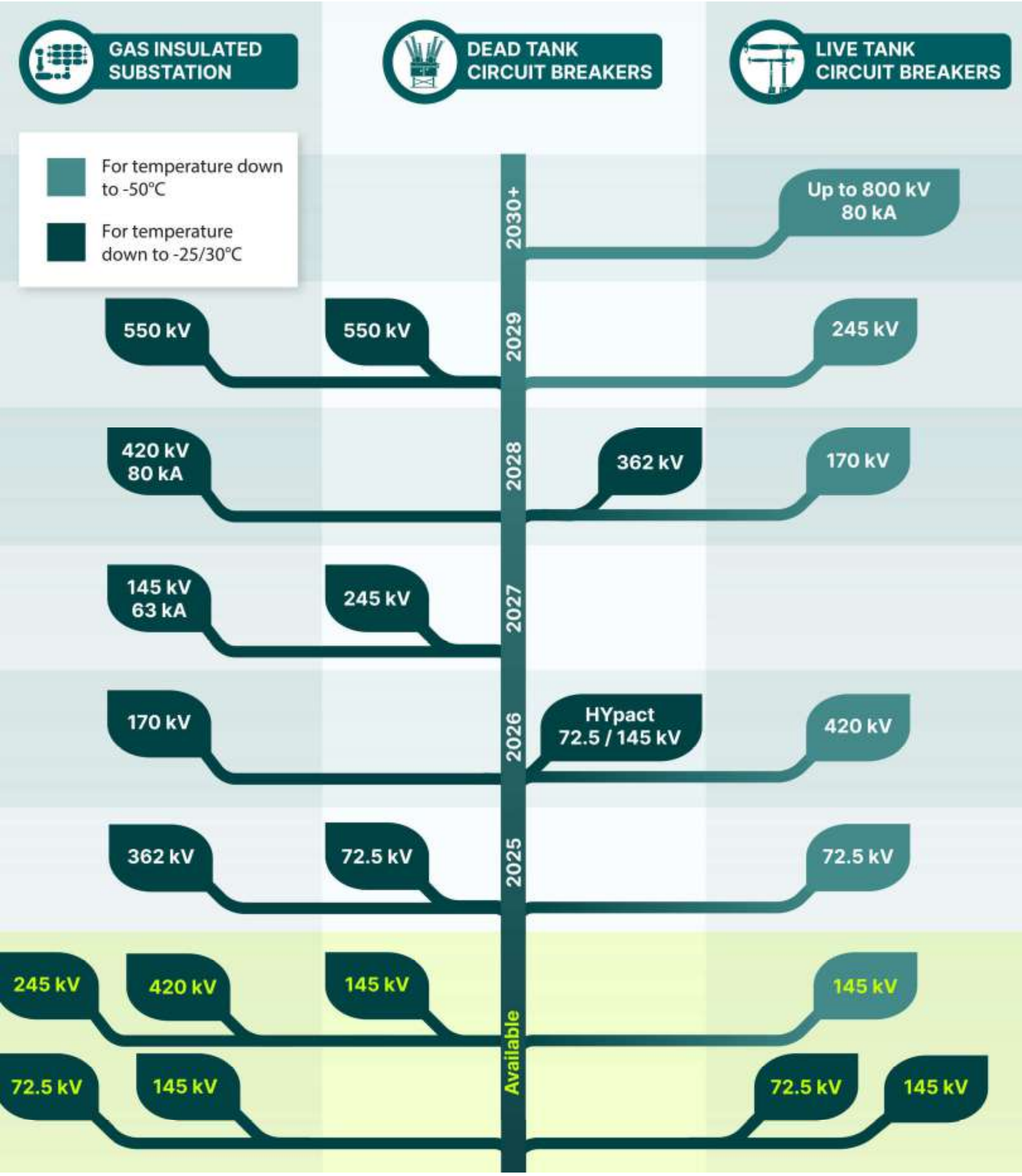
$CO_2$+$O_2$ + $C_4F_7N$

g3

## LIVE TANK CB

$CO_2$+ $O_2$

## DELIVER THE LOWEST LIFECYCLE $CO_{2eq}$ EMISSIONS

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# THE ROADMAP

6

# What is $g^3$ compared to $SF_6$?

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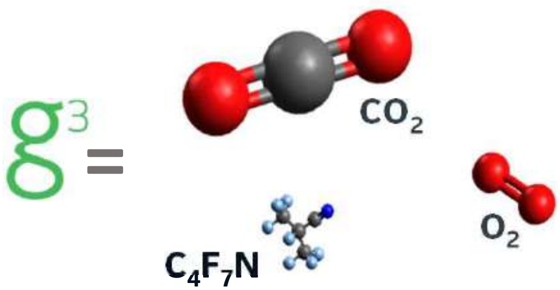
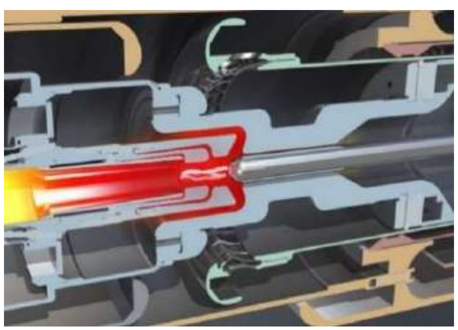
## What is $g^3$?

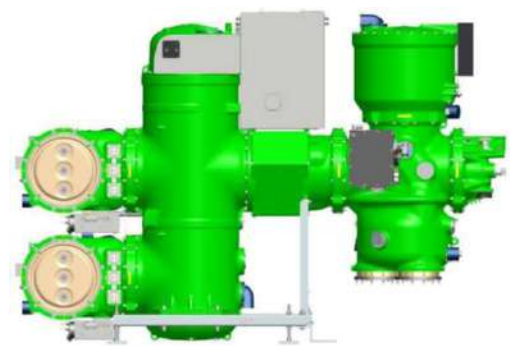


- $CO_2$: Improves the arc extinction capability.
- $O_2$: stabilizes the gas against decomposition in arcing.
- $C_4F_7N$: boosts insulation and arc quenching performances.

## How is it solving the $SF_6$ GWP challenges?

- **Comparable performance** and **size** as $SF_6$
- **99%** decrease of GHG emissions compared to $SF_6$
- **Overall, lowest $CO_2$ footprint** compared to all alternatives
- Only solution to **decarbonize existing assets**
- Only solution **scalable to all voltages / ratings**



*Typical GIS Switchgear filled with $g^3$ gas*

# Lifecycle carbon emission – $g^3$ benefits

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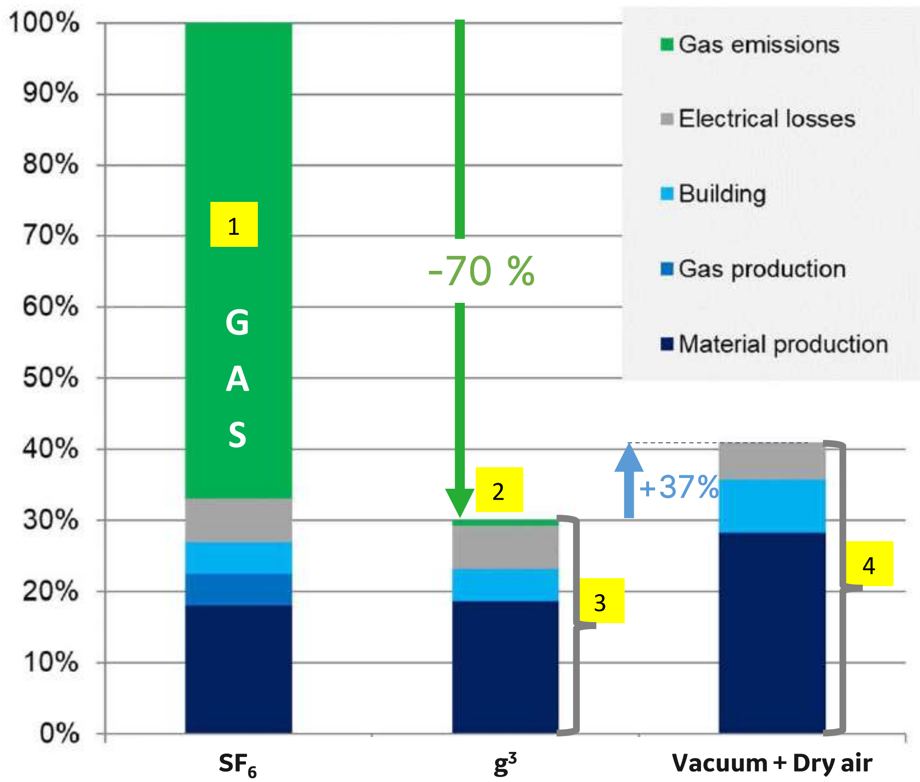



**145 kV GIS Lifecycle Assessment & Environmental Impact**

1. $SF_6$ is the main contributor to the carbon footprint over 40yrs
2. $g^3$ reduces significantly the gas impact (~ 1 % of the remaining impact)
3. $g^3$ switchgear has same dimensions ➔ not changing other environmental impacts
4. Dry air insulation requires bigger switchgears → This increase of size leads to a larger CO2 footprint and therefore a transfer of pollution

$g^3$ products offers the lowest environmental footprint over the full product life cycle

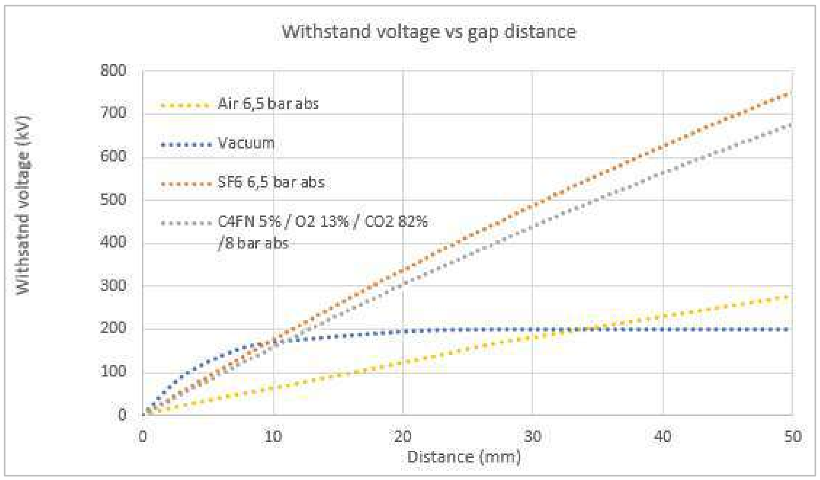
The gas GWP is not the criteria to assess the carbon footprint of a switchgear

