Digital enabled Sustainable Transformer Technologies

Energy & Digital World (EDW) 2024 – Knowledge Session 1.3, 13:30 – 14:30

Nattapat Kuntawong, APMEA Application Engineering

Hitachi Energy

Agenda

1. EconiQ™ Transformers Solutions
    a. Sustainability in Transformers
    b. Ester Fluids Benefits & Challenges
    c. Life Cycle Assessment and Circularity
2. Transformers Life Extension
    a. Digitalization – TXpert Ecosystem
3. Enhancing safety
    a. Rupture resistant tank

Design, Performance and Driving Considerations for Sustainable Transformers

EconiQ Transformers

2024-02-12

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Introduction

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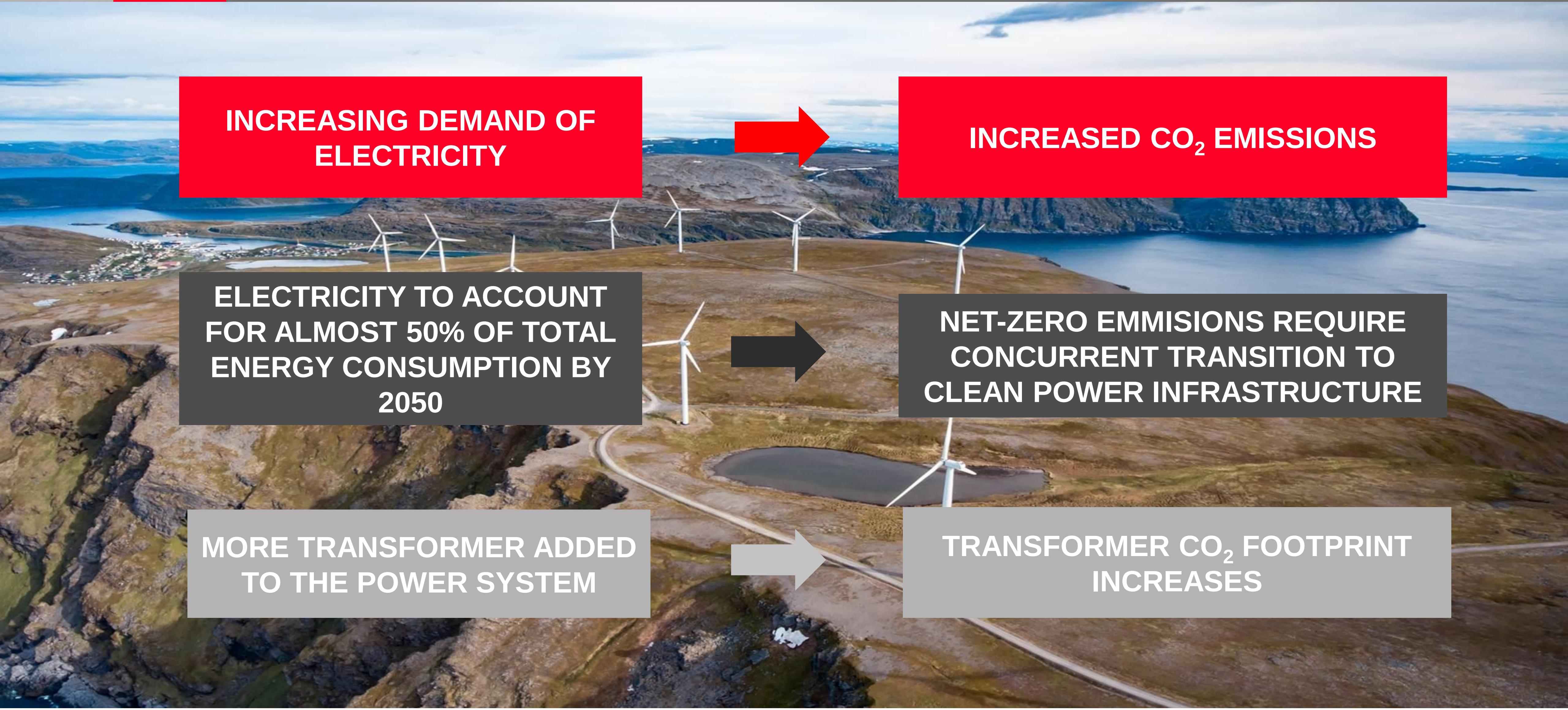

INCREASING DEMAND OF ELECTRICITY → INCREASED CO_2 EMISSIONS

ELECTRICITY TO ACCOUNT FOR ALMOST 50% OF TOTAL ENERGY CONSUMPTION BY 2050 → NET-ZERO EMMISIONS REQUIRE CONCURRENT TRANSITION TO CLEAN POWER INFRASTRUCTURE

