Will Electrical Industry Succeed In Phasing-out SF_6 From MV Switchgear?

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Power Technology Research Inc.

Founded in 2016

Owned and operated by researchers, analysts, and power engineers

Objective:

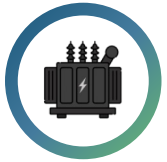
To understand the recent and upcoming changes to our electric infrastructure while identifying and communicating the best technologies and associated business models applied by industry leaders.

COVERAGE

Power Grid

New Energy

Specialized Power Grid & New Energy Market Research



Transformers
(Dist., Power)

Substation Automation
(Dist. vs Cent.)

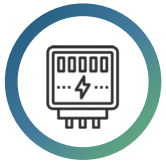
EV Charging Infrastructure
(Public, Private, Passenger/Comm.)

Switchgear
(HV, MV)

Port Electrification
(Shore-to-Ship, Microgrid)

Energy Storage Value Chain
(Utility Scale, C&I)

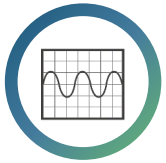
Flexible AC Trans. Systems
(SVCs, STATCOMs)



Smart Meters
(Power Quality, AMI)

Comm. & Off-Highway Vehicles
(BEVs, PHEVs, ICEs)

HVDC Market Analysis
(VSC, LCC, Cables)



Power Factor Correction
(Active, Passive)

Hydrogen in Power Sector
(Tech., Demand, Value Chain)

Synchronous Condensers
(4-Pole, 6-Pole,...)

Grid Communication
(Private LTE, 5G)

Impact of EVs on Power Grid
(Quantitative, Trafo., Switchgear)

Agenda

Introduction - 5 mins

Overview of SF_6 energy & MV Switchgear Market

Legislative Processes around SF_6

SF_6-free Switchgear Market Outlook

Audience Q&A - 10 mins

Will Electrical Industry Succeed In Phasing-out SF_6 From MV Switchgear?

Contents

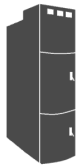
PTR MV Switchgear Service Overview

PTR MV Switchgear Service Overview

Market Sizing Overview: 12 Verticals, 6 Product Types

Utility Distribution | Wind Generation | Solar Generation | Conv. Generation | Automotive | O&G | Mining | Chemical | Steel | Data Centers | Buildings | Transport Infr.

Primary Systems (AIS & GIS)



Primary MV Switchgear Systems

Secondary Systems, RMUs (AIS & GIS)

Secondary MV Switchgear Systems

Overhead Equipment

OCBs, Reclosers

Voltage Segments by Product

1-12kV | 12-17.5kV | 17.5-24kV | 24-42kV

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Unit Numbers by Voltage Segment (2018-2026)

Installed Base | New Additions | Replacement

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Definitions

Definitions

AIS vs. GIS

Aspect	AIS	GIS
Design standards	IEC (e.g., IEC 62271-1, IEC 62271-200, IEC 62271-100 …etc)	IEC (e.g., IEC 62271-1, IEC 62271-200, IEC 62271-100 …etc)
Media used for "Busbar" insulation	Air	SF6
Media used for "Switching"	Air, Oil, SF6 or Vacuum	SF6 or Vacuum
Dimensions/physical size/footprint	Relatively larger, as clearances are in "Air", thus some safe clearances must be maintained to satisfy the dielectric performance.	Relatively smaller (sometimes combining more than one function in one gas tank thus considerably reducing overall line-up dimensions/footprint)
Sensitivity to environment/pollution	Moderate, pollution & humidity can have some effects on insulation that is exposed in air	Excellent, gas tank usually with high ingress protection (e.g., IP67) with very little sensitivity to environment, humidity, even altitude
Maintenance requirement	Moderate	Minimal, because the busbars & switching units are both completely sealed thus limiting the need for insulation cleaning & need for user intervention.

Equipment Covered

Complete MV Switchgear coverage

Equipment/Company	EATON	SIEMENS	ABB	Schneider Electric
AIS Primary	• MMS • Power Xpert UX 	• NXAIR • 8BT1 	• UniGear 	• PIX 
GIS Primary	• Power Xpert XGIS 	• 8DAB 12 	• ZX 	• GMA • GHA 
AIS Secondary	• Xiria E • Power Xpert FMX 	• SIMOSEC 	• UniSec 	• SM6-36 
GIS Secondary	• RVAC 	• 8DJH 	• SafeRing 	• RM6 
Outdoor Circuit Breaker	• CES-40.5 	• Live-Tank 3AF04/3AF05 	• OVB • OHB • PVB 	• VOX • PCOB 36 
Reclosers	• Nova • VSA • 6H, V6H 	• SDR • CMR 	• GridShield • OVR 	• E-series • U-series • W-series 

Overview of SF_6 in Energy & Beyond

Background

Overview of SF_6 in Energy & Beyond

23,500 times and 3200 years

The global warming potential of SF_6 gas is 23,500 times that of CO_2 over a period of 100 years where atmospheric life of SF_6 is around 3,200 years.