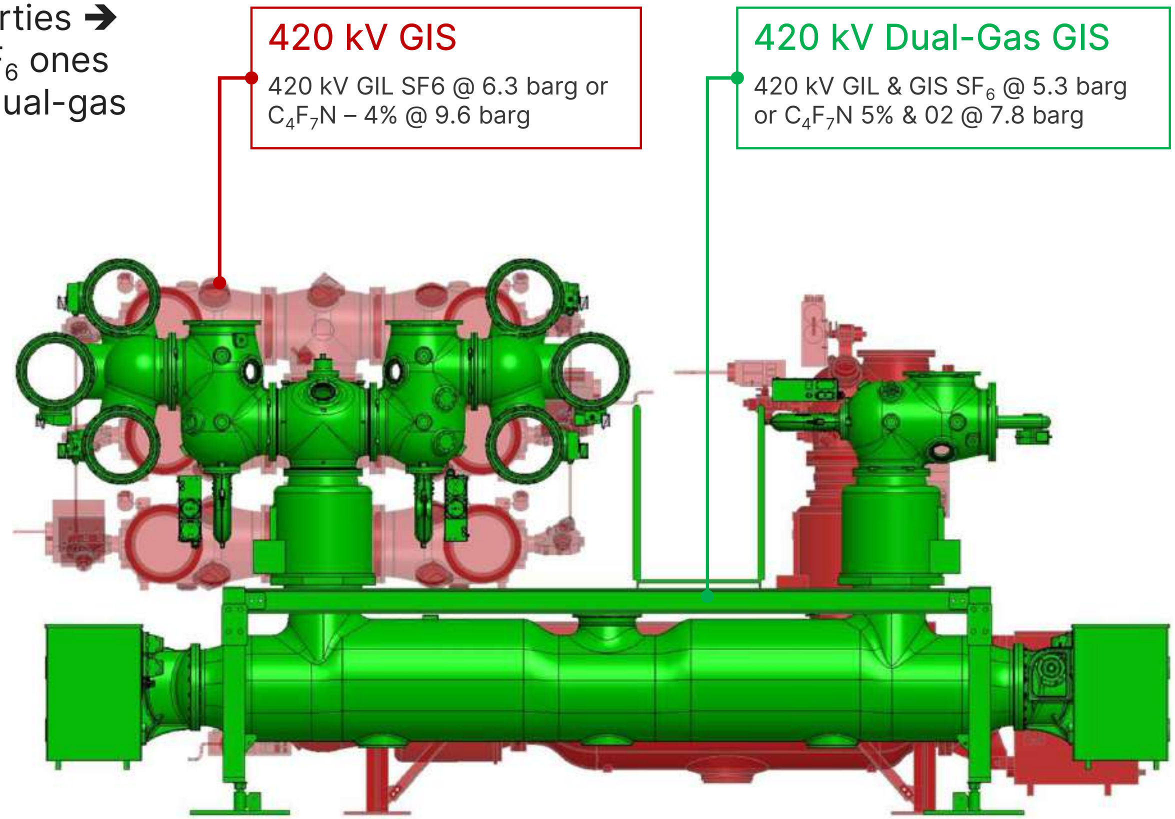
# Dual-Gas 420 kV GIS

lifeGRID
Cleaner energy · Safer future

GE VERNOVA

$C_4F_7N$ mixtures demonstrate high insulation properties ➔ g[3] metal-enclosed switchgear is as compact as $SF_6$ ones with same performance and we can even design dual-gas compatible concepts




**Same footprint for both $SF_6$ & $C_4F_7N$ GIS/GIL**

# $g^3$ Portfolio Adoption

GE VERNOVA

60+ LEADING UTILITIES

Have decided to install equipment with $g^3$



$g^3$ Gas–Insulated Substations
145 kV, -25 °C
100+ sites – 1000+ bays

$g^3$ Gas–Insulated Substations
420 kV, -25 °C
20+ sites – 150+ bays

$g^3$ Gas–Insulated Lines
420 kV, -25 °C / -30°C
20+ sites – 30+ km

$g^3$ AIS – Live Tank CB
145 kV, -30 °C
50+ sites – 150+ LT

# $g^3$ – Gas Management

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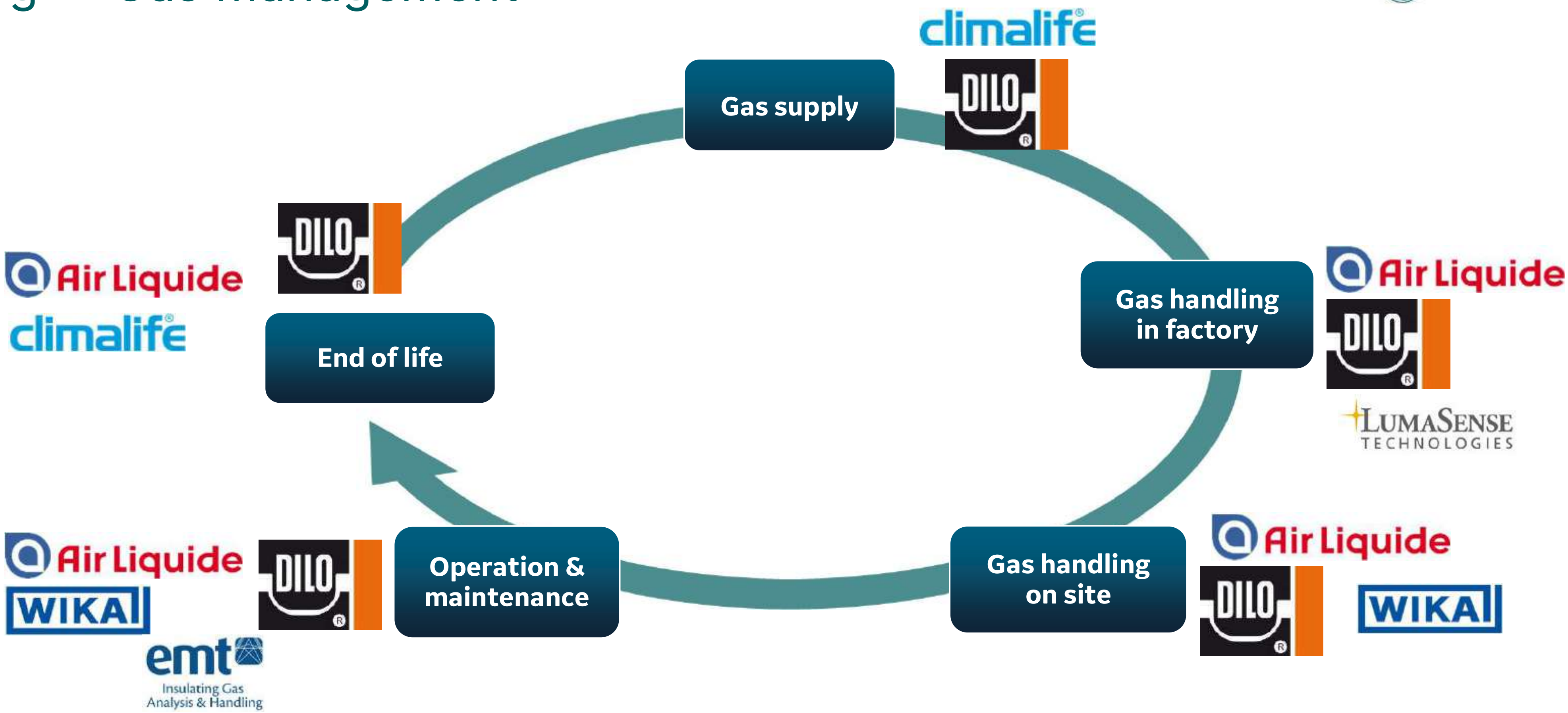


Solutions developed with 3rd parties for complete substation life cycle

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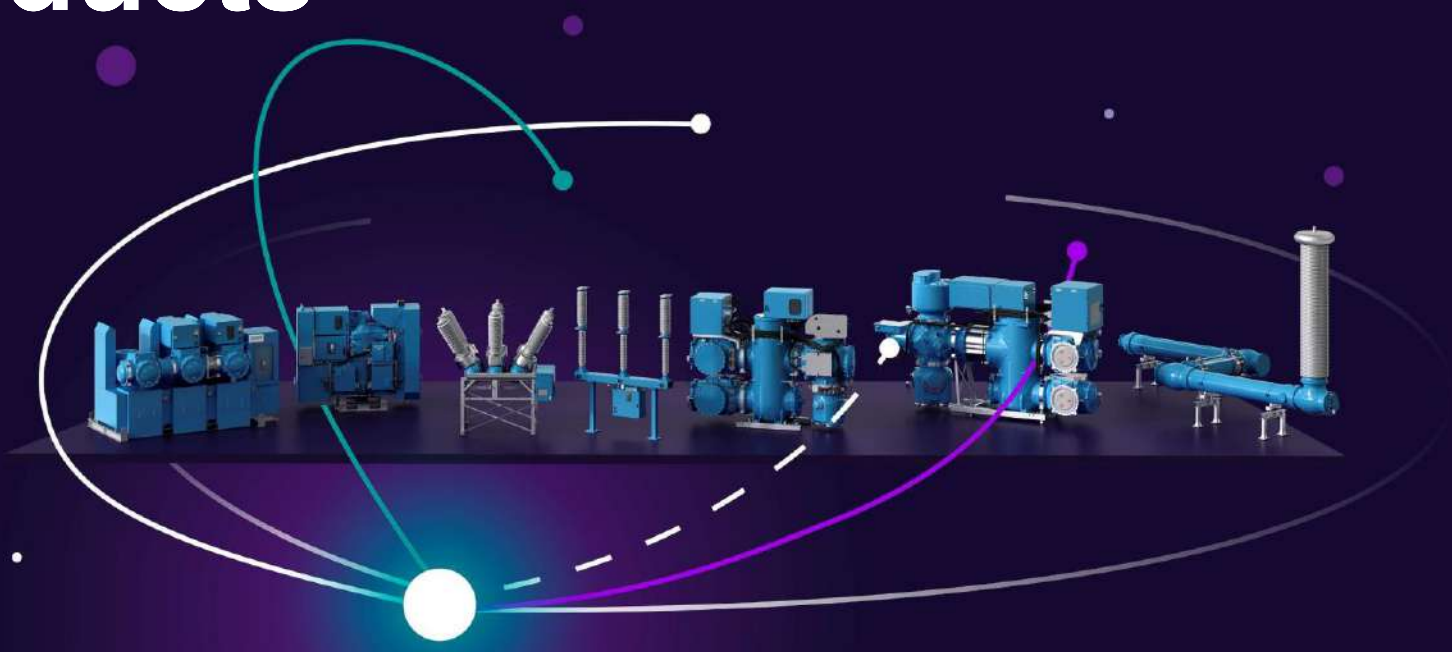
# Siemens Energy Blue high-voltage products

## Sustainable Zero-impact switchgear for a net Zero future



Status: April 2025

# There is an increasingly urgent need to achieve decarbonization in all sectors worldwide – actions to reduce GHG emissions must be taken fast

- In the UNFCCC (United Nations Framework Convention on Climate Change) Paris Agreement signed by 189 countries in 2015, it was agreed to limit anthropogenic global warming to well under 2º centigrade
- Each country must determine and report regularly on how it intends to mitigate its greenhouse gas emissions and thus reduce global warming
- Up to now more than 100 countries have submitted a net-zero document (Net-Zero Tracker)