MORE TRANSFORMER ADDED TO THE POWER SYSTEM → TRANSFORMER CO_2 FOOTPRINT INCREASES

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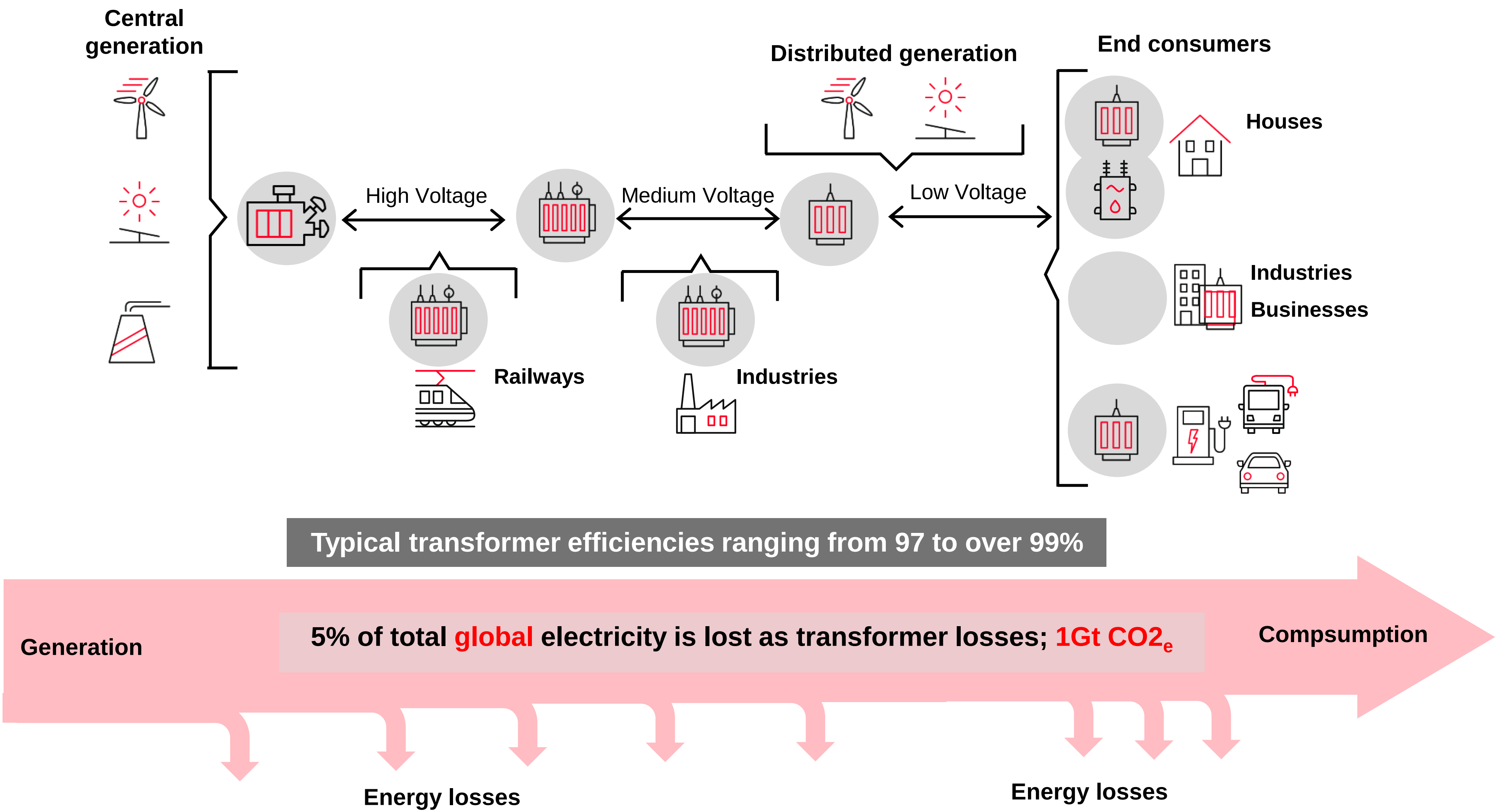
Transformers: Backbone of Low Carbon Power Grid



Public

https://www.iea.org/reports/sustainable-recovery
https://ourworldindata.org/co2-emissions#global-co2-emissions-from-fossil-fuels-and-land-use-change