55% by 2030

Under the European Green Deal, there is a push to reduce the GHG emissions by 55% by 2030.

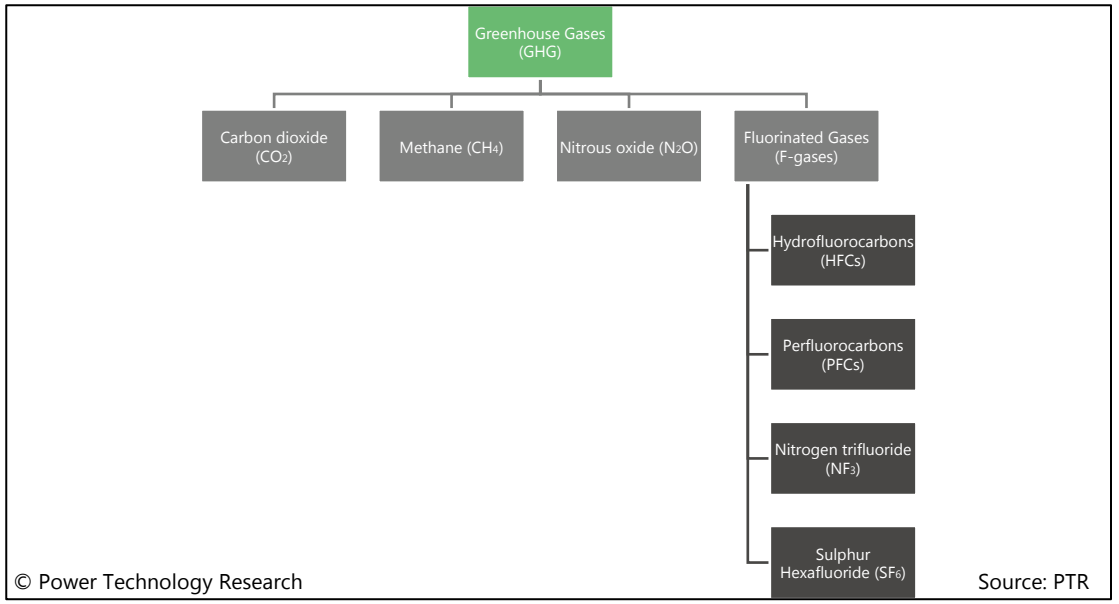
SF_6 in Switchgear

The use of SF_6 still remains large in both MV and HV electrical equipment such as switchgear mainly because

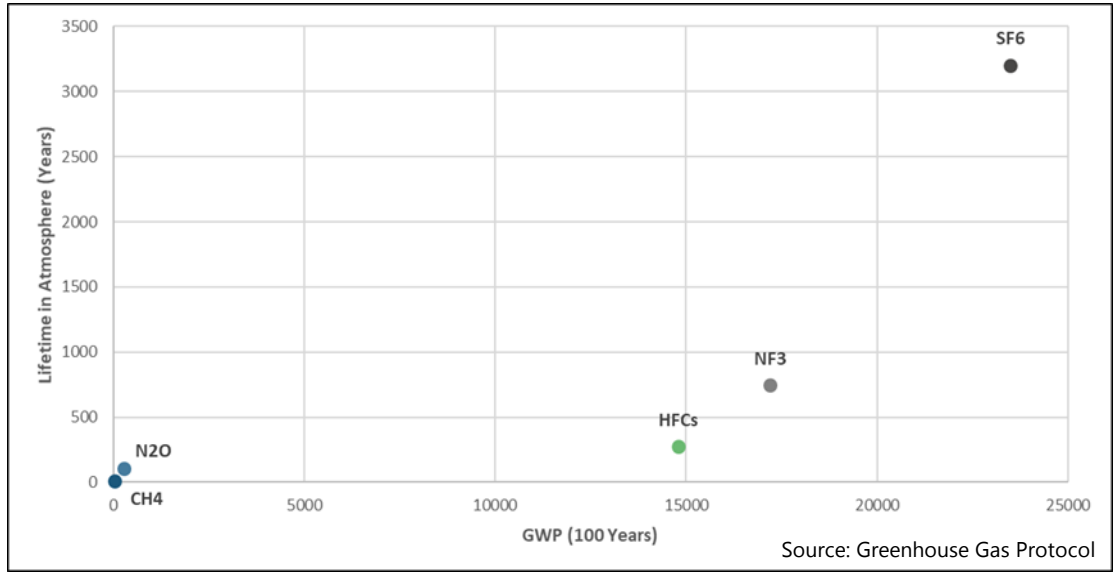
- Excellent electrical insulation
- Reduction in size

85%

Around 85% of all SF_6 produced is used in the electric power industry.