**US**
2035: 100% clean electricity
2050: Net zero GHG pollution

**EU**
2050: First climate-neutral continent

**China**
> 2030: $CO_2$ emission peak
> 2060: Carbon neutrality

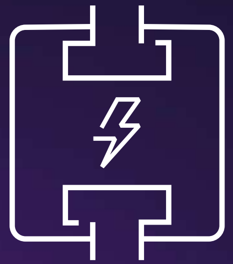
# The Blue portfolio is based on game-changing technology: vacuum switching and clean air insulation

## Clean air ($N_2$ + $O_2$ ) insulation

- Zero $CO_2$emissions, lowest $CO_2$ 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)

= **Clean, safe and future-proof regarding F-gas and PFAS regulation!**

# The Blue portfolio comprises individual products & solutions, supporting our clients on their way to Zero

## Up to 145 kV

### Wind Tower and Offshore Blue GIS™

- 72.5 kV / 31.5 kA
- Optimized switchgear for application in wind turbines, with vacuum CB and clean air insulation

### Blue Circuit Breaker™ Live Tank

- up to 145 kV / 40 kA
- World's first LT CB with vacuum interrupter and clean air insulation

### Blue GIS™

- 145 kV / 50 kA
- World's first 145 kV GIS switchgear with vacuum CB and clean air insulation
- Optimized footprint by using LPIT[1]

### Blue Circuit Breaker™ Dead Tank

- 145 kV / 63 kA
- World's first 145 kV DT vacuum CB with clean air insulation
- Same footprint as $SF_6$ product

## Higher voltages (available)

### Blue Clean Air GIB™

- 420 kV / 63 kA
- 245 – 400 kV = combined solution GIS + Blue GIB (30 – 65% less $SF_6$)

### Blue Circuit Breaker™ Live Tank[2]

- up to 420 kV / 63 kV
- World's first 420 kV LT breaker with clean air insulation
- Same footprint as $SF_6$ product

[1] Low Power Instrument Transformer
[2] available 2026

# Customer product evaluation criteria for switchgear products

**Environmental impact**

**Health & safety**

**Performance**

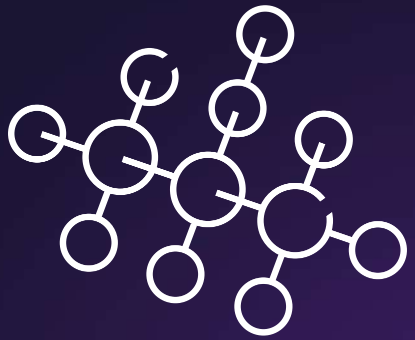
**Gas handling & costs**

**Manufacturer competence**

# Three isolation mediums: a comparison

**Vacuum / clean air**

$N_2$ and $O_2$ (80% / 20%)



**$CO_2$-F mix fluoronitrile[1]**

$(CF_3)_2CFCN$

**$SF_6$ sulfur hexafluoride**

$SF_6$

[1] Fluor-ketone gas mix is not considered due to its inability to withstand temperatures below 5°C

# Criteria 1: Environmental impact


**Vacuum / clean air**

Zero greenhouse gas

GWP = 0

(Immediately absorbed)

**$CO_2$-F mix fluoronitrile**

Greenhouse gases

GWP ~ 500

(Lifetime 30 years)

**$SF_6$ sulfur hexafluoride**

Greenhouse gas

GWP ~ 24,300

(Lifetime 1,000 years)

Vacuum / clean air is the **most environmentally friendly** switching technology in the world

# Criteria 2: Health & safety

**Vacuum / clean air**

Vacuum: Zero decomposition products; sealed for life

Clean air: non-toxic decomposition products, non-hazardous

Gas leakage < 0.1% p.a./compartment

**$CO_2$-F mix fluoronitrile**

Toxic decomposition products (details unknown)

Hazardous (details unknown)

Gas leakage < 0.5% p.a./compartment (details unknown)

**$SF_6$ sulfur hexafluoride**

Toxic decomposition products

Hazardous when inhaled, causes skin and eye irritation

Gas leakage < 0.1% p.a./compartment

Vacuum / clean air is **non-toxic, non-hazardous** and does not require special safety systems such as ventilation or $CO_2$-monitoring

# Criteria 3: Performance

### Vacuum / clean air

Vacuum circuit breaker can switch up to 30 times 40 kA currents

Zero degradation of short-circuit switching performance

From -60 °C to +55 °C

### $CO_2$-F mix fluoronitrile

$CO_2$-F mix shows decreasing switching performance

Does not recombine completely after arcing

From -30 °C to +55 °C

### $SF_6$ sulfur hexafluoride

$SF_6$ CB can switch up to 10 times 40 kA currents

Long term stability ($SF_6$ gas recombines)

From -40 °C to +55 °C

Vacuum / clean air offers the **highest short-circuit switching capability** without degradation and can be operated in a wide temperature range, being especially suitable for **very low temperature applications**

# Criteria 4: Gas handling & costs

**Vacuum / clean air**

Vacuum interrupter is sealed for life > Zero maintenance

No special tools, training, ventilation or reporting

No recycling or special EOL treatment necessary

Lowest lifecycle costs

**$CO_2$-F mix fluoronitrile**

unknown

Special tools, training, ventilation and reporting

No recycling option, disposal can cause extra $CO_2$

Higher lifecycle costs

**$SF_6$ sulfur hexafluoride**

Additional gas maintenance

Special tools, training, ventilation and reporting

Can be cleaned and re-used (extra effort)

Higher lifecycle costs

Vacuum / clean air is maintenance- and regulation-free and requires no special EOL treatment.
Overall it has the lowest lifecycle costs

# Criteria 5: Manufacturer competence

**1970**

First HV GIS with air insulation 170 kV

**1976**

First MV vacuum CB

**2010**

First HV vacuum CB with clean air 72.5 kV

**2017**

First HV vacuum GIS with clean air 72.5 kV

**2017**

First HV vacuum CB with clean air 145 kV

**2018**

First HV vacuum GIS with clean air 145 kV

**2022**

First GIB with clean air 420 kV

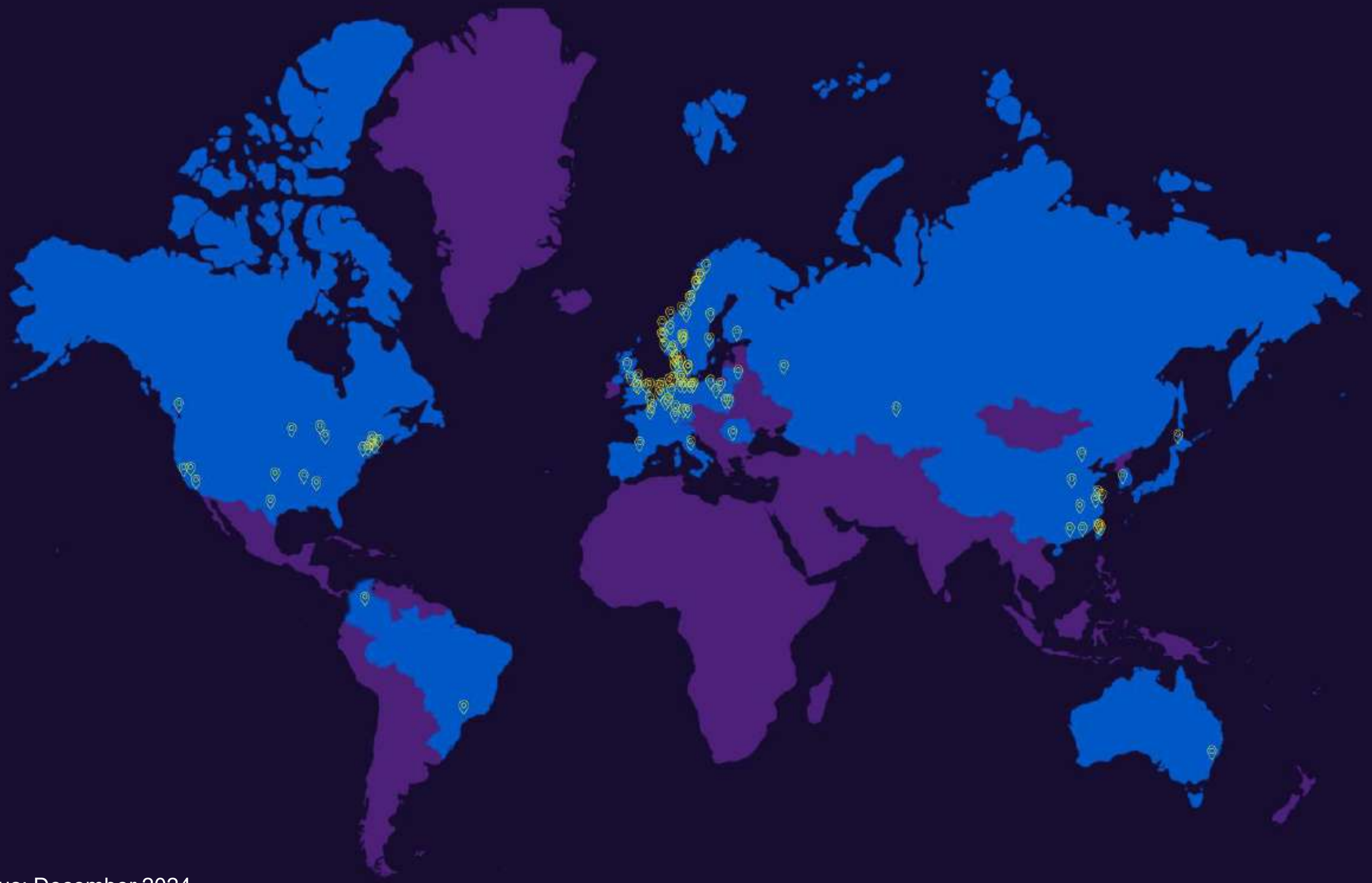
**2024**

New wind tower GIS with clean air 72.5 kV

Design & engineering → Manufacturing → Test lab → Supply → Installation, testing, commissioning → Training & after sales

Siemens Energy has **over 60 years of experience** in switchgear with **global production** of 48,000+ GIS bays and 165,000+ CBs as well as more than **50 years of experience in vacuum and air insulation** technology

# Zero-harm energy transmission is already becoming a reality around the world



**> 32 million hours**
of commercial operation

**~ 7,600,000 tons**
of $CO_2$-equivalent saved

**> 6,000 units**
sold

**> 2,000 units**
already in operation

Status: December 2024

# The world's first $SF_6$-free high-voltage switchgear with clean air insulation

## Key facts

- Customer: Netze BW GmbH, Germany
- Modernization of a 110 kV substation in Noerdlingen
- Operation requires no $SF_6$ or any other greenhouse gas
- Year of order: 2017
- Energization: 2018

## Circuit breakers

- Installation of two $SF_6$-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