Decarbonization

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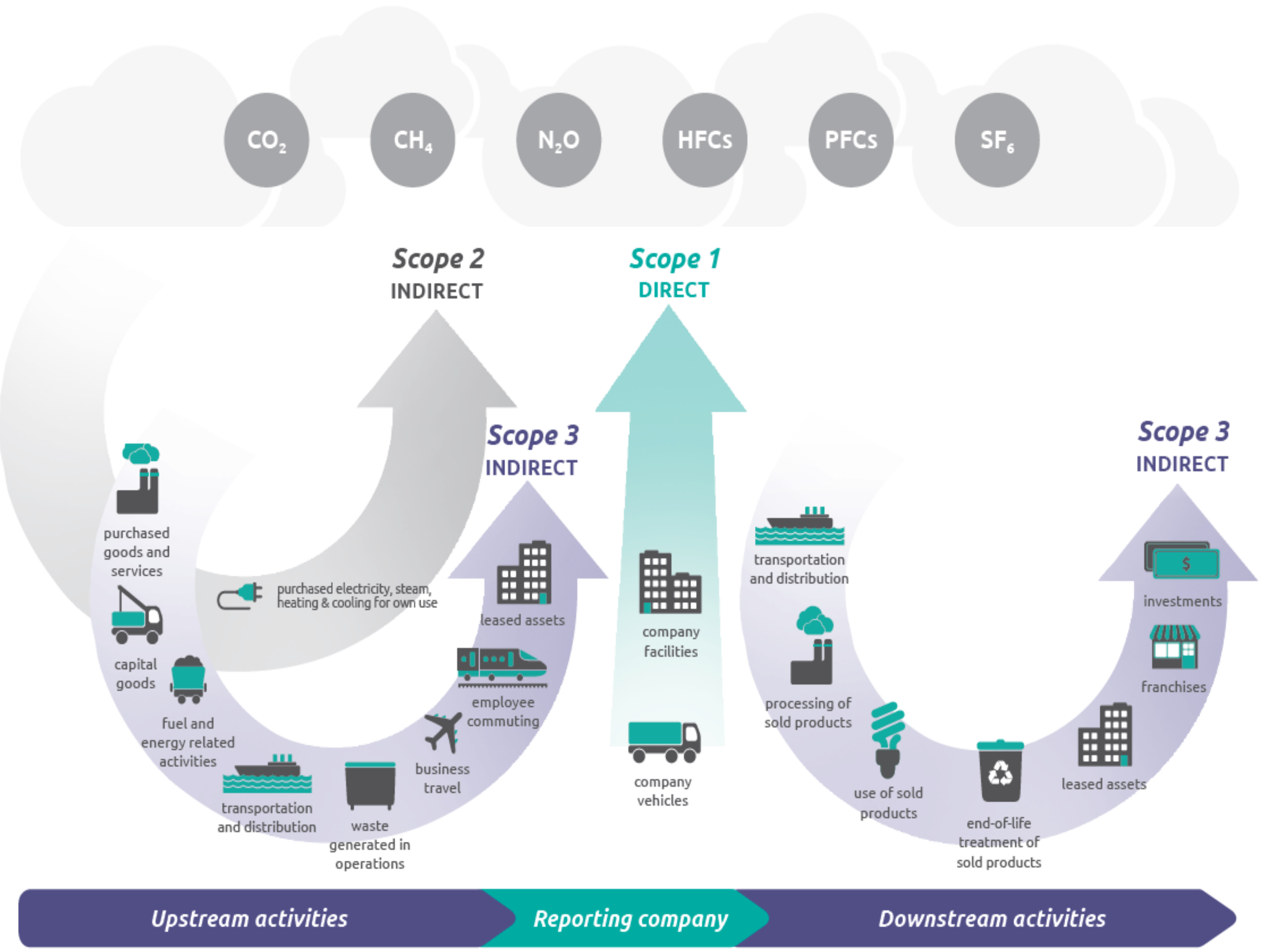
The **GHG (Greenhouse gases) protocol** is the main global standard to account for organizational GHG emissions. It defines emissions as Scope 1, Scope 2 and Scope 3. For a transformer user-

- **Transformer operational losses** contribute to carbon emissions from 'purchased electricity' i.e., **scope 2**. They mainly depend on transformer efficiency and energy mix / grid emission factor

- **Emissions from manufacturing of transformers** contribute to carbon emissions from 'capital goods' i.e., **scope 3 GHG emissions**. They mainly depend on carbon footprint of raw materials used, followed by energy mix of the manufacturing facility



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Decarbonization: Impact of Grid Emission Factor

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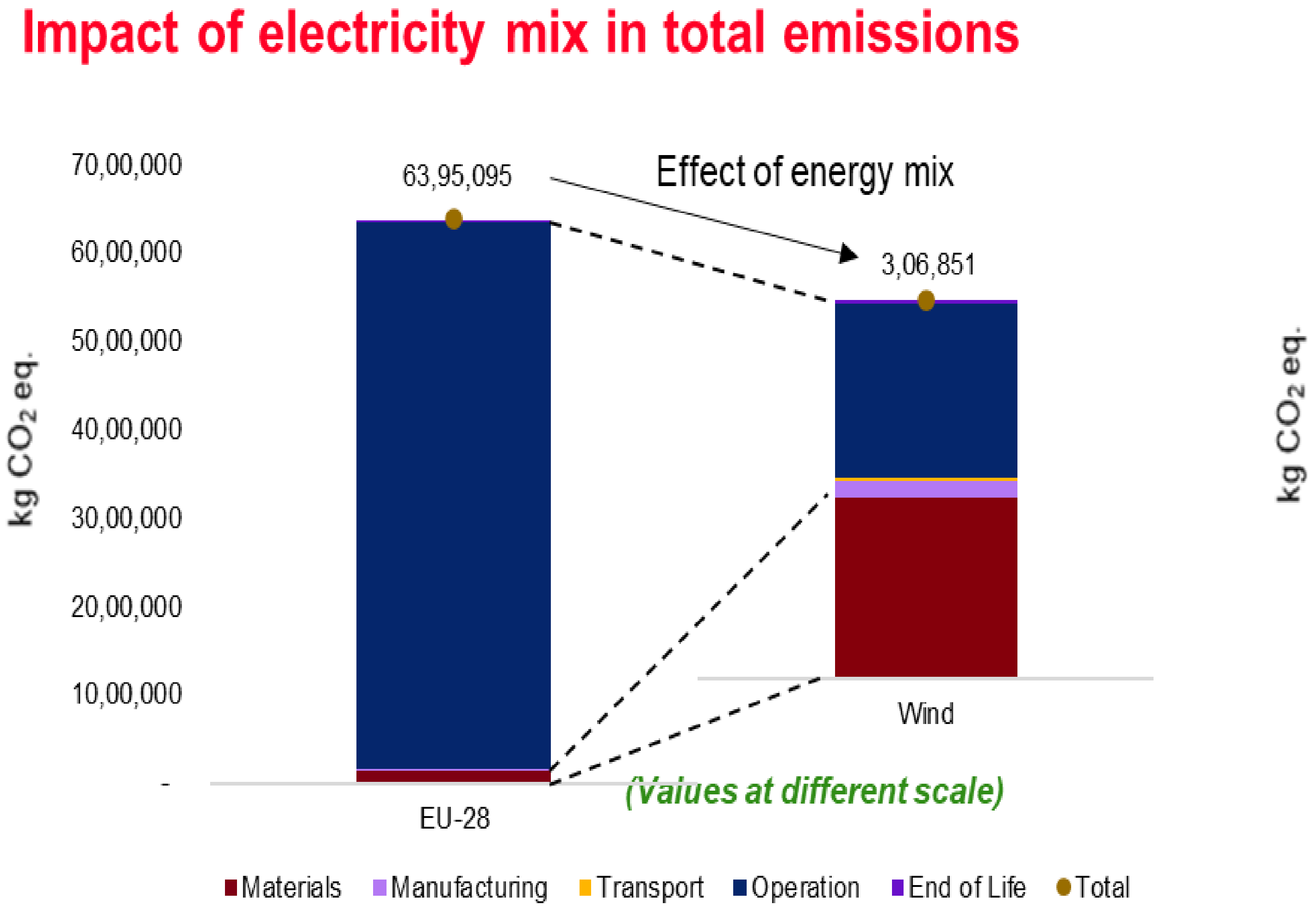
- Optimization should be done based on application, electricity mix, loading profile and material usage

