NATIONAL DESIGNATED ENTITY (NDE) GERMANY | CTCN EASTERN EUROPE NDE FORUM

Business and Industry: F-gases Phase-out & Leakage Control

Session 5: Overview of Technical Assistance Support · 8 September 2026

Dietram Oppelt · Managing Director, HEAT GmbH / NDE Germany Technical Lead

FOCUS AREAS: SF6-Free Grid Switchgear · Natural Refrigerants in Industry · Leakage Control · CTCN Assistance

Strategic Scope: Two Complementary Industrial Frontiers

Structuring F-gas elimination across electrical power grids (Section 1) and industrial cooling (Section 2)

SECTION 1: POWER GRIDS & ELECTRICAL UTILITIES

SF6 Elimination, Closed-Loop Handling & Clean Grid Modernization

- **Target Scope:** Medium-voltage (12–72.5 kV) and high-voltage (145 kV+) switchgear in transmission & distribution networks.
- **Strategic Driver:** SF6 has GWP of 24,300 and 3,200-yr atmospheric persistence. Grid expansion risks 30–40 yr emission lock-in.
- **Commercial Status:** Market-ready non-SF6 vacuum interrupters and technical air solutions with 32% lower 40-yr operational TCO.
- **Stewardship Priority:** Immediate 4-stage closed-loop handling and leak reduction across existing assets (proven via CTCN Senegal / SENELEC).
- **Deck Mapping:** Detailed in Slides 3 to 8 (Regulatory bans, alternative technologies, TCO parity, and Senegal case study).

SECTION 2: BUSINESS & INDUSTRY (COOLING & AGRO-FOOD)

Direct Leapfrogging to Natural Refrigerants (Propane, CO2, Ammonia)

- **Target Scope:** Industrial refrigeration, commercial cold storage, food processing chillers, and export supply chains.
- **Strategic Driver:** Kigali Amendment HFC phase-down, steep quota cuts, refrigerant price volatility, and emerging EU/global PFAS bans.
- **Commercial Status:** Mature natural solutions (R290, R744, R717) deliver 10%–22% higher seasonal energy efficiency, lowering operational costs.
- **Market Advantage:** Permanent regulatory future-proofing: eliminates dependence on imported fluorinated chemicals and preserves EU market access.
- **Deck Mapping:** Detailed in Slide 9 (Market readiness, thermodynamic efficiency, and business rationale for agro-food exporters).

CROSS-CUTTING SYNTHESIS & NDE ASSISTANCE MECHANISM (SLIDES 10–12): While equipment engineering differs between high-voltage switchgear and industrial chillers, both sectors share identical institutional imperatives: establishing national asset baselines, updating public green procurement rules, training certified handlers, and mobilizing CTCN bilateral technical assistance to de-risk investment. Slides 10–12 provide the actionable roadmap for NDEs and energy ministries.

The Strategic Dilemma: Clean Electrification vs. F-Gas Lock-In

Section 1: Power Sector · Clean grid expansion risks locking in potent GHGs through 2060+

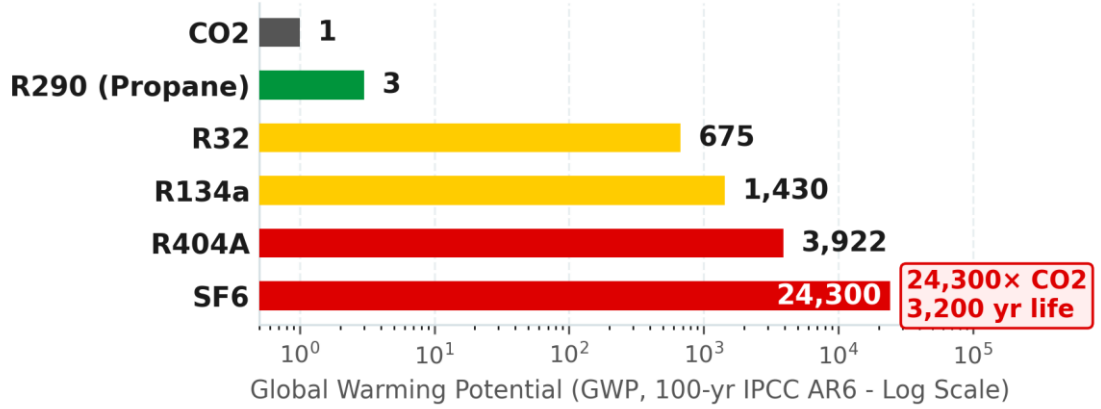


FIGURE: Modern MV Substation Switchgear & Vacuum Circuit Breaker Unit

24,300× **SF6 GLOBAL WARMING POTENTIAL**

The most potent GHG known (IPCC AR6 100-yr). 1 kg SF6 = 24.3 t CO2e. Electrical T&D accounts for ~85% of global SF6 stock.