# The world's first $SF_6$-free gas-insulated switchgear with clean air and vacuum technology

## Key facts

- Customer: BKK Nett, Norway
- Modernization of a 145 kV Koengen substation in Bergen – Norway's largest cruise port
- Operation requires no $SF_6$ or any other greenhouse gas
- Year of order: 2018
- Energization: 2020

## 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

# First $SF_6$-free gas-insulated busducts with clean air for Alyth substation

## Key facts

- Customer: Scottish & Southern Electricity Networks
- Location: United Kingdom
- Operation of GIB requires no $SF_6$ or any other greenhouse gas
- Year of order: 2022
- Energization: 2023

## Gas-insulated busduct

- New switchgear for 275 kV Alyth substation, including infrastructure ready for future scalability to 400 kV
- Project involves the installation of 8VQ3 Blue clean air gas-insulated bus ducts (GIB) measuring a length of more than 500 meters

## Customer benefits

- Blue GIB technology replaces $SF_6$ with clean air and has Zero direct $CO_2$ emissions
- Easiest gas handling process
- More than 2 million kg $CO_2e$ saved compared to a $SF_6$-based GIB during a lifetime of 40 years

## 4. Recommendations to CEA

In alignment with the United Nations Sustainable Development Goal 12 (*Responsible Consumption and Production*), Target 12.7 specifically calls for the implementation of sustainable public procurement practices that are consistent with national policies and priorities. For the power sector, this necessitates a paradigm shift in how tenders are structured, evaluated, and awarded moving beyond purely techno-commercial considerations to incorporate environmental and lifecycle sustainability metrics. The inclusion of $SF_6$-free technologies such as Blue GIS in tender specifications is a direct response to this mandate, enabling procurement processes that prioritize climate-resilient, low-emission, and circular-economy-compliant solutions.

By embedding sustainability criteria such as Global Warming Potential (GWP), recyclability, carbon footprint reduction, and end-of-life management within the tender evaluation framework, utilities and regulators reinforce their commitment to India's climate action targets and global environmental governance. Moreover, such criteria support multiple SDGs, notably SDG 13 (*Climate Action*), SDG 9 (*Industry, Innovation and Infrastructure*), and SDG 7 (*Affordable and Clean Energy*), while giving operational effect to SDG 12.7. It also enhances transparency, promotes innovation among OEMs, and unlocks eligibility for international green financing and ESG-linked funding mechanisms. As India positions itself for a sustainable and future-ready grid infrastructure, aligning tender evaluation methodologies with SDG 12.7 is not just a policy recommendation, it is a strategic imperative.

As majority of the available technologies in the energy sector have different functional and design aspects, it is proposed that a point-based approach be adopted for a techno-commercial review

| **Tender Evaluation Criteria**: | |
|---|---|
| **Criteria** | **Points** |
| **Equipment Price** | **40** |
| **Technical** | **40** |
| **Sustainability** | **20** |
| **Total Evaluation:** | **100** |
| | |
| **1. Technical (General)-Detailed Criteria** | **20** |

| Tender Evaluation Criteria: | |
|---|---|
| **Criteria** | **Points** |
| Physical footprint (dimensions) | 10 |
| 3ph switching capability > 12 times 40kA | 5 |
| Leakage rate <0,1% | 3 |
| Building ventilation required | 2 |
| | |
| **1.1 Technical (Installation & Maintenance)** | **20** |
| Special gas processing equipment required | 5 |
| Availability of insulating gas (no of suppliers) | 5 |
| Gas handling / contamination tests / precaution measures | 5 |
| Ease of degassing and gassing | 3 |
| Training and reporting efforts | 2 |
| | |
| **2.1 GWP Insulating Gas: (Detailed Sustainability criteria)** | **10** |
| > 1 - 1000 | 3 |
| > 0,1 - 1 | 5 |
| < 0,1 | 10 |
| | |
| **2.2 HSE Aspects** | **6** |
| No F- gas used / No environmental risks (water/soil) due to PFAS | 2 |
| Not Harmful to health/ no toxicity classification | 2 |
| Non-Hazardous or non-toxic decompensation products | 1 |
| Finalized HSE regulation assessment /hazard analysis | 1 |
| | |
| **2.3 EPD, Diversity & Wages & LTIF-Rate** | **4** |
| Environmental Product Declaration available (yes/no) | 1 |
| Target of diversity/inclusion goals and fulfilment | 1 |
| Paying wages > labour agreement | 1 |
| LTIF Rate < 0,3% (TRIR) | 1 |

A point-based evaluation system in tendering introduces transparency, objectivity, and alignment with strategic priorities by assigning quantifiable scores to both technical and non-technical criteria. This structured approach allows evaluators to holistically assess not only price and performance but also critical dimensions such as sustainability, innovation, lifecycle cost, and compliance with environmental goals (e.g., UN SDG Target 12.7). By incorporating weighted points for features like fluorine-free insulation, low GWP technologies, and long-term regulatory resilience, such a system ensures that tenders reward value-driven, future-ready solutions rather than short-term cost considerations alone ultimately enabling more responsible and forward-looking procurement decisions.
This system is particularly effective in comparing technically diverse switchgear designs by providing a structured framework to assess qualitative and performance-based differences on a common scale. It enables the inclusion of key differentiators such as insulation medium, arc interruption technology, environmental impact, modularity, maintenance requirements, and operational track record each assigned specific weightage. This approach ensures that even when technologies vary significantly in design philosophy or materials (e.g., vacuum vs. gas interruption, synthetic vs. natural insulation), their merits can be objectively evaluated against pre-defined benchmarks. As a result, technically superior and future-resilient solutions can be recognized and rewarded, even if they differ from conventional configurations promoting innovation while maintaining fairness and transparency in procurement.

## 5. Conclusion

Blue GIS marks a pivotal step in India's transformation toward a decarbonized, intelligent, and resilient power transmission and distribution network. With its use of clean air insulation (a mixture of Nitrogen and Oxygen) and vacuum-based arc interruption, Blue GIS eliminates the use of greenhouse gases entirely, offering a climate-neutral switchgear solution that is inherently safe, regulation-proof, and future-ready. Its adoption at scale can contribute to the avoidance of millions of tons of $CO_2$-equivalent emissions while delivering superior operational performance across reliability, safety, and maintenance metrics. In this context, the role of tender evaluation frameworks becomes critical. The integration of a point-based evaluation system one that assigns quantifiable weightage to environmental performance, lifecycle sustainability, and technological innovation will allow policymakers and utilities to make procurement decisions that go beyond first-cost considerations. Such a system ensures that technically diverse solutions are assessed transparently and objectively, enabling the selection of designs that best align with India's long-term energy and environmental goals.

Moreover, embedding sustainability criteria into public procurement practices directly supports United Nations Sustainable Development Goal 12.7, which advocates for "promoting public procurement practices that are sustainable, in accordance with national policies and priorities." By formally recognizing environmental attributes such as GWP-zero insulation, non-toxic materials, recyclability, and reduced end-of-life hazards within the tendering process, CEA can institutionalize sustainable procurement as a cornerstone of power sector modernization.

Annexure-III

**भारत सरकार/ Government of India**
**विद्युत मंत्रालय/ Ministry of Power**
**केन्द्रीय विद्युत प्राधिकरण/ Central Electricity Authority**
**विद्युत प्रणाली अभियांत्रिकी एवं प्रौद्योगिकी विकास प्रभाग**
**Power System Engineering & Technology Development Division**

**Date: 07.01.2026**

सेवा में,

<As per attached list>

**विषय: Minutes of the second meeting of the committee regarding use of Green GIS (Green GIS Committee) in Indian Grid– reg.**

महोदया/ महोदय,

The second meeting of the Green GIS Committee was held under the chairmanship of Chief Engineer (PSE&TD Division), CEA on 23.12.2025 at 14:00 hrs at Samvaad Conference Hall, CEA, Sewa Bhawan, R K Puram Sector-I, New Delhi.

Minutes of the meeting are enclosed herewith for kind information and necessary action please.

**Encl: As above**

**भवदीय/ Yours faithfully,**

Digitally signed by Bhanwar Singh Meena Date: 07-01-2026 10:49:09

**(भंवर सिंह मीना / Bhanwar Singh Meena)**

**निदेशक/ Director**

**To**

1. Director, ET&I Division, CEA
2. Director, CE&ET Division, CEA
3. M/s CTUIL, 2nd Floor, Corporate Centre, Plot No:2, "Saudamini",Sec-29, Near IFFCO Chowk, Gurgaon Email: kksarkar@powergrid.in CC: coo-ctu@ctuil.in
4. M/s Powergrid Corporation of India Ltd Saudamini, Plot No. 2, Sector-29 Gurgaon-122001 (Haryana) Email id: msrao@powergrid.in , rpsrana@powergrid.in, rajivranjan1@powergrid.in , ravindrangupta@powergrid.in CC: cmd@powergrid.in
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# Annexure-III

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**Copy to**

1. SA to Chairperson, CEA
2. SA to Member (PS), CEA

Annexure-III

# Power System Engineering & Technology Development Division
## Central Electricity Authority

**Minutes of the Second Meeting of the Green GIS Committee held on 23.12.2025**

1. The second meeting of the Green GIS Committee was convened on 23.12.2025 at 14:00 Hrs at Samvaad Conference Hall, 6th Floor, Sewa Bhawan, R.K. Puram Sector-1, New Delhi under the chairmanship of Chief Engineer (PSE&TD Division), CEA. The list of participants is given at **Annexure-I.**

2. At the outset, Chief Engineer (PSE&TD Division), CEA welcomed all the participants. He stated that CTUIL, during the 24th NCT meeting, informed that the existing 132 kV Badarpur (Powergrid) switching station was commissioned in 1999 and had completed 25 years of service in 2024. PGCIL, being the owner of the switching station, is facing challenges in the operation and maintenance of the facility. In order to enhance system reliability, it was considered prudent to upgrade the switching station from the existing single main and transfer bus scheme to a double main transfer bus scheme, along with conversion from Air Insulated Switchgear (AIS) to Gas Insulated Switchgear (GIS). Further, it was proposed in the 24th NCT meeting that the upgradation may be implemented using Green GIS in place of conventional GIS. In this regard, a committee was constituted vide CEA letter dated 18.12.2024 to explore the use of Green GIS in Indian Grid (Green GIS Committee). He mentioned that the first meeting of the committee was held on 14.07.2025 wherein representatives from M/s Hitachi Energy, M/s GE and M/s Siemens gave presentation about their Green GIS product. The present meeting was being held to discuss certain general items as well as specific items requested by various members covering various aspects of using Green GIS in the Indian Grid. To begin with, as M/s Hyosung and M/s Toshiba were attending for the first time, he requested them to present details about their Green GIS products.

3. Representative from M/s Hyosung stated that they are developing their Green GIS product in Korea and they are also using the same gas composition based on fluoronitrile. He mentioned that the 132 kV Green GIS product has already been type tested, the 400 kV Green GIS product has been developed and is currently undergoing type testing, and the 220 kV Green GIS product is planned to be completed in the second half of 2026. Regarding the cost comparison, he mentioned that the cost of their Green GIS is minimum 4-5 times of conventional SF6 gas based GIS if imported from Korea. He further mentioned that detailed presentation regarding the Hyosung's Green GIS product will be shared in due course.