- Considering environmental impact and future grid generation mix (added renewable sources) will change the optimization



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Decarbonization: Partnering for energy efficiency

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"

Switching to energy-efficient transformers brings significant economic and environmental benefits for governments, businesses and consumers

United for Efficiency (U4E) from United Nations Environment Programme

U4E UN environment programme
United for Efficiency

Actively driving higher energy efficiency standards in transformers

IEEE Advancing Technology for Humanity

CENELEC

cigré FOR POWER SYSTEMS EXPERTS

IEC

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Sustainability in Transformers - Value Proposition

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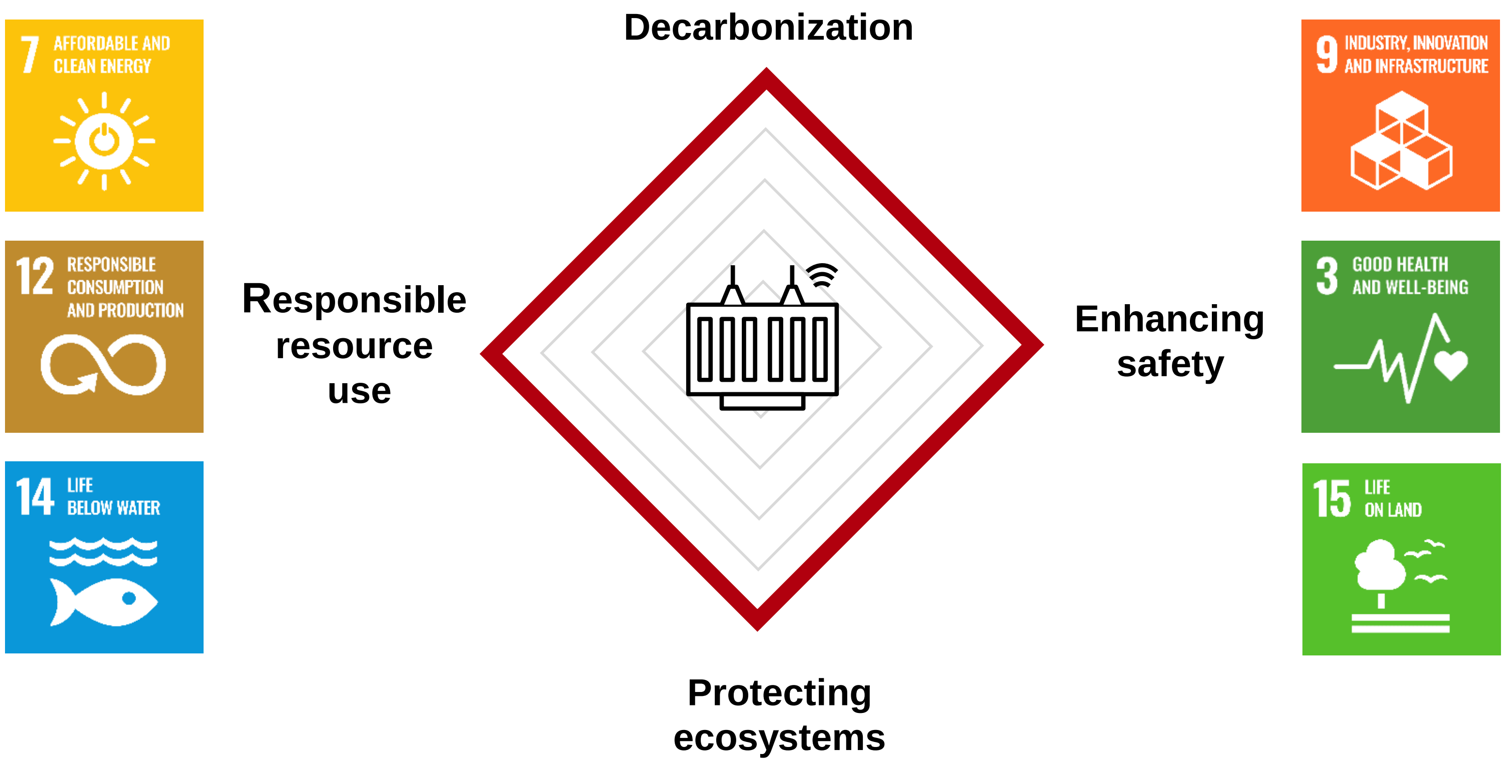
Electrical Grids and Industries operate in increasingly complex business and social environment