Source: PTR



Source: Greenhouse Gas Protocol

Overview of SF6 in Energy & Beyond

Uses of SF_6

- Gas-insulated switchgear (HV & MV)
- Other electrical equipment (GIL, CB, TRAFO)
- Particle and electron accelerators
- Process gas in the semiconductor industry
- Tracer gas for leak detection
- Production of magnesium
- Production of aluminum
- Military aircraft radars

- Sound-proof windows
- Tennis balls
- Shoe soles
- Car/truck tires

Overview of MV Switchgear Market

Landscape of MV Switchgear

Global Historical Landscape of Medium Voltage Switchgear

19.4 BUSD

In 2021, annual market for MV switchgear units is 19.4 billion USD globally.

52%

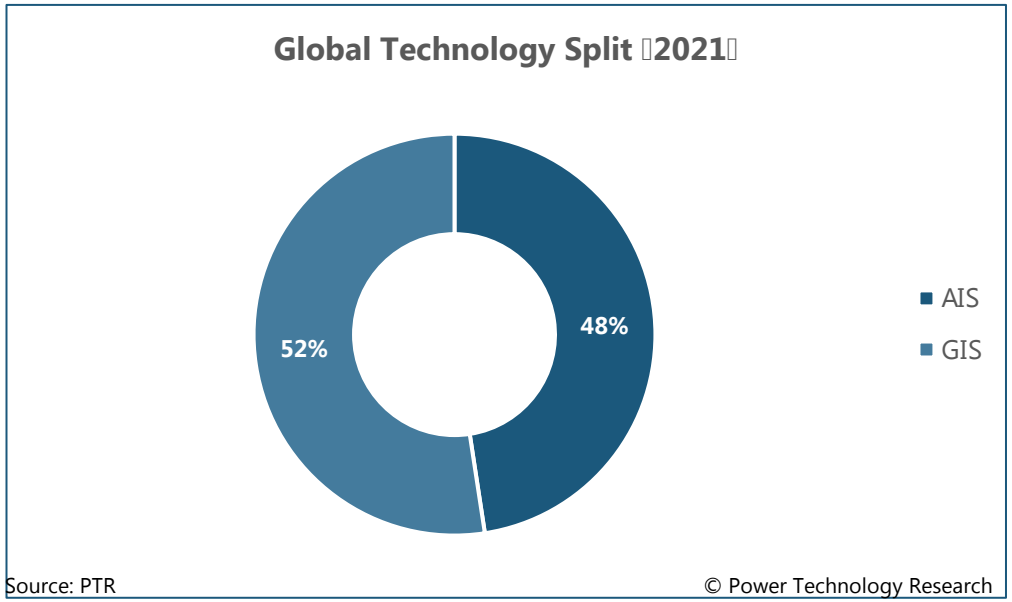
In 2021, 52% (by units) of the installed switchgear units were GIS based while 48% were AIS based units.

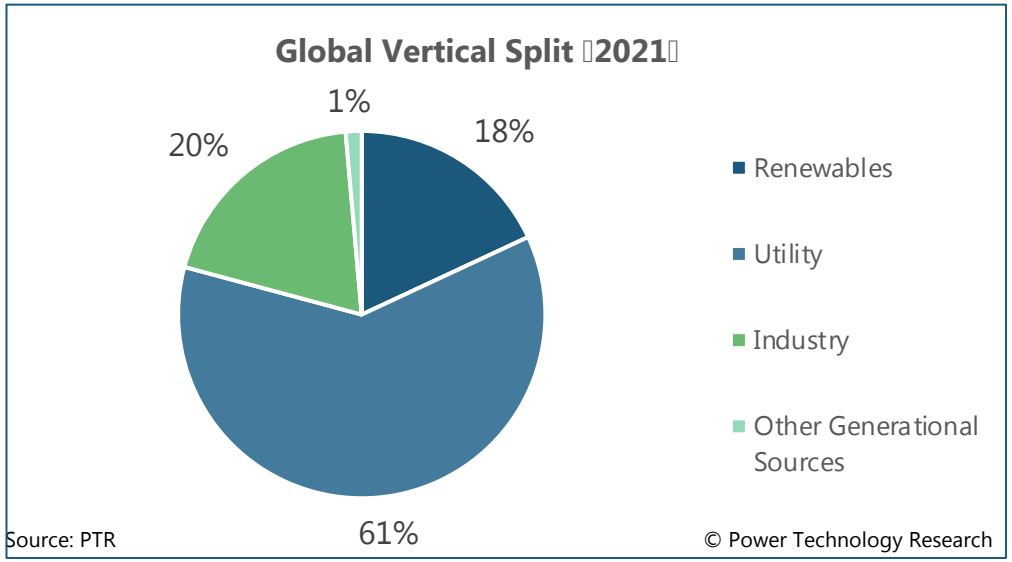
61%

From an end-application perspective, 61% of the MV switchgear units were installed by utility sector in 2021 whereas renewables i.e., wind and solar contributes to 18% of the switchgear demand..