4. In this connection, CE (PSE&TD), CEA inquired about the permissible gas leakage limit. In this regard, the representative from M/s GE stated that as per IEC standard, the maximum allowable leakage limit for SF6 gas is 0.1% and for non-SF6 gas is 0.5%.

5. Representative from M/s Toshiba presented a white paper (**Annexure-II**) about their Green GIS product. The salient points of the presentation are as follows.
   (i) The paper emphasizes the need for phased reduction and eventual replacement of $SF_6$-based switchgear in the Indian power sector due to its extremely high Global Warming Potential (GWP), aligning with India's commitment to reduce carbon emissions by 2030.

Annexure-III

(ii) It was highlighted that global regulations in regions such as the EU and USA are already driving $SF_6$ phase-out, making it imperative for India to proactively frame a regulatory and adoption of roadmap for $SF_6$-free technologies

(iii) The document recommends natural origin gases (including dry air / synthetic air and vacuum technologies) as the most sustainable alternative, based on Life Cycle Assessment (LCA), low or zero GWP, absence of Per and Polyfluoroalkyl Substances (PFAS), and favorable Environment, Health and Safety (EHS) characteristics.

(iv) Key criteria for selecting alternative gases were discussed, including non-toxicity, non-flammability, zero ozone depletion potential, stable supply chain, ease of handling, and suitability for high-voltage and high-current applications.

(v) AEROXIA™ $SF_6$-free GIS technology was highlighted as an example of mature alternative gas-based switchgear, with 72/84 kV F-gas-free GIS already developed and successfully deployed, including installation at TEPCO Power Grid's Fuchu Substation in Japan, demonstrating technical feasibility and operational reliability of natural origin gas solutions.

(vi) F-Free High Voltage Switchgears Technology and Product Development Road maps expected are as below.

  (a) Solid Insulated Switchgear (SIS): Available for Up To 72 kV
  (b) Gas Insulated Switchgear (GIS):
    - 72 kV (31.5 kA): Available
    - 220 kV (50 kA): FY 29 - FY 30
    - 400 kV (63 kA): FY 31 - FY 32
  (c) Gas Insulated Bus Ducts (GIB):
    - 400 kV (63 kA): FY 25 - FY 26
    - 220 kV (50 kA): FY 27 - FY 28

(vii) It was suggested that an institutional framework and financial incentives, similar to Green Innovation Funds in Japan and EU Life Fund, be explored to promote R&D, pilot projects, and early adoption of F-free switchgear in India.

6. Representative from M/s Toshiba stated that size of their Green GIS product is little bit larger than the conventional SF6 based GIS equipment. However, with increase in the voltage level the size will be reduced compared to Conventional GIS. He mentioned that as 70-80% of the gas is generally present in the Bus Duct itself, developing Green Gas Insulated Bus Duct would make Green GIS based products viable. He also added that M/s Toshiba has developed 400 kV Gas Insulated Bus Duct, and have already supplied around 4.2 km and 2.8 km Gas Insulated Bus Duct in RE integration projects in Gujrat's Kavda area.

7. Representative from M/s Hitachi stated that their Green GIS costing is presently around 6 to 8 times compared to conventional GIS because they get entire quantum from overseas factory. Representative from M/s GE also informed that their product's cost would be around 6 to 8 times. Representative from M/s Siemens stated that they are not using the fluoronitrile based gas, but due to technology development charges which are associated with their product, its costing would also be in the same range.

   In this connection, GE representative stated that OEMs may submit a budgetary offer based upon a particular configuration and then the Committee may review the same. On this, Director (PSE&TD), CEA requested OEMs to submit the same.

Annexure-III

8. CE (PSE&TD), CEA enquired about the interoperability of different OEM's GIS. Regarding the interoperability of two conventional SF6 gas based GIS, representative from M/s Powergrid stated that the connection between the existing and new SF6 gas based GIS is executed via a custom-designed Interface Adaptor Module equipped with a gas-tight barrier insulator. This ensures that each GIS section operates as an independent gas zone, preventing the mixing of SF6 gas and allowing for different operating pressures. Further the governing factor would be the gas pressure difference between two compartments, which would be in the range of 2.5 to 3 Bar. It was further mentioned that in case of high pressure difference, two barrier with dummy isolator in-between may be used to accommodate the pressure difference.

9. Regarding the interoperability of two SF6 free GIS or SF6 gas and non-SF6 gas based GIS, OEMs mentioned that this need to be explored because presently there is no such practical installation available. In this regard, the representative from POWERGRID highlighted that interoperability between GIS systems using different insulating gases may pose operational risks. He explained that in the event of failure of the gas barrier or sealing arrangement between two such systems, there is a risk of intermixing of different gases. Such intermixing can adversely affect the dielectric and arc-quenching properties of the insulating medium, as the gas mixture would no longer meet the design specifications of either system. This would impact system reliability and safety. Hence, interoperability of GIS with different gas technologies requires careful design, robust gas separation measures, and clear operational guidelines. They may be avoided altogether.

10. OEMs suggested that pilot projects for implementation of Green GIS should preferably be taken up as Greenfield installations and executed using equipment from a single OEM. This approach would avoid interoperability issues associated with different gas technologies and operational risks related to gas intermixing or interface failures.

11. Director (PSE&TD), CEA enquired about the feasibility of retro-filling / replacement of conventional GIS with SF6 free gas. In this regard, representative from M/s Hitachi stated that retro-filling with $SF_6$-free gas is technically feasible for certain existing GIS components such as Gas Insulated Bus Ducts (GIBs), Current Transformers (CTs), Disconnectors, and Earth Switches. However, it was clarified that retro-filling is not feasible for Circuit Breakers, as the interrupting chambers are subjected to high temperature rise during switching operation.

12. CE (PSE&TD), CEA enquired about upgradation of the existing substation with Green GIS. In this regard, OEMs stated that whether the conversion is from AIS to Green GIS or from conventional $SF_6$-based GIS to Green GIS, upgradation of the existing infrastructure is not possible. Therefore, complete dismantling of the existing infrastructure would be required, making such projects effectively Greenfield installations. However, the representative from M/s GE mentioned that in the case of fluoronitrile-based Green GIS, the overall equipment size is expected to be almost similar to conventional GIS, and hence reuse of the existing GIS building may be possible, subject to detailed engineering and layout verification.

13. CE (PSE&TD), CEA enquired about Hybrid configuration of GIS. In this regard, representative from M/s Powergrid stated that in a Hybrid GIS configuration, except the main bus bar, all other components would be housed within $SF_6$-filled compartments. He

Annexure-III

further mentioned that the entire installation would be outdoor, with suitable modifications in the paint and surface coating of equipment to meet environmental and site conditions. The representative from M/s Hitachi added that in the case of upgradation to Hybrid GIS, it may not be necessary to dismantle the existing bus bars and gantries, thereby reducing the extent of civil works and overall implementation time.

14. From a sustainability and decarbonization perspective, the representative from M/s Hitachi explained that at higher voltage levels such as 420 kV and even 800 kV, adoption of Dead Tank Circuit Breaker based solutions can significantly reduce SF6 usage. He highlighted that in such configurations, Gas Insulated Bus Ducts are not required, and since a major portion (around 70–80%) of the total SF6 in conventional GIS installations is contained in the long bus ducts, their elimination results in a substantial reduction in SF6 gas. He further stated that at both 420 kV and 800 kV, Dead Tank Breaker solutions are available wherein the Circuit Breaker, Current Transformers, and Disconnecting functions can be integrated, thereby completely eliminating the need for GIBs. This design approach offers a practical pathway for SF6 reduction and decarbonization at higher voltage levels.

15. Representative from M/s Powergrid stated that during normal operation of GIS, floating metallic particles may become mobile within the gas compartments, and such particles can lead to voltage drop and possible flashover at any location in the GIS installation. In this context, the CE (PSE&TD Division), CEA enquired about the availability and effectiveness of partial discharge monitoring systems for Green GIS, considering the associated insulation and reliability aspects. On this, the representative from M/s Siemens stated that they follow the same gas handling procedure as conventional GIS for Green GIS. Representative from M/s Hitachi stated that Gas Circuit Breaker technology has been in use for nearly 50 years, with SF6 being the established insulating and interrupting medium. He explained that while developing $SF_6$-free GIS, a gas-based solution was deliberately chosen to retain the proven advantages of gas insulation and interruption. The insulating gas mixture selected for their Green GIS comprises CO2+O2+C4FN (fluoronitrile). He further mentioned that Partial Discharge (PD) phenomena are inherent to gas-insulated systems and therefore PD may also occur in SF6 free GIS. However, adequate PD mitigation measures and monitoring solutions are available, and PD monitoring techniques applicable to SF6 GIS can also be effectively implemented for SF6 free GIS.

16. Representative from M/s Powergrid stated that at present, no established method is available for effective cleaning or purification of contaminated SF6 gas once it is degraded in service. In this context, the CE (PSE&TD Division), CEA requested OEMs to submit details on whether any method or technology is available for cleaning or reconditioning contaminated Green GIS gas, including its feasibility, effectiveness, and operational limitations.
17. Regarding the availability of Green GIS gas in India, the representative from M/s Hitachi informed that they are sourcing the Green GIS gas from M/s Laxmi Organic, which has a manufacturing facility in Gujarat. In this regard, the CE (PSE&TD), CEA requested M/s Hitachi to submit details of the production capacity and supply capability of M/s Laxmi Organic. He further requested Powergrid and the concerned OEMs to submit estimates of $SF_6$ gas requirement and Green GIS gas requirement for a typical 100 MVA substation, for assessment and comparison purposes.

Annexure-III

18. OEMs mentioned that they are willing to setup a manufacturing facility in India, if sufficient demand will be there in India. They also suggested for time bound phase out of SF6 gas similar to Europe. In addition to it, OEMs mentioned that training required for the handling of Green GIS installation will be same as conventional SF6 based GIS.

19. Representative from M/s GE proposed that pilot projects of Green GIS should be undertaken separately for each voltage level, as power system conditions, transient voltages, and switching phenomena vary significantly with voltage level. He emphasized that the operational performance and reliability of equipment at one voltage level cannot be directly extrapolated to higher voltage levels. Further, representative from M/s Siemens also added that pilot projects from various OEM at various sites of India should be executed. In this regard, it was pointed out that since OEMs had already executed Green GIS projects worldwide at different voltage levels, they might have already got the required experience. Moreover, implementation of pilot projects of each type of technology at different voltage levels in India with SF6 free GIS may not be feasible.

20. OEMs stated that the execution time for Green GIS projects is expected to be about 20–25% longer than that of conventional SF6 based GIS projects, primarily due to the import dependency of equipment at the present stage. It was further mentioned that the procurement process would remain similar to conventional GIS projects, wherein the Green GIS equipment would be supplied by the GIS OEMs, while gas handling systems and testing equipment would be provided by the EPC contractors.