- Improve safety for people and reduce risk for equipment
- New equipment efficiency standards
- Emission control and regulations
- Renewable government mandates
- Required investment in new equipment
- Corporate image, sustainability goals

Creating more value with less impact



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EconiQ™ Transformers – Liquid Filled

Customized solutions co-created for your needs	Finding together the **best balance among material usage and efficiency** considering energy mix, application and surrounding ecosystem
Transparent sustainability performance	Transparency on Environmental **Life Cycle Performance** to guide sustainability optimization and enable co-creation

A portfolio of solutions for enhanced sustainability performance

Reduced carbon footprint over the life cycle	Manufactured with **fossil-free electricity in our factories** Reduction in carbon emissions from TCO **optimized solutions for losses** or from material usage, with quantified sustainability benefits
Ecosystem protection Enhanced safety	**Biodegradable and higher flash point fluids**, reducing impacts of eutrophication, fresh- water toxicity and minimizing fire hazards.
Responsible use of resources	Following **stringent regulations** for our materials **Disassembly manual** at delivery of the transformers, with **guidance for recycling and waste disposal**

EconiQ™ - Ester Fluids

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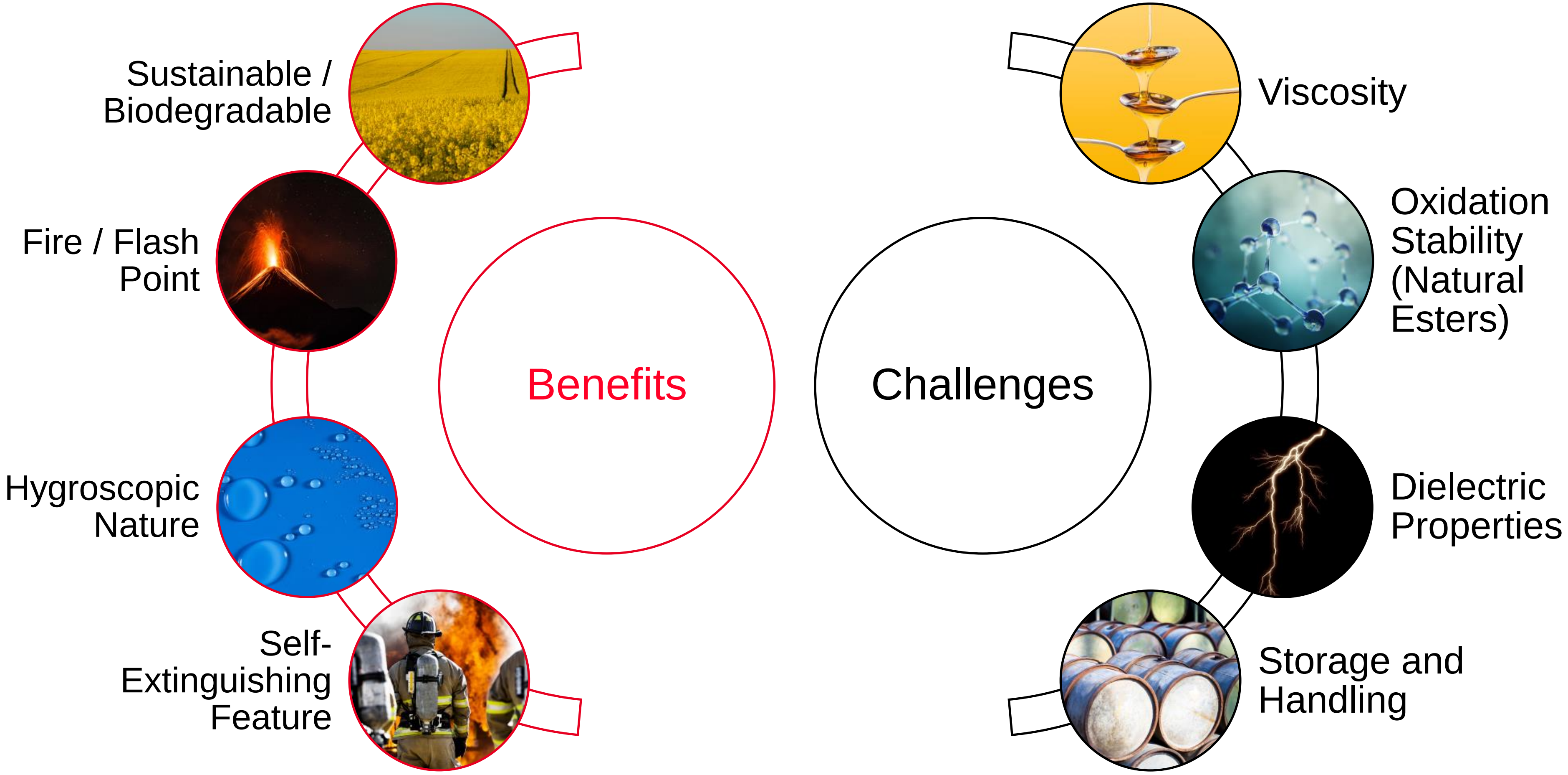