3,200 yrs **ATMOSPHERIC PERSISTENCE**

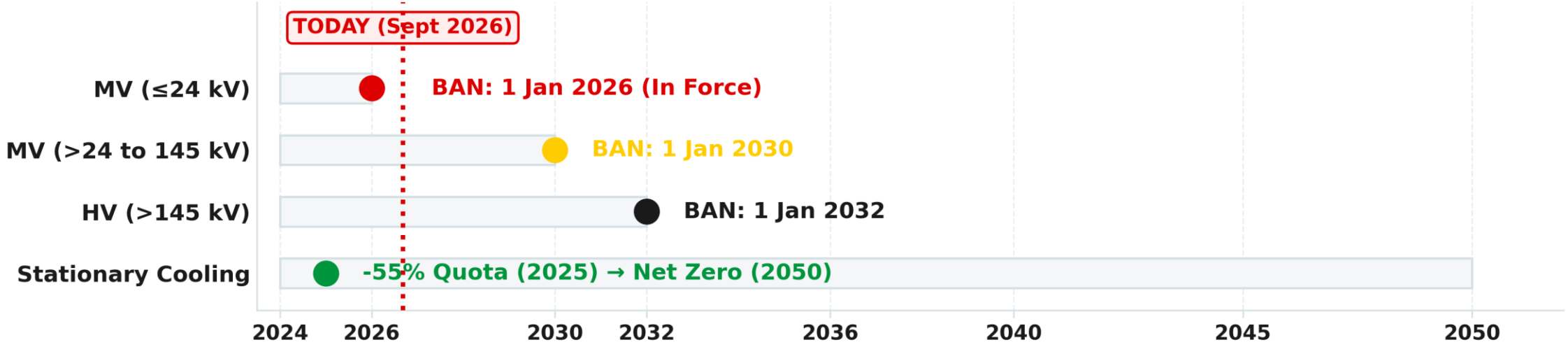
Virtually permanent atmospheric residency. Any gas leaked today accumulates irreversibly in the atmosphere.

30–40 yrs **GRID ASSET LIFETIME**

Switchgear energized today remains in service into the 2060s. F-gas procurement creates decades of emission & ESG liabilities.

Regulatory Benchmarks: EU F-Gas Regulation & Global Grid Mandates

Section 1: Power Sector · Firm phase-out dates eliminate market ambiguity and drive global OEM retooling



MV Switchgear Ban · 2026 / 2030

- ≤24 kV: Banned from 1 Jan 2026.
- >24 to 145 kV: Banned from 1 Jan 2030.
- Clean air & vacuum insulation mature.

HV Switchgear Ban · 2032 (>145 kV)

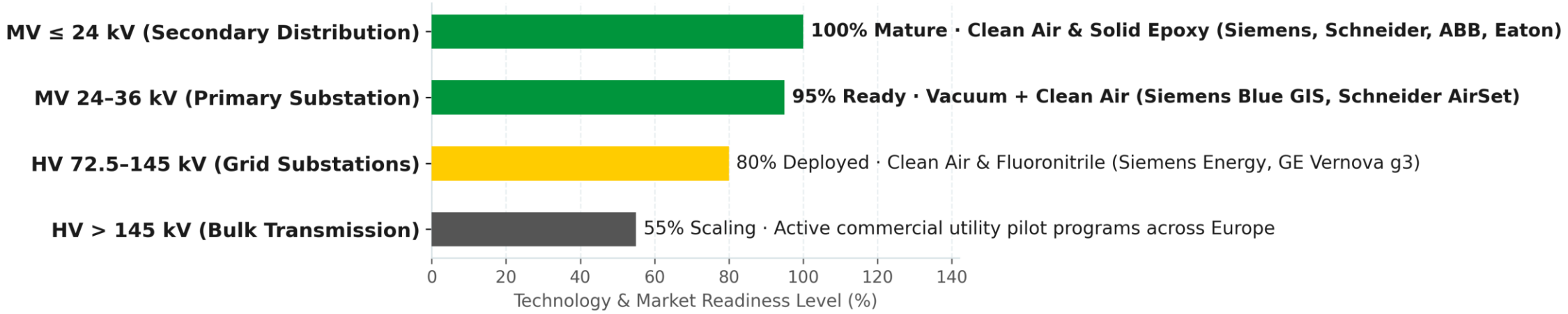
- >145 kV: Complete ban from 2032.
- European TSOs commissioning GIS.
- Equal short-circuit & footprint specs.