21. The committee suggested that the possibility of expanding and using same manufacturing facility of SF6 GIS for Green GIS equipment may be explored. OEMs informed that the same may be feasible with some modifications in the existing facilities.

22. OEMs informed that the tests required for Green GIS would largely be the same as those conducted for conventional SF6 based GIS. However, they indicated that certain additional tests may be required in Green GIS. CE (PSE&TD), CEA requested to submit the list of additional tests required to be conducted on Green GIS compared to conventional GIS along with relevant standards. It was suggested that CPRI may be requested to develop the test facility for such additional tests.

23. M/s Siemens presented an example of tender evaluation criteria for Green GIS projects (**Annexure-III**). It was indicated that, in addition to the conventional technical and commercial evaluation, environment-related parameters may be considered in bid evaluation. These criteria may include assessment of the environmental impact of the insulating gas, its Global Warming Potential (GWP), Health, Safety and Environmental (HSE) aspects, and the non-toxic and non-hazardous nature of gas decomposition products. Representative from M/s Hitachi also proposed the integration of Life Cycle Assessment (LCA) in tender evaluation process, ensuring compliance with global standards and LCA standards.

24. W.r.t. a query on Sf6 leakage data, DD (CE&ET Division), CEA stated that they maintain the CO2 emission data of Thermal Power Plant. However, they do not maintain any record of SF6 leakage in substation. In this regard, Director (PSE&TD), CEA mentioned that an exercise was undertaken by CE&ET Division, CEA whereby utilities were requested to share the SF6 leakage monitoring data. CE (PSE&TD), CEA remarked that

Annexure-III

leakage happens at substation as well as at manufacturing facility. Therefore, it may be mentioned in the guidelines itself that both utility and manufacturing facility should maintain the SF6 leakage monitoring data and share with CEA on regular interval. Further, representative from M/s Hitachi mentioned that ET&I Division, CEA issued an advisory regarding SF6 gas leakage limit i.e. 0.1 %, however, it has been observed that some utilities are not following it. Therefore, it is suggested that 0.1% gas leakage must be made mandatory for all utilities and inclusions in technical specification in line with IEC and CEA advisory. In this regard, it was noted that leakage depends upon the equipment design and O&M practice. The leakage rate can be limited with improved design and O&M practice.

25. CE (PSE&TD), CEA concluded the meeting by requesting the OEMs to furnish the following details:
    (i) Details of the Green GIS technology proposed covering various technical parameters including Gas Composition.
    (ii) Portfolio of Green GIS products.
    (iii) Relevant IEC/ other international standard on Green GIS.
    (iv) Regulations/ Guidelines of EU and USA on Green GIS.
    (v) EU Policy on phase reduction of SF6 gas.
    (vi) Model Tender document for Green GIS for the technologies available.
    (vii) Details of Type tests, Acceptance tests, Routine tests to be conducted on Green GIS, along with relevant standards.
    (viii) The list of additional tests required to be conducted on Green GIS compared to conventional GIS along with relevant standard.
    (ix) Model Guidelines for deployment of Green GIS technology in India.
    (x) Model Guidelines for phasing out of SF6 in India.

It was stated that after obtaining all pertinent details, Draft Report of the Committee would be prepared, and shared with all the members for comments, and the same would be finalized in the next meeting.

The meeting ended with thanks to all the participants.

*****

Annexure-III

**Annexure-I**

## List of Participants

**CEA**

1. Sh. N.R.L.K Prasad, Chief Engineer (PSE&TD Division)
2. Sh. Bhanwar Singh Meena, Director (PSE&TD Division)
3. Sh. Pankaj Kumar Verma, Deputy Director (PSE&TD Division)
4. Sh. Manoj Kumar, Deputy Director (CE&ET Division)
5. Sh. Bhavesh Mahawar, Assistant Director (PSE&TD Division)

**POWERGRID**

1. Sh. Ravindra Nath Gupta, Chief GM
2. Sh. Rajeev Ranjan, DGM
3. Sh. Pradeep Seervi, Manager Tech. Development

**SIEMENS ENERGY**

1. Sh. Rajeev Virdi, Chief Manager
2. Sh.Vaibhav Aaradhi, Sr. Manager
3. Sh. Harsh Trivedi, Manager

**HITACHI ENERGY**

1. Sh. Dheeraj Jain, Head GIR India
2. Sh. Dhiraj Fanish, Head Renewables
3. Sh. Rajdeepak Pandey
4. Ms. Shafali Asthana, Head Business Development & Marketing

**Toshiba (TTDI)**

1. Sh. Rajib N Chaudhary, VP

**HYOSUNG T&D**

1. Sh. Rohit Kumar, Tyagi, (DGM-Sales)

**GE VERNOVA**

1. Sh. Amit Narway, Regional leader Sales
2. Sh. Anjan Banerjee, Head of Marketing

<u>Annexure-III</u>

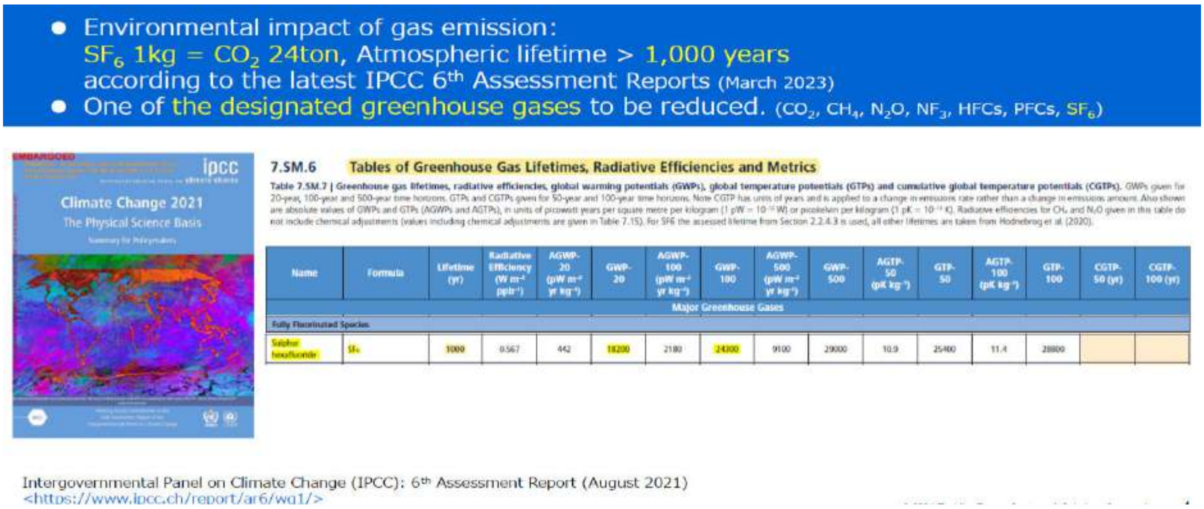
**Annexure-II (M/s Toshiba)**

This paper is to formulate a robust basis that may be considered for adopting SF6 Free High Voltage Gas Insulated Switchgears to mitigate the impact of SF6 gases on Indian Power sector and lists the suggested way forward for adoption of such alternative Gas based High Voltage Gas Insulated Switchgears.

Phased Removal / Reduction of high potent greenhouse Fluorinated gases such as SF6 (GWP of 1kg SF6 = **24,300** kg CO2) from Indian Power Sector could lead to significant savings in terms of CO2 contribution from Power Sector and contributing to the Indian pledge (***reducing total projectedcarbon emissions by 1 billion tonnes by 2030***) committed by our honorable Prime Minister.

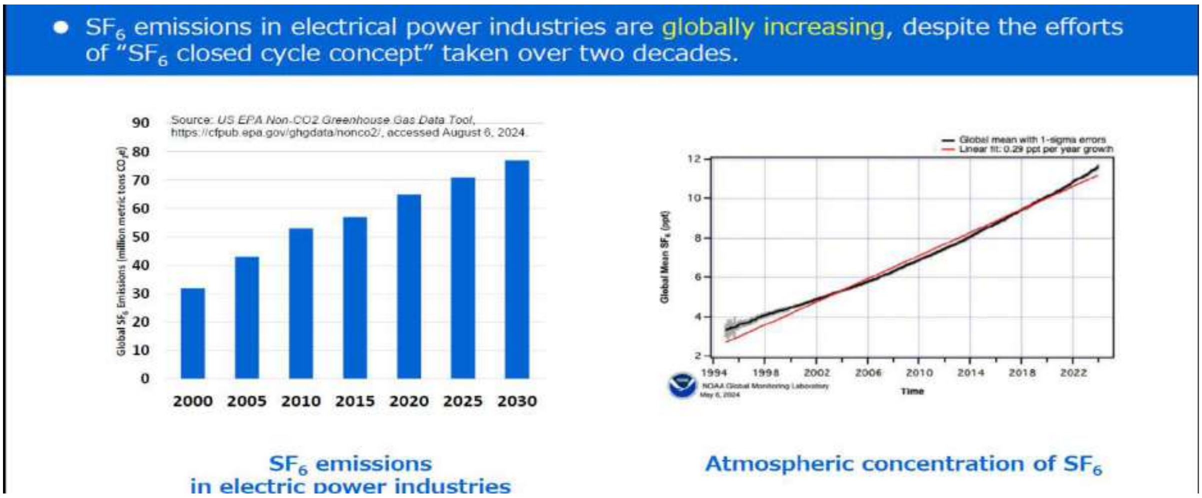
Like many other countries, Indian power sector also extensively uses fluorinated gases like SF6, majorly across Transmission & Distribution sector. Typically, all Circuit breakers & Gas Insulated Switchgears utilize SF6 gas since many years.