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EconiQ™ - Ester Fluids Benefits

Economical

- Reduced or delayed investments
- Reduced maintenance costs
- Higher revenues (Overloadability)
- Reduced risk of environmental fines

Social

- Less flammable
- Reduced risk of explosion
- Longer life expectancy
- Overloadability

Ecological

- Renewable sources
- Biodegradability
- Non-toxic waste
- Low carbon-footprint

EconiQ™ - Ester Fluids Design Considerations

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Dielectric and Thermal Design

- Dielectric design verification through simulations software is must as the development of flash over is faster in ester oil at lower stress levels
- Established design rules for Thermal calculations and analysis considering viscosity factor of ester fluids is required

Ensuring Compatibility of all materials used

- Most common materials used in transformers (copper, steel, aluminum, cellulose, etc.) are compatible with ester fluids.
- However, some rubbers may not be compatible with some ester fluids.

Natural Ester fluids exhibit poor stability to oxidation.

- Requirement to provide Sealed Nitrogen Blanket or Constant Oil Pressure System with a bag (COPS).
- limiting exposure to the atmosphere

Higher viscosity of Ester oils compared to mineral oil.

- Slower rate of impregnation of cellulose - Improper impregnation can generate partial discharges
- Adequate rules for impregnation process

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EconiQ™ Transformers – Track Record

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Over
209 ester-filled power transformers[1]
installed in
21 countries

More than
10,500 MVA
delivered with a total of over
950 years
in-service

Plus, over **65,000** ester-filled distribution transformers[2]

Biodegradable[3]

Reduced fire risk[4]

Longer lifetime
due to ~10˚C higher operating temperature and an increased overload capability

Footprint and cost reduction
with no need for fire walls and

Tested up to **420 kV/BIL 1425 kV**

[1] Greater than 25 MVA or 72.5 kV
[2] 10,000+ units ≤ 5MVA & Um ≤ 36.5 kV, 2,000+ units ≤ 25MVA & Um ≤ 72.5 kV
[3] As designated by the Environmental Protection Agency
[4] 360˚C fire point and self extinguishing

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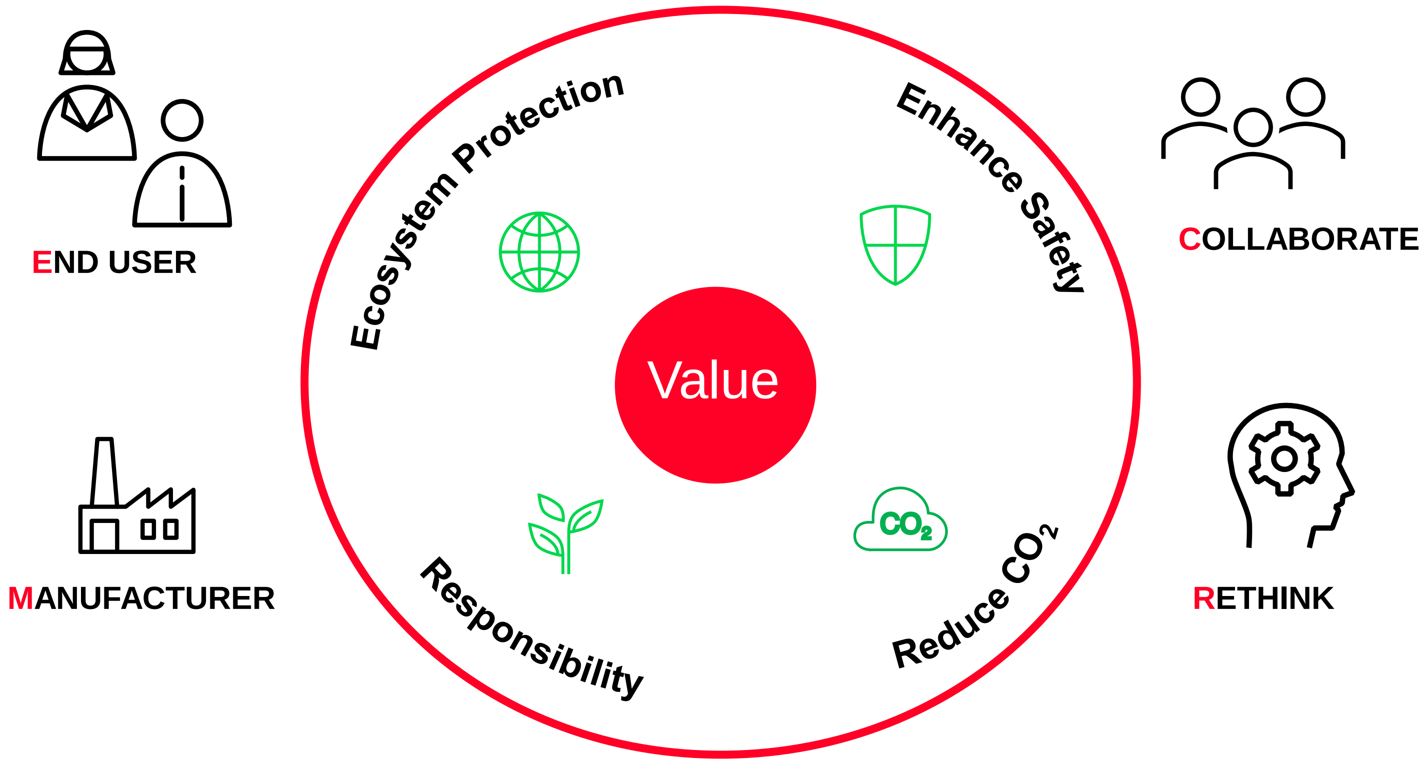
LCA – The importance of Co-Creation