~70%

Within renewables sector ~70% of the installed switchgear is gas insulated compared to other industries.

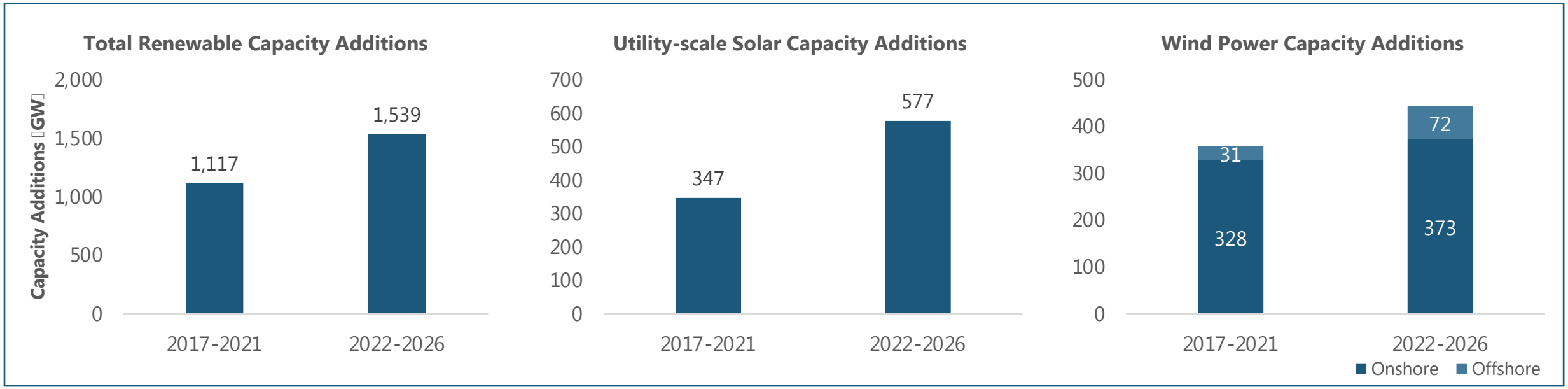




Evolving Targets of Clean Energy

Comparison of historical and forecast years

~40% higher capacity additions in forecast years



Need of SF_6 in Renewable Sector

Owing to compactness and maintenance requirements wind is predominantly GIS driven market

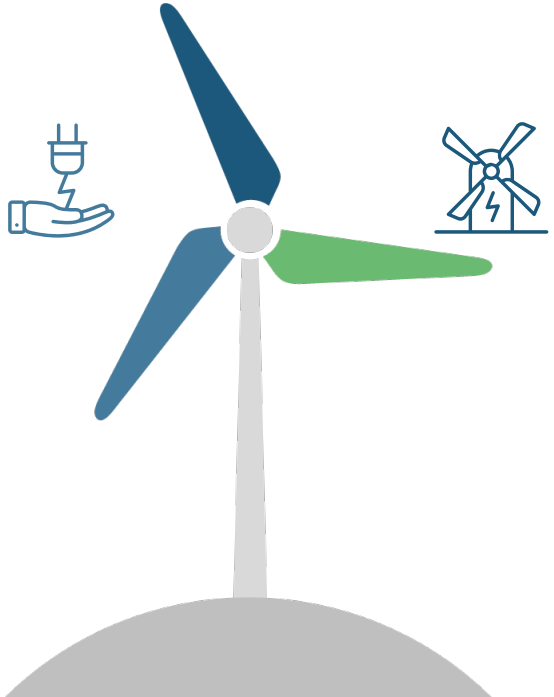
SF_6 Emissions from Renewable Energy Sector

Significant capacity additions of renewables are projected in Europe by 2030, making them hotspots for switchgear suppliers. Therefore, presenting two options for the electrical industry:

- Opting for MV SF_6-based GIS, resulting in **approximately 674.3 million CO_2 equivalent** emissions from the MV switchgear used within the renewable sector during the next decade.
- Employing SF_6-free solutions and playing their part in making Europe the world's first climate-neutral continent by 2050 under the European Green Deal.

Resistant to harsh environmental conditions

Switchgear installed offshore requires high maintenance due to harder salinity corrosion, higher humidity, and more temperature variance.



Compactness

Switchgear needs to be installed in the base of a wind turbine where there is limited space, therefore it must be compact (deeper with less height) to make it feasible to fit in the base

Legislative Processes around SF_6

Legislative Processes around SF_6

Developments towards phasing out SF6

MAC Directive (2008-2017)