**Global Warming Potentials of SF6:**



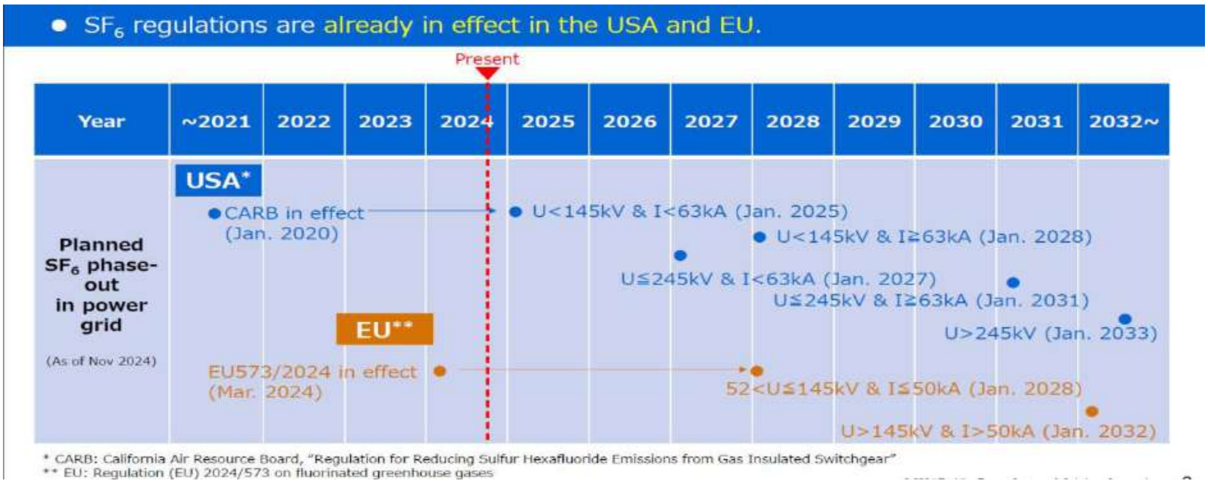

| Name | Formula | Lifetime (yr) | Radiative Efficiency ($W m^{-2} ppb^{-1}$) | AGWP-20 ($pW m^{-2} yr kg^{-1}$) | GWP-20 | AGWP-100 ($pW m^{-2} yr kg^{-1}$) | GWP-100 | AGWP-500 ($pW m^{-2} yr kg^{-1}$) | GWP-500 | AGTP-50 ($pK kg^{-1}$) | GTP-50 | AGTP-100 ($pK kg^{-1}$) | GTP-100 | CGTP-50 (yr) | CGTP-100 (yr) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Major Greenhouse Gases | | | | | | | | | | | | | | | |
| Fully Fluorinated Species | | | | | | | | | | | | | | | |
| Sulphur hexafluoride | $SF_6$ | 1000 | 0.567 | 442 | 18200 | 2180 | 24300 | 9100 | 29000 | 10.9 | 25400 | 11.4 | 28800 | | |

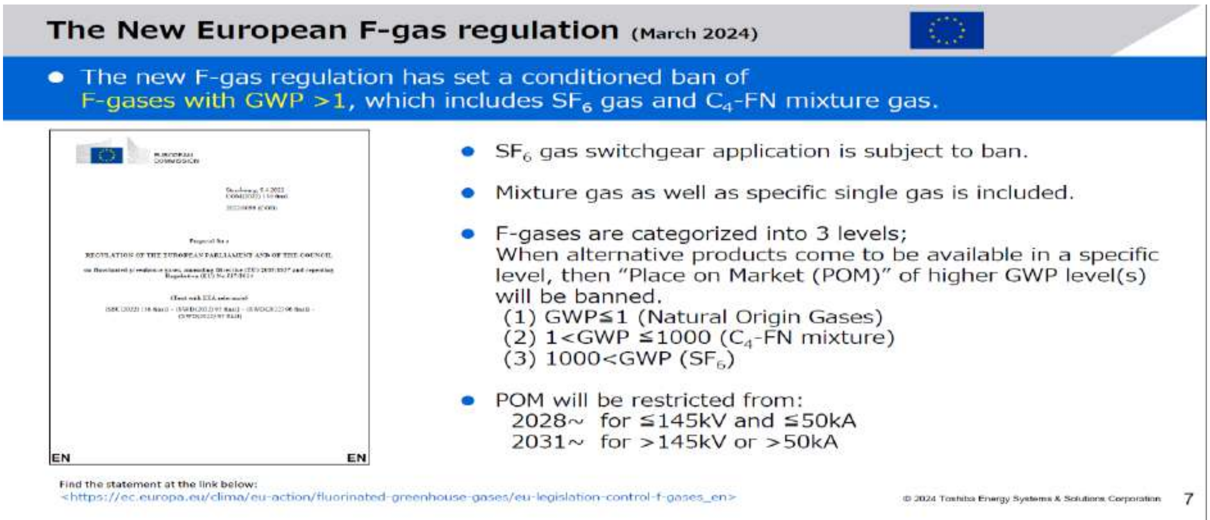
**SF6 gas in power grids**



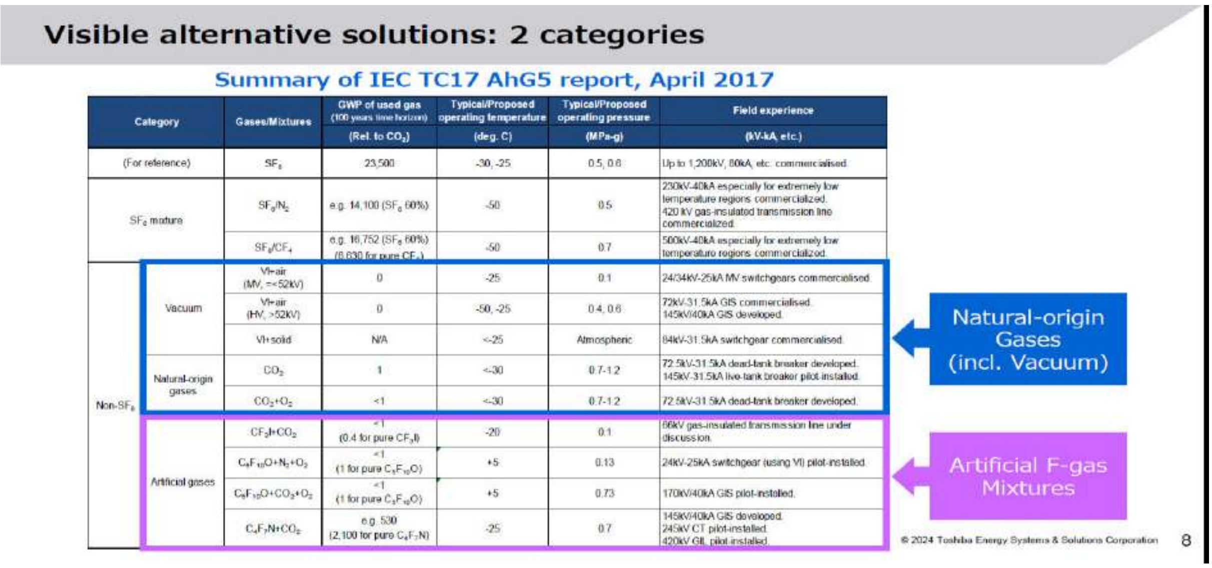
There is an urgent regulation to phase out or mitigate the impacts related to such high potent gas, like USA and EU.

**SF6 phase-out schedule (USA and EU)**




**ALTERNATIVE GAS SOLUTIONS:**




| Category | | Gases/Mixtures | GWP of used gas (100 years time horizon) (Rel. to $CO_2$) | Typical/Proposed operating temperature (deg. C) | Typical/Proposed operating pressure (MPa-g) | Field experience (kV-kA, etc.) |
|---|---|---|---|---|---|---|
| (For reference) | | $SF_6$ | 23,500 | -30, -25 | 0.5, 0.6 | Up to 1,200kV, 80kA, etc. commercialised. |
| $SF_6$ mixture | | $SF_6/N_2$ | e.g. 14,100 ($SF_6$ 60%) | -50 | 0.5 | 230kV-40kA especially for extremely low temperature regions commercialized. 420 kV gas-insulated transmission line commercialized. |
| | | $SF_6/CF_4$ | e.g. 16,752 ($SF_6$ 60%) (6,630 for pure $CF_4$) | -50 | 0.7 | 500kV-40kA especially for extremely low temperature regions commercialized. |
| Non-$SF_6$ | Vacuum | VI+air (MV, =<52kV) | 0 | -25 | 0.1 | 24/34kV-25kA MV switchgears commercialised. |
| | | VI+air (HV, >52kV) | 0 | -50, -25 | 0.4, 0.6 | 72kV-31.5kA GIS commercialised. 145kV/40kA GIS developed. |
| | | VI+solid | N/A | <-25 | Atmospheric | 84kV-31.5kA switchgear commercialised. |
| | Natural-origin gases | $CO_2$ | 1 | <-30 | 0.7-1.2 | 72.5kV-31.5kA dead-tank breaker developed. 145kV-31.5kA live-tank breaker pilot-installed. |
| | | $CO_2+O_2$ | <1 | <-30 | 0.7-1.2 | 72.5kV-31.5kA dead-tank breaker developed. |
| | Artificial gases | $CF_3I+CO_2$ | <1 (0.4 for pure $CF_3I$) | -20 | 0.1 | 66kV gas-insulated transmission line under discussion. |
| | | $C_5F_{10}O+N_2+O_2$ | <1 (1 for pure $C_5F_{10}O$) | +5 | 0.13 | 24kV-25kA switchgear (using VI) pilot-installed. |
| | | $C_5F_{10}O+CO_2+O_2$ | <1 (1 for pure $C_5F_{10}O$) | +5 | 0.73 | 170kV/40kA GIS pilot-installed. |
| | | $C_4F_7N+CO_2$ | e.g. 530 (2,100 for pure $C_4F_7N$) | -25 | 0.7 | 145kV/40kA GIS developed. 245kV CT pilot-installed. 420kV GIL pilot-installed. |

**Annexure-II (M/s Toshiba)**

## ALTERNATIVE GAS SOLUTIONS, APPROACH BEING FOLLOWED IN JAPAN:

- "$SF_6$ Alternative Gas Study Group" was established in 2017 as a collaboration framework of almost all Japanese stakeholders*.
- Intensive discussion had been done to reach a unified policy of emerging $SF_6$ alternative technologies, which was published in 2020 as the "7 requirements" and has been recognized as a typical guideline to evaluate emerging alternative technologies.

*** "$SF_6$ Alternative Gas Study Group" is composed of 11 utilities in Japan, 7 manufacturers and 6 academia and CRIEPI, together with FEPCJ and JEMA as observers.**

## "7 requirements" to evaluate $SF_6$ alternative technologies

| No. | Category | Requirement |
|---|---|---|
| 1 | EHS | Short and long term toxicities, environmental impact, climate impact, flammability |
| 2 | Service Condition | Normal service conditions specified in standards |
| 3 | Gas Supply | Stable supply of gases from multiple sources now and in the future |
| 4 | Gas Handling | Simple gas handling processes |
| 5 | Ownership Cost | Total equipment life cycle cost similar to $SF_6$ |
| 6 | Installation | Installation and replacement where space is limited |
| 7 | Rating Range | Support up to 550 kV maximum system operating voltage |



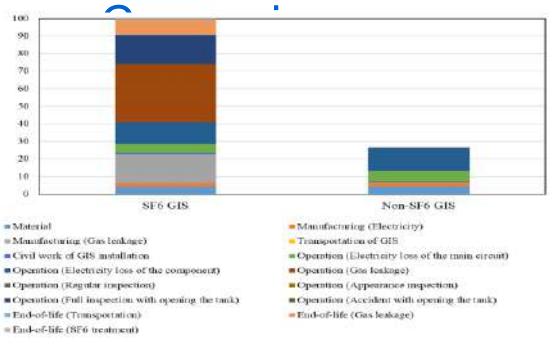
## NATURAL ORIGIN GAS_ BEST CHOICE OF ALTERNATIVE GAS SOLUTION:

**Derive Environmental benefit by natural origin gas solutions**

- Minimizing not only GWP but also overall environmental life cycle impact.
- The freedom from regulation related to GWP (emissions tracking, reporting) reduces operating costs and improves business continuity.
- No PFAS

| Gas or Gas Mixture | GWP |
|---|---|
| $SF_6$ 100% | 24,300 |
| $CO_2^* + O_2 + C_4$-FN 4% | 327 |
| $CO_2^*$ 100% | 1.0 |
| $CO_2^* + O_2$ 30% | 0.8 |
| $N_2$ 79% + $O_2$ 21% (Synthetic air) | 0 |

Environmental LCA* *LCA: Life Cycle Assessment




- F-gas free natural origin gas, GWP*1 <1, ODP*2 =0, PFAS*3 free.
- No potential risks of EHS, future regulation and gas supply.
- Long-term reliability and easy gas handling.