Valuable approach in developing sustainable transformers!

EconiQ™ - Responsible use of resources over the entire lifecycle

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Material Compliance

Full global compliance to all local, regional and global legislations (environmental, material and product) by all suppliers and supplied products

- REACH
- Conflict Minerals
- Substances of Concern in Products (SCIP)
- Cobalt Policy…

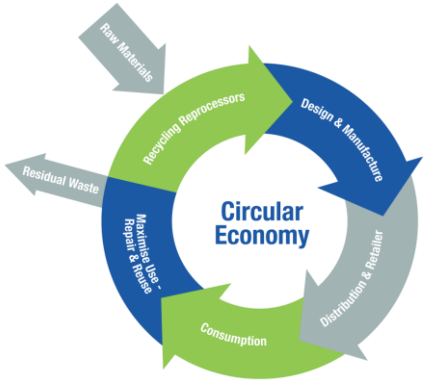
Sustainable Supply Chain

Supplier Sustainability Development Program

Reduction of carbon footprint of main materials, steel, aluminum and copper.(in progress)

Ecovadis Sustainability Assessment - one of the world's largest & most trusted provider of business sustainability ratings

Disassembly and recycling Manuals



Increasing demand in the market of disassembly instructions and guidelines for end-of-life recycling and disposal.

Our Commitment is to provide with EconiQ transformers (in progress)

- Provide safe instructions for disassembly.
- Guidelines for recycling and disposal of materials.

Approved suppliers for use of recycled mineral oil for new transformers

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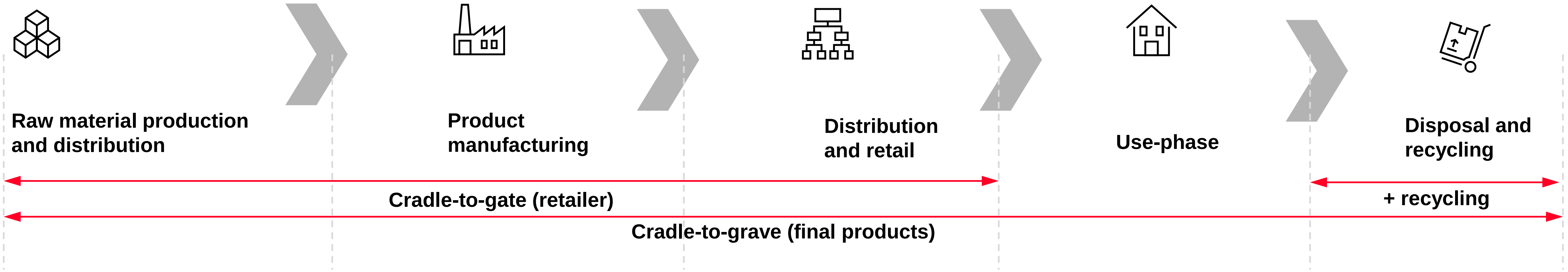
Quantifies the environmental impact of a product or a system during life-cycle stages from cradle-to-gate, cradle-to-grave and other scenarios

Standard Methodology,

Inhouse tools, expertise and data

According to **ISO 14040 & 14044 and / or ISO 14067**

Modeling the transformer life cycle, data from internal and external approved sources (energy data from our factories, data from suppliers, scientific databases), standard LCA software programs