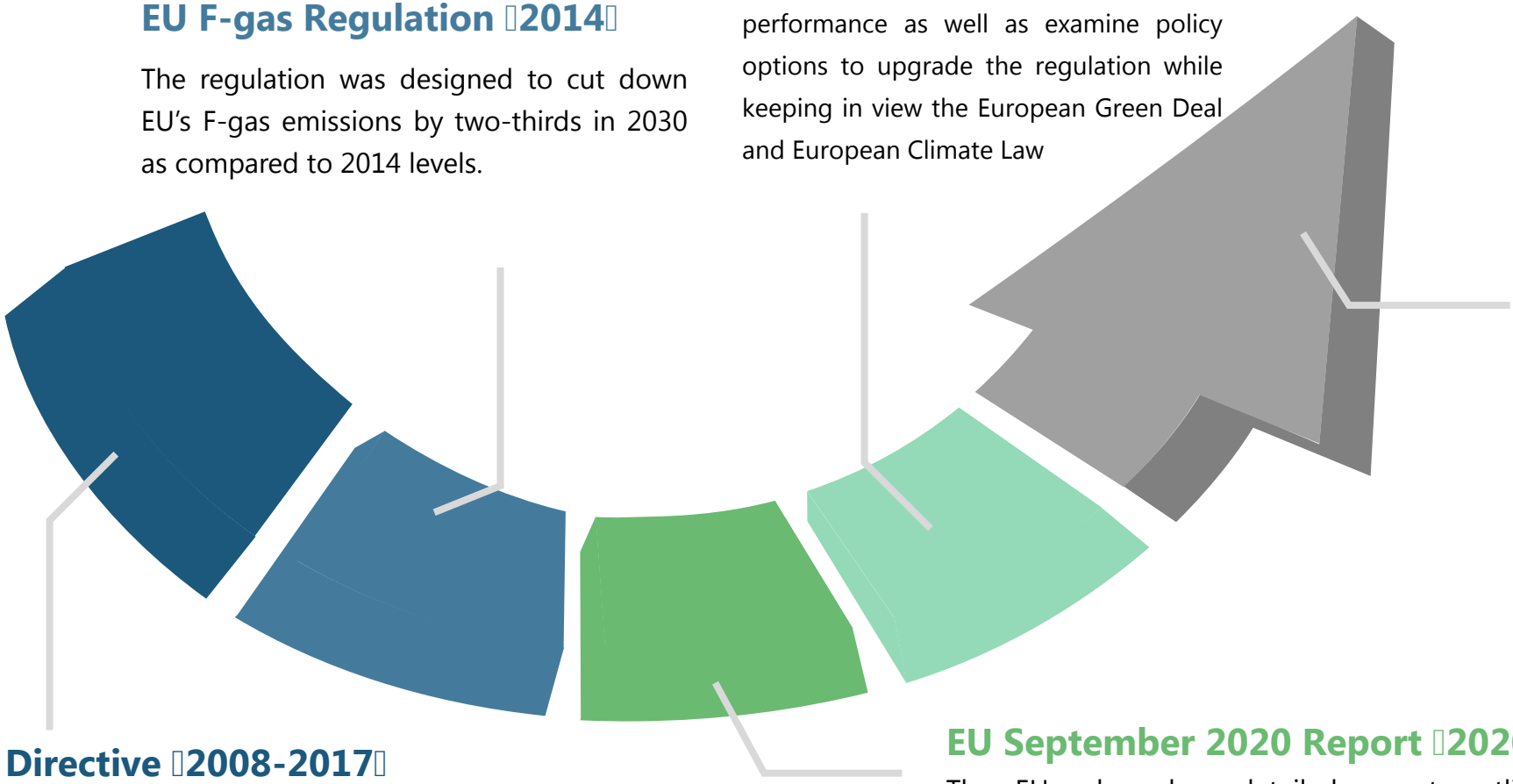
It bans the use of F-gases having GWP of more than 150 times than CO_2 in air conditioning systems in passenger cars and vans

EU F-gas Regulation (2014)

The regulation was designed to cut down EU's F-gas emissions by two-thirds in 2030 as compared to 2014 levels.

Review of F-gas Regulation 2014 (2022)

The EU Commission will review the performance as well as examine policy options to upgrade the regulation while keeping in view the European Green Deal and European Climate Law



EU September 2020 Report (2020)

The EU released a detailed report outlining alternatives to SF_6 use in switchgear and other equipment related to switchgear