Global Market Impact · OEM RETOOLING

- Global switchgear OEMs shifting production lines.
- Procuring SF6 risks severe spare parts obsolescence.
- Kigali mandates reinforce non-fluorinated path.

Technology Solutions: Commercial SF6-Free Power Grids

Section 1: Power Sector · Non-SF6 switchgear is commercially available across all grid voltage tiers



Clean Air + Vacuum (MV)

COMMERCIALLY MATURE

Natural treated air (N2 and O2) insulation with hermetic vacuum interrupters. Operating at scale in distribution substations (Siemens Blue GIS, Schneider AirSet).

Solid Dielectric & Epoxy (MV)

ZERO CHEMICAL RISK

Cast-resin and epoxy insulation completely eliminates pressurized gas vessels. Standard for compact Ring Main Units (RMUs) and distribution networks (Eaton, ABB).

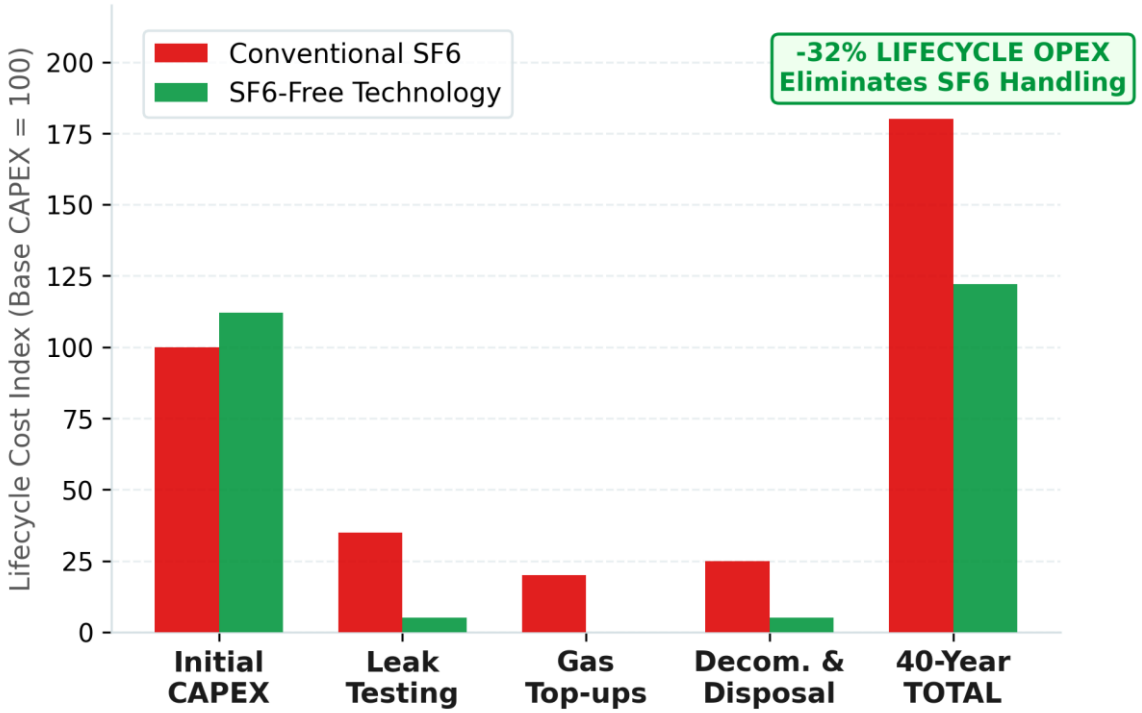
High-Voltage Alternatives (HV)

OPERATING IN TRANSMISSION

Clean air vacuum GIS (up to 145 kV) and fluoronitrile gas mixtures (g3, >99% GWP reduction) energised across German, UK, and Nordic transmission networks.

Total Cost of Ownership: 40-Year Economic Parity for Power Grids

Section 1: Power Sector · Higher initial equipment purchase is fully offset by lower operational and disposal OPEX



-32% **LIFECYCLE OPEX SAVINGS**

Eliminating specialized gas handling labor, annual leak testing, pressure recalibration, and gas top-up purchases over 40 years of service.