***1 GWP: Global Warming Potential *2 ODP: Ozone Depletion Potential *3 PFAS: Per- and polyfluoroalkyl substances.**

**Annexure-II (M/s Toshiba)**

**Joint statement by T&D equipment manufacturers (2 Nov 2021)**

- Commitment to delivering switchgear using natural origin gases was jointly released.

10 manufacturers listed below (called by Toshiba and Siemens Energy) undersigned to pursue natural origin gas solutions for sustainable, climate-neutral power grids.

- Eaton (USA)
- ILJIN (Korea)
- Meiden (Japan)
- Mitsubishi (Japan)
- MEPPI (USA)
- Nuventura (Germany)
- Schneider (France)
- Siemens (Germany)
- Siemens Energy (Germany)
- Toshiba (Japan)

Find the statement at the link below:
<https://www.toshiba-energy.com/en/info/info2021_1102.htm>


Toward T&D equipment free of fluorinated gases for sustainable, climate-neutral power grids

A joint statement of T&D equipment manufacturers

: <u>Example</u> **SF6 Gas Free GIS Technology / Product:**

***AEROXIA*™ 72/84kV F-gas free GIS**

- *AEROXIA*™ F-gas free solution fully complying with the "7 requirements".

EHS (Environment, Health and Safety) ✓ | -25°C Service Condition ✓ | Stable Supply ✓ | Gas Handling ✓ | LifeCycle Cost ✓ | FootPrint ✓ | 550kv Voltage Coverage ✓


| | |
|---|---|
| Rated voltage (kV) | 72/84 |
| Rated interruption current (kA) | 31.5 |
| LI withstand voltage (kV) | 350/400 |
| PF withstand voltage (kV) | 140<br>160 across the gap |
| Rated current (A) | 1200/2000/3000 |
| Rated frequency (Hz) | 50/60 |
| Short-time withstand current (kA x 2 sec) | 31.5 |
| Standards | JEC: 72/84 kV |

# Annexure-III

**Annexure-II (M/s Toshiba)**

**First installation**

- 72kV $SF_6$-free GIS was successfully energized in February 2023 in Fuchu Substation of TEPCO Power Grid, Inc. as the first $SF_6$-free modern substation in Japan.

72kV $SF_6$-free GIS in Fuchu Substation of TEPCO Power Grid Inc.

Under consideration of the above developed Technology and first Products in advanced countries like Japan, when defining the Transition to Alternative Gas Insulated Equipment in power systems, regulations must consider the following:

**(i) Alternative Gas for Sustainability:**

Detailed evaluation, cautious and careful choice_of the Product with Alternative Gas (F- Free Switchgears) is to be exercised.

Due considerations to choose the sustainable option, most Sustainable amongst Natural Origin Gasses (incl. Vacuum) and Artificial F-Gas Mixtures; Choice of Gas is to be made considering potential risk of EHS, GWP Target (e.g.0 OR <1), commonly used Stable gas supply, ease in gas handling and scalability (e.g. 63 kA interruption & >4kA current capabilities).

**(ii) Properties of Alternative Gas:**

Defining Properties of SF6 Gas free medium (E.g. Dry Air or Synthetic Air or any other Natural Origin gas solution) to be considered while making the choice also should consider:

- Gasses that contribute to Lowest possible GWP values (<0 or <1)
- No Ozone depleting potential, No acidification potential
- Non-toxic (non-carcinogenic, non-mutagenic)
- Non-flammable, Extremely stable
- Low boiling point, insulating medium does not liquefy
- No gas recycling requirement
- Stable Supply Chain
- Without specal tools and Adaptations for Handling the gas durign the lift time
- No mandatory gas recycling requirement
- No Per and polyfluroalkyl substances (PFAS Free)
- Safe to release into outside air (If necessary)

**(iii) Robust Supply Chain of Alternative Gases:**
Definition of Alternative Gasses is a vital aspect to consider in the Regulations. Choice of Gas(es) shall be evaluated and identified, evaluation shall consider the following aspects:

- EHS aspects like Hazards to health and life of human beings involved int eh production of Gas(es)
- Open-Source availability of such identified gases, without any limitations to use due to Patents
- Local Manufacturing capability of Gas to be aligned with the Introduction or phasing out of SF6 based SWGR Products

***(iv)*** **Footprint of F- Free Gas**:

Footprints are expected to be increased. Allowance in planning shall afford the enhanced footprints to allow early adoption of the technology, while the efforts and possibilities for optimization of the footprint continue.

**(v) Framework for Adoption of F- Free Switchgear**:

Appropriate Framework in terms of incentives for indigenous development or transfer of technology, indigenous capability building of alternative gas(es), Eligibility criteria for introducing such alternative technology-based Transmission Equipment, with an aim to develop domestic competence building from the initial stages of technology adoption, are provided

**(vi) Road Map for Adoption of F- Free Switchgear**:

Prepare and robust, reliable and practically realisable road map with due consultation with all Indian Manufacturers with the relevant technology and taking the above listed aspects into consideration.

The Road Map is to detail the Immediate, Short, Medium and Long Terms Measures and Technologies that are to be adopted for realising the CO2 reduction plan in the T&D Equipment, both already installed as well as those to be installed in future.

Road Map should be based and aligned to local/ domestic manufacturing and supply capabilities, identifying the first adoption cycle and the phase out cycle

Road Map shall clearly address the timelines and step wise transition for each Type, Voltage Level of the Products that are to be replaced with F-Free Switchgear, bringing out Year Wise steps foreseen in the transition and full migration in T&D Equipment.

F-Free High Voltage Switchgears Technology and Product Development Road maps expected are as below:

- Solid Insulated Switchgear (SIS): Available for Up To 72kV
- Gas Insulated Switchgear (GIS):
  - 72kV (31.5kA): Available
  - 220kV (50kA): FY 29 - FY 30
  - 400kV (63kA): FY 31 - FY 32
- Gas Insulated Bus Ducts (GIB):
  - 400kV (63kA): FY 25 - FY 26
  - 220kV (50kA): FY 27 - FY 28

Following may be considered as an example, for developing the transition coverage for the entire range and ratings:

- First Adoption: FY 28
- First Supply: FY 30
- First Stage Phase Out: FY 35

In order that early adoption is encouraged, adoption of Feeder Gas Insulated Busduct with natural Origin based GIS Equipment for phase segregated installations e.g of Voltage Levels of 400kV from FY 28 Onwards can be considered as a Target.

**(vii) Funding for F- Free Switchgear:**

"Green Innovation Fund" and "EU Life Fund" are examples of initiatives to promote F-Free Switchgear in Japan and EU respectively. These along with other incentives being extended to R&D, Proto-Typing etc. in countries like Japan and EU are to be studied and similar or better platform are to be provided to ensure early Catch-Up and soonest adoption of F-Free Switchgears in Indian T&D sector also.

Annexure-III (M/s Siemens)

# Way forward: Inclusion of sustainability criteria helping customers to support UN Global Goals

**There had already been 'Environment based' factor of evaluation in the Bidding in many regions like EUR/ UK/ NAM**

| **Tender Evaluation Criteria**: | |
|---|---|
| Equipment Price | 40 |
| Technical | 40 |
| Sustainability | 20 |
| Total Evaluation: | **100** |
| | |
| Technical (General) | **20** |
| Physical footprint (dimensions) | 10 |
| 3ph switching capability > 12 times 40kA | 5 |
| Leakage rate <0,1% | 3 |
| Building ventilation required | 2 |
| | |
| Technical (Installation & Maintenance) | **20** |
| Special gas processing equipment required | 5 |
| Availability of insulating gas (no of suppliers) | 5 |
| Gas handling / contamination tests / precaution measures | 5 |
| Ease of degassing and gassing | 3 |
| Training and reporting efforts | 2 |
| | |
| GWP Insulating Gas: | **10** |
| > 1 - 1000 | 3 |
| > 0,1 - 1 | 5 |
| < 0,1 | 10 |
| | |
| HSE Aspects | **6** |
| No F- gas used / No environmental risks (water/soil) due to PFAS | 2 |
| Not Harmful to health/ no toxicity classification | 2 |
| Non-Hazardous or non-toxic decompensation products | 1 |
| Finalized HSE regulation assessment /hazard analysis | 1 |
| | |
| EPD, Diversity & Wages & LTIF-Rate | **4** |
| Environmental Product Declaration available (yes/no) | 1 |
| Target of diversity/inclusion goals and fulfilment | 1 |
| Paying wages > labour agreement | 1 |
| LTIF Rate < 0,3% (TRIR) | 1 |

**More attention with UN Global goals on Sustainability (Target 12.7)**

**Target 12.7:**
**Promote sustainable public procurement practices**


- Regulations/ Policies
- Bid evaluation covering sustainability criteria's like
  - Environmental impact/ risks
  - % GWP
  - HSE Aspects
  - Non-Hazardous or non-toxic decomposition

# Annexure-IV

## Model Tender Evaluation Criteria for Green GIS for the Technologies Available

| Evaluation Point | Score/ Weight |
|---|---|
| **I. Technology & Reliability** | **9** |
| **(a) Product maturity & references** | 3 |
| **(b) Lifetime of the Product** | 2 |
| **(c) Footprint / Dimensions** | 2 |
| **(d) Gas Tightness / Leakage Rate** | 2 |
| **II. Operation & Maintenance** | **8** |
| **(a) Maintainability and Lifecycle Support** | 2 |
| **(b) Inspection & Revision Intervals** | 1 |
| **(c) Gas Handling and Maintainability** | 2 |
| **(d) Special Training of Maintenance Personnel for Insulation Gas** | 1 |
| **(e) Gas availability** | 2 |
| **III. Sustainability, Environmental Protection & HSE** | **8** |
| **(a) Global Warming Impact Reduction** | 3 |
| **(b) Toxicity and Health Risks** | 2 |
| **(c) End-of-Life Gas Handling (After Decommissioning)** | 1 |
| **(d) Environmental Product Declaration (EPD) / Life Cycle Assessment (LCA)** | 2 |
| **IV. Invest & Expenses (TOTEX)** | **75** |
| **(a) Capital Expense (CAPEX)** | 50 |
| **(b) Operational Expenditure (OPEX)** | 20 |
| **(c) End-of-Life Costs (Disposal, Decommissioning)** | 3 |
| **(d) Gas Costs (Procurement, Lifetime, Disposal)** | 2 |
| **Total** | **100** |

**In addition to above, provisions of the Government of India Orders on Make in India shall also be followed.**