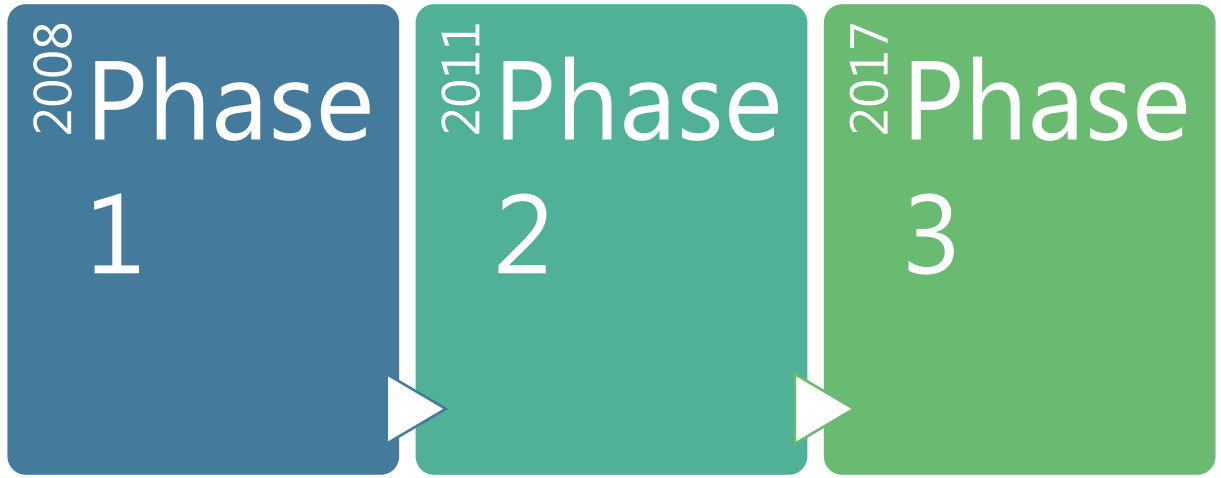
Proposed Regulation to ban SF_6 (2022)

To achieve carbon neutrality targets by 2050, recently European Commission announced a new proposed regulation to phase out SF6 in new electrical equipment by 2030.

European Directive on MACs

MAC = Mobile Air-conditioning Systems

- Fluorinated greenhouse gases with a global warming potential (GPW) higher than 150, compared to CO_2 will no longer be used in MAC systems.
- The use of HFC134a (the standard refrigerant in cars) was banned from some vehicle types starting in 2013 and all new vehicles after 2017.



F-gas Regulations 2014

Core Aim of the Regulation (EU) No 517/2014 on Fluorinated Greenhouse Gases Proposed in 2014

01.

A phase down of HFCs in various applications.

02.

Better containment of F-gases in their applications.

03.

Recovery of F-gases from equipment reaching their EoL.

04.

Training and certification of technical personnel working with F-gases' handling.

05.

Reporting of production, import and export data within the EU.

06.

Labelling of certain products and equipment containing those gases

EU September 2020 Report

Detailed report outlining alternatives to SF□ used in switchgear and related equipment □ published in September 2020

MV Secondary Distribution

SF_6 was still dominant switchgear sales but commercial alternatives have become available for applications up to 24 kV.

MV Primary Distribution

a growing number of SF_6-free switchgear solutions are being developed and offered by manufacturers.

EU September 2020 Report

Related Equipment

MV instrument transformers and capacitors

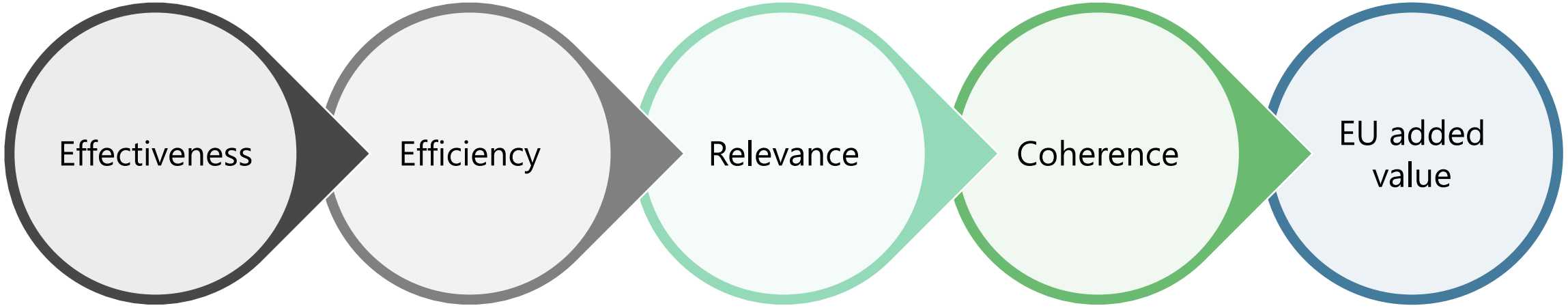
Bushings/GIS Lines/GIS Busbars & Busducts

HV Equipment

Commercialization after 2025 expected for SF_6-free equipment for voltages up to 245kV.