Zero **GAS REGULATORY COMPLIANCE COST**

No mandatory F-gas registry reporting, no specialized technician handling licenses, and total immunity from future fluorinated greenhouse gas taxation.

100% **END-OF-LIFE DECOMMISSIONING SAFETY**

Zero hazardous waste disposal fees upon retirement. Non-SF6 switchgear requires no hazardous substance evacuation or expensive thermal destruction.

** Internal calculations and lifecycle cost modeling based on 40-year utility maintenance records, leak testing, technician licensing, and hazardous disposal avoidance.*

Operational Priority: Safe Management Practices & Closed-Loop Handling

Section 1: Power Sector · Four-stage operational protocol to eliminate venting and manage legacy assets safely

STAGE 01 · BASELINE

Digital Inventory

SUBSTATION REGISTRY

- **Asset Registry:** Map all GIS bays, ratings, serials, and commissioning dates.
- **Mass Balance:** Reconcile nameplate capacity with measured operational gas mass.
- **Leak Log Tracking:** Audit historical top-ups to isolate chronic leaking substations.
- **Central Registry:** Digital MRV database for reporting and grid modernization.

✓ GOAL: 100% Asset Visibility

STAGE 02 · DETECTION

Leak Detection

PROACTIVE SCREENING

- **Infrared OGI:** Deploy optical gas imaging cameras to visualize invisible SF6 plumes.
- **Sniffer Probes:** Target flanges, pipe seals, valves, and burst disc membranes.
- **Predictive Action:** Repair chronic micro-leaks before low-pressure alarms trip.
- **Root Cause Fix:** Replace degraded elastomer seals with hermetic metal gaskets.

✓ GOAL: Zero Undetected Leaks

STAGE 03 · SERVICING

Certified Servicing

ZERO-VENTING PROTOCOL

- **Certified Engineers:** Accredited utility technician licensing for all gas handling.
- **Hermetic Carts:** Oil-free mobile recovery carts with dry compressor loops.
- **Gas Quality Testing:** Measure moisture (dew point), SO2, and purity before reuse.
- **Strict Protocol:** Zero venting policy with mandatory mass-balance logging.

✓ GOAL: 100% Gas Recovery

STAGE 04 · DESTRUCTION

Safe Destruction

END-OF-LIFE RECOVERY

- **Deep Evacuation:** Recover ≥99.5% of residual gas from decommissioned vessels (<20 mbar).
- **Thermal Destruction:** High-temperature incineration (≥1,100°C) with alkaline scrubbing.
- **Scrap Verification:** Safe decontamination of switchgear metals before recycling.
- **Chain of Custody:** Verifiable certified destruction certificates for carbon credit/MRV.

✓ GOAL: Zero Residual Release

Field Evidence: CTCN Technical Assistance in Senegal (SENELEC)

Section 1: Power Sector · Empirical baseline, 19-substation inventory & roadmap with SENELEC (2024–2026)

19 Substations

COMPREHENSIVE NATIONAL AUDIT

Exhaustive field audit across Dakar's high- and medium-voltage grid, creating Senegal's 1st national SF6 mass balance.

1st Baseline

VERIFIABLE ASSET REGISTRY

Reconciled nameplate ratings against utility gas cylinders, establishing historical leak rate baselines and tracking.

Zero-Venting

OPERATIONAL PROTOCOL REFORM

Transitioned utility maintenance from reactive top-ups to hermetic closed-loop servicing and leak elimination.

Phase 1 · Substation Inventory

ASSET MAPPING

- Audited 19 HV/MV substations across Dakar urban and peri-urban networks.
- Reconciled nameplate data against real gas cylinder purchase records.
- Identified oldest, highest-risk GIS bays for targeted leak remediation.

Phase 2 · Mass-Balance & MRV

VERIFIABLE BASELINE

- Established Senegal's 1st national SF6 mass-balance accounting framework.
- Developed Tier-2 emission quantification methodology adapted to grid data.
- Replaced rough one-off estimates with repeatable annual reporting protocol.