Review of F-gas Regulation 2014

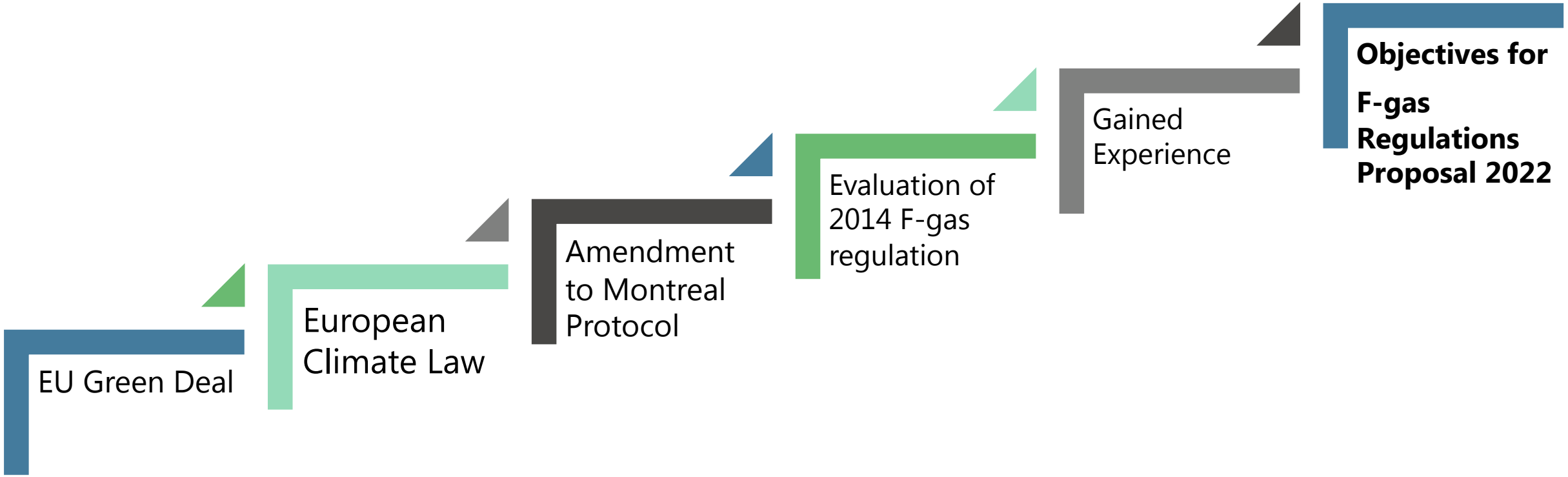
Evaluation and Impact Assessment for amending F-gas Regulation (EC) No 517/2014 Published in March 2022



Key Metrics

F-gas Regulation Review 2022

Reasons for a Review of Regulation



F-gas Regulation Review 2022

Proposal Draft Released in April 2022

2022

MILESTONE 01

- Proposal repeals Regulation (EU) No 517/2014 (F-gas Regulation)
- Increased F-gas emission reductions.

2030

MILESTONE 02

- 55% Emissions Reductions, Increased from 40%.
- **SF_6 phased out in all electrical equipment particularly switchgear by 2031.**

2050

MILESTONE 03

- EU to be carbon-neutral by 2050
- Reduction in the EU GHG) of 490 Mt (CO_2 equivalent) by 2050

Where does the Technology Stand Today?

Comparison between SF_6-free & SF_6-based Switchgear

Comparison between SF_6-free & SF_6-based Switchgear

SF_6-free Switchgear can be as compact as SF_6-based switchgear All in all, today s alternative offerings are on par with SF_6-based switchgear

Technical Features

- **Insulation capability and arc quenching capability** of SF_6 is much better than alternatives available in the market.
- Both SF_6-free primary and secondary GIS, target equal **breaking capacities** as SF_6-based switchgear since the performance requirements are mandated by the network structure.
- A complete portfolio of SF_6 alternatives exists for up to 24 kV (with some solutions being even available up to 40.5 kV).

Total Cost of Ownership (TOC)

TOC of SF6-free switchgear is considerably less as compared to SF6-based switchgear

- Initial cost of purchase is 15-25% higher
- Maintenance cost is similar
- End of life cost is ~25% less than SF-6 based switchgear.

Interrupting Mediums	Insulating Mediums
Oil	Oil
Air	Air
SF_6	SF_6
Vacuum	SF_6 alternatives • Aletrnative F - gas mixtures • Natural origin gases (e.g., pressurized air) • Solid dielectric

MV SF_6-free GIS Projects and Pilots

12kV		24 kV (or 25.8 kV)		36 kV (or 40.5 kV)		
Arc quenching principle	Electric insulation medium	Arc quenching principle	Electric insulation medium	Arc quenching principle	Electric insulation medium	
Vacuum	Dry air	Vacuum	Dry air	Vacuum	Dry air	Primary
Vacuum	$CO_2/N_2/O_2$	Vacuum	C5-FK/dry air	Vacuum	C5-FK/dry air	
Vacuum	C5-FK/dry air					
Dry air	Dry air	C5-FK +dry air	C5-FK/dry air			Secondary switchgear
Vacuum	Dry air	Vacuum	C5-FK/dry air			
Vacuum	$CO_2/N_2/O_2$	Vacuum	Dry air			
Vacuum	Synthetic ester (liquid)					