Phase 3 · Safe Handling & Roadmap

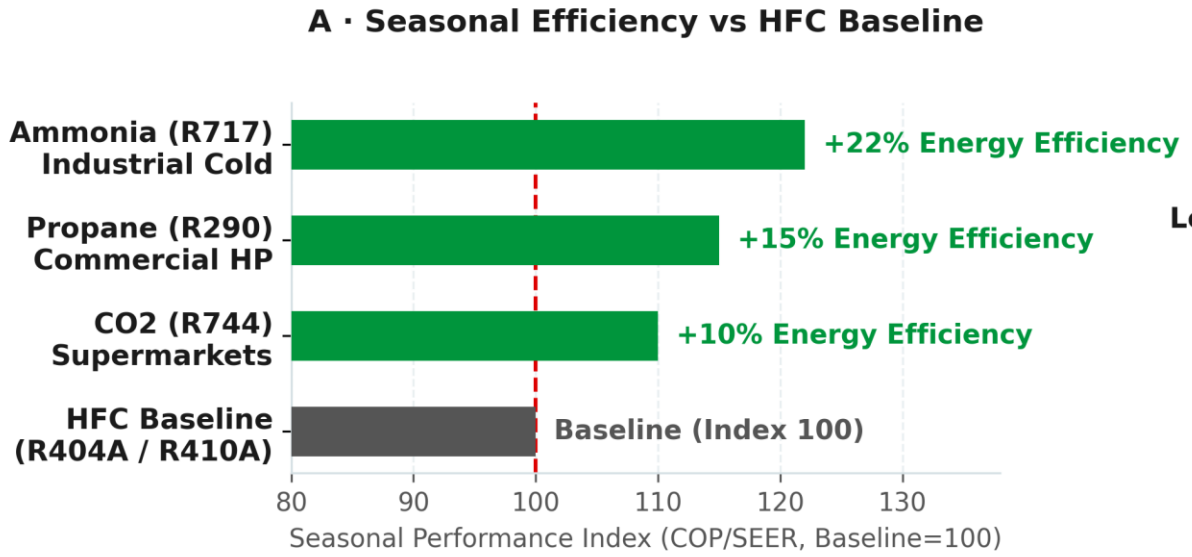
CAPACITY BUILDING

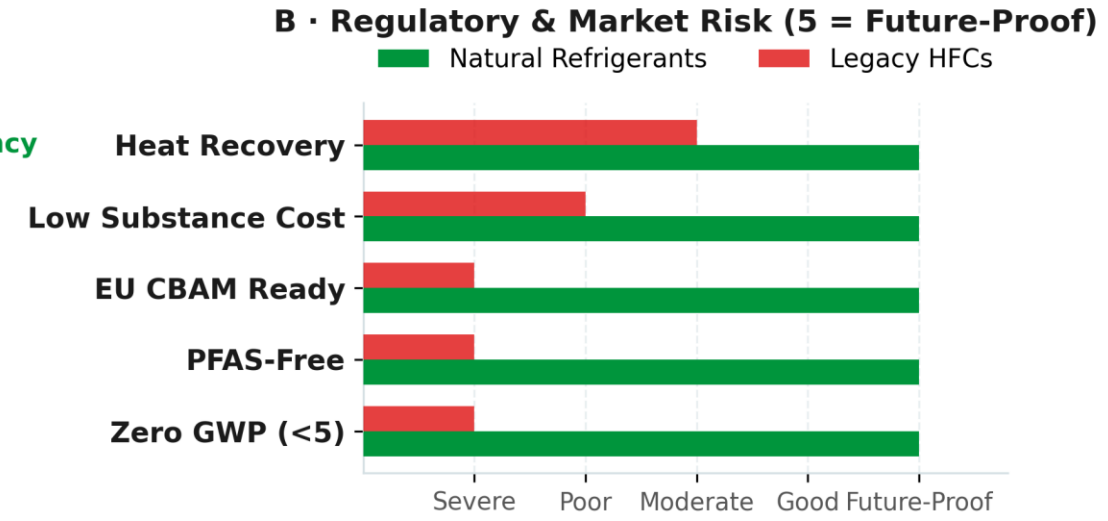
- Prepared utility safe handling guidelines and closed-loop recovery rules.
- Trained SENELEC utility engineers on hermetic maintenance protocols.
- Structured non-SF6 pilot tender specifications for upcoming grid expansion.

ONGOING CTCN TA IMPLEMENTATION: CTCN technical assistance transforms utility operations rapidly: establishing an asset registry, stopping chronic leaks with predictive tools, and preparing utilities for SF6-free procurement.