Bottlenecks for adopting SF_6-free Switchgear

SF_6-free Switchgear is not easily adopted by the end customers

01 **Reluctance towards adopting new technology**

02 **Questions on the reliability**

03 **Lack of proper regulations**

SF_6 Alternatives

Few examples of SF_6 Alternatives

SF_6 Alternative Products

ABB

PRODUCTS	PrimeGear ZX0	PrimeGear ZX0	ZX2 AirPlus - Primary GIS	SafeRing AirPlus- RMU	SafePlus Air - RMU
INSULATION	●	●	●	●	●
COMPOSITION OF INSULATION	■	■	■	■	■
RATED VOLTAGE (KV)	12	24	up to 40	24	12
RATED CURRENT (A)	1250	1250	2000	630	630

ABB

PRODUCTS	SafeRing Air - RMU	UniSec AirPlus	SafePlus AirPlus	Elastimold Modular switchgear for subsurface and vault applications	Elastimold Padmount switchgear
INSULATION	●	●	●	●	●
COMPOSITION OF INSULATION	■	■	■	—	—
RATED VOLTAGE (KV)	12	up to 24	24	up to 38	—
RATED CURRENT (A)	630	630	630	—	—

ABB

PRODUCTS	Elastimold Tru-Break switchgear module
INSULATION	●
COMPOSITION OF INSULATION	—
RATED VOLTAGE (KV)	up to 29.3
RATED CURRENT (A)	630

Schneider Electric

PRODUCTS	SM AirSeT	PremSet
INSULATION	●	●
COMPOSITION OF INSULATION	■	■
RATED VOLTAGE (KV)	up to 24	up to 17.5
RATED CURRENT (A)	up to 1250	up to 1250

EATON

PRODUCTS	MMS	Power Xpert FMX	Power Xpert UX	xGear	SVS
INSULATION	●	●	●	●	●
COMPOSITION OF INSULATION	—	—	—	—	—
RATED VOLTAGE (KV)	up to 24	up to 24	up to 24	up to 24	up to 24
RATED CURRENT (A)	up to 3150	2000	up to 4000	up to 3150	up to 1250

EATON

PRODUCTS	Power Xpert UX 36	Xiria E	Magnefix	Xiria	Xiria xGear
INSULATION	●	●	●	●	●
COMPOSITION OF INSULATION	—	—	—	—	—
RATED VOLTAGE (KV)	36	up to 24	up to 15	up to 24	up to 24
RATED CURRENT (A)	up to 2500	630	up to 450	630	630

EATON

PRODUCTS	ISG-SD padmount switchgear	ISG-SD submersible switchgear	ISG-SD wallmount / vaultmount switchgear
INSULATION	●	●	●
COMPOSITION OF INSULATION	—	—	—
RATED VOLTAGE (KV)	up to 27	up to 27	up to 27
RATED CURRENT (A)	600	600	600

SIEMENS

PRODUCTS	8DAB 12 - blue GIS	8DJH 12 - blue GIS	NXPLUS C 24 - blue GIS	8DJH 24 - blue GIS
INSULATION	●	●	●	●
COMPOSITION OF INSULATION	■	■	■	■
RATED VOLTAGE (KV)	up to 12	up to 12	up to 24	up to 24
RATED CURRENT (A)	up to 2750	up to 630	up to 1250	up to 630

G&W Electric

PRODUCTS	Trident-ST	Trident-S	Trident-SP	Trident-SR
INSULATION	●	●	●	●
COMPOSITION OF INSULATION	—	—	—	—
RATED VOLTAGE (KV)	up to 35	up to 35	up to 35	up to 35
RATED CURRENT (A)	630	630	630	630

Conclusion

Conclusion

Perception of relatively lesser reliability & higher initial cost are the two main constraints towards the widespread adoption of alternatives

EV charging and renewables are expected to be the key growth drivers

The global warming potential of F-gases has been revised and the GWP of SF_6 has increased from 23,500 to 25,200 relative to the previous Assessment Report

Since alternatives for SF_6-free HV switchgear are few, the MV switchgear market offers the best opportunity to reduce SF_6 emissions.

Overall, eyes are on the EU for the 2022 final verdict regarding the revisions of F-gas regulations, which would be a big deciding factor, that could enforce SF_6 alternatives.

Even though initial costs are high upfront, Total Cost of Ownership is lower, and utilities can focus on this to take benefit of this technology.

Given the main purpose of adding renewables into the generation mix is to reduce the GHG footprint, thus renewables will to be the first to transition to alternatives.

Questions & Answers

Audience Q&A

PTR s MV Switchgear Market Research

Analysis of MV Switchgear (AIS/GIS) around the globe

MV Switchgear Market Analysis

- Regional/Country market by Units & Revenue
- 12 application verticals (TSO, DSO; Wind, Solar, Steel, Mining,…)
- 6 product types (Primary AIS, Secondary AIS, Primary GIS…)

Regional MV Switchgear Market Reports

- Regional Market Sizing (TAM by Units & Revenue)
- Competitive Analysis (Market Shares)
- AIS and GIS covered

PTR Sonar Power Grid

- Weekly updates on key market happenings
- Proprietary desktop/mobile app

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