Business & Industry: Natural Refrigerants Pathway

Section 2: Industrial Horizon · Extending F-gas elimination to industrial cooling, cold chains, and agro-food exporters





BUSINESS RATIONALE FOR INDUSTRY & AGRO-FOOD EXPORTERS: Transitioning directly to natural refrigerants (R290, R744, R717) delivers a double dividend: 10%–22% lower seasonal electricity bills and total immunity from future fluorinated chemical bans, quota shortages, and emerging global PFAS regulations. It safeguards export competitiveness into EU markets.

Mobilizing Support: The CTCN & NDE Assistance Route

Synthesis & Support · How Eastern European and Central Asian NDEs can initiate technical assistance and catalytic financing

STAGE 1 · NATIONAL ENTRY POINT

Country Demand & NDE

- National Designated Entity (NDE)
- Line Ministries (Energy / Env.)
- Power Utilities & Industrial Parks
- Identified Grid & Cooling Priorities

STAGE 2 · PROJECT PREPARATION & STANDARDS

CTCN Technical Assistance

- National F-gas Baselines & MRV
- Policy & Technology Phase-Out Roadmap
- Grid Code Revision & Tender Specs
- NDE Germany Bilateral Twinning

STAGE 3 · BANKABLE INFRASTRUCTURE FINANCE

Catalytic Investment

- Green Climate Fund (GCF Readiness)
- EBRD & EIB Grid Modernization Loans
- World Bank Power Infrastructure Loans
- Viability-Gap Pilot De-risking

HOW NDE GERMANY & BILATERAL COOPERATION SUPPORT YOUR TRANSITION:

- **Direct Peer Exchange:** Bilateral technical cooperation from NDE Germany sharing model tender specifications and IEC/EN equipment standards.
- **Utility Twinning Programs:** Connecting regional grid operators with European utilities experienced in operating non-SF6 switchgear.
- **Unlocking Multilateral Investment:** CTCN technical assistance acts as project preparation to de-risk capital from GCF, EBRD, EIB, and World Bank energy loans.

Key Recommendations for NDEs, Regulators & Grid Operators

Synthesis & Action · Three strategic action points to establish F-gas leadership and avoid long-term carbon lock-in

01 · Clean Procurement

MANDATE ZERO F-GAS IN NEW TENDERS

Specify SF6-free switchgear in all new medium-voltage distribution tenders and require natural refrigerants (R290, R744, R717) in industrial cooling contracts. Prevent 40-year carbon and chemical compliance lock-in.

02 · Asset Stewardship

SAFE MANAGEMENT & MASS-BALANCE

Prioritize digital tracking, mandatory mass-balance accounting, and specialized technician protocols for legacy equipment. Enforce closed-loop recovery carts and safe end-of-life destruction to eliminate venting.

03 · Standards & Codes

REGULATORY ALIGNMENT

Align domestic grid codes and utility interconnection rules with EU Regulation 2024/573 and updated IEC/EN safety norms to provide equipment manufacturers and utilities with long-term market certainty.

CTCN TECHNICAL ASSISTANCE BACKSTOPPING: The CTCN is positioned to provide targeted technical assistance across all three recommendation areas: supporting NDEs with model procurement clauses, national inventory MRV methodologies, and grid code harmonization.

Priority Action Areas for National Designated Entities

Synthesis & Action · Concrete entry points for NDEs to de-risk national grid and industrial cooling transitions

01 · Clean Grid Tenders

PROCUREMENT SPECIFICATIONS

- Review upcoming utility capital plans and distribution network expansions.
- Introduce SF6-free technical specifications for MV switchgear (≤24 kV and 24 to 72.5 kV).
- Prevent purchasing 40-year emission liabilities and avoid future retrofit costs.

02 · National Asset Baselines

OPERATIONAL STEWARDSHIP

- Request utility SF6 mass-balance records and national chemical import logs.
- Prioritize physical asset inspections and leak screening at older substations.
- Require certified closed-loop gas recovery carts to eliminate maintenance venting.

03 · Bilateral & CTCN Support

PARTNERSHIP & PIPELINE

- Engage NDE Germany for model tender specifications and utility peer twinning.
- Formulate a country-driven CTCN technical assistance request for national roadmaps.
- Structure bankable investment components to access EBRD, GCF, and World Bank climate finance.

THE CORE TAKEAWAY: **"Two choices on the grid: zero-F-gas procurement today, or 40-year emissions liabilities."**

Dietram Oppelt · Managing Director, HEAT GmbH / NDE Germany Technical Lead

Email: dietram.oppelt@nde-germany.de · Web: www.nde-germany.de · Session 5 Joint Q&A (10:30–11:00 AZT)