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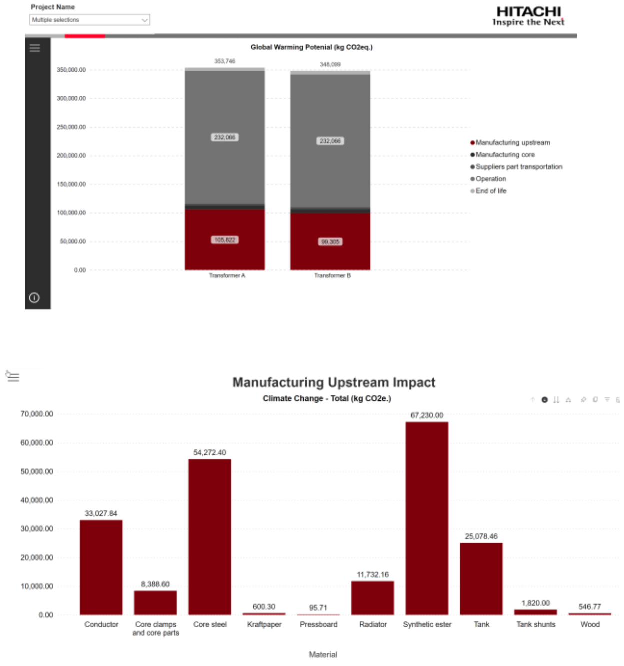
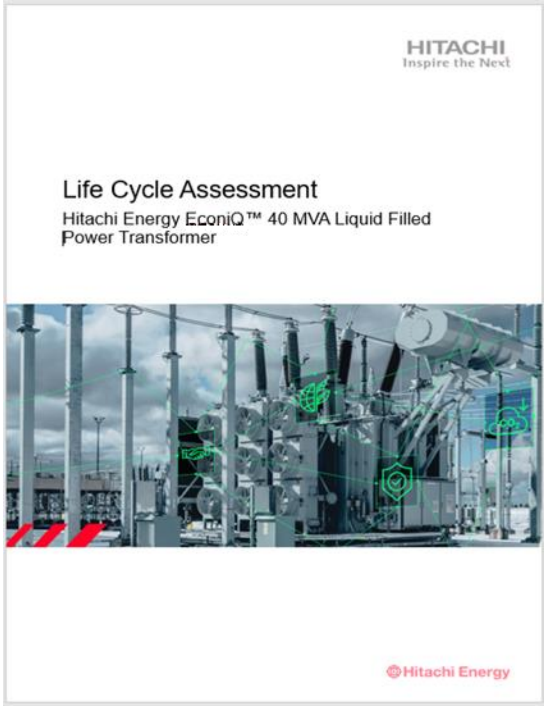
EconiQ™ - Transformer’s life cycle environmental impacts

From preliminary to detailed and 3rd party verified studies and declarations

Standardized → *On-demand*

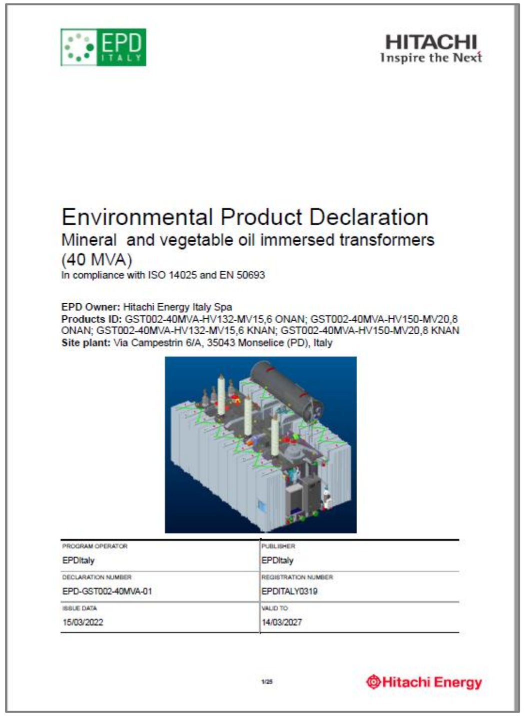


Environment impact /Carbon footprint calculator tool – a good and preliminary estimation



Detailed LCA[1] studies with LCA software tools based on methodologies aligned with ISO standards.

Product Carbon Footprint – derived from LCA study including PCR[2], third party verified



EPD[3] – derived from LCA study, including PCR, third party verified, available on EPD operator website

LCA: Life Cycle Assessment ; PCR: Product Category Rules ; EPD: Environmental Product Declaration

How can EconiQ™ support you on your sustainability journey

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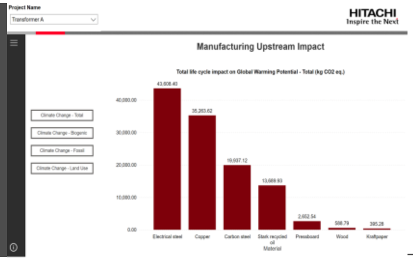
COMING SOON

(Online) Total Cost of Ownership (TCO) Tool

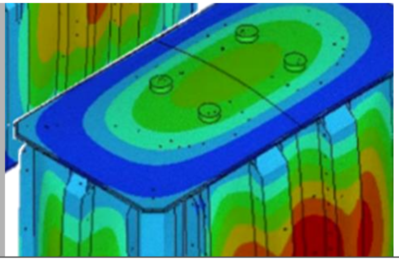
Comparing many transformers on TCO, energy losses, operational CO_2 emissions, payback time by considering impacts of carbon costs, changes in grid carbon intensity over lifetime…

Inhouse Life-cycle Impact Assessment (LCA) Tool



Preliminary & full-scale assessments of life-cycle environmental impacts, carbon fooprint at tendering and engineering stages

Advanced Design & Simulation Tools



Design for product sustainability: Optimizing resource, energy and material efficiency
Design for manufacturing sustainability: energy efficiency, reducing environmental impacts, enhancing health & safety
(Today: 100% CO_2-Free electricity in all factories)

Operational Lifetime Optimization

Condition assessment & diagnostics – Transformer and components

Digital solutions for retrofit - TXpert offering

Life extension solutions - Quantification of life-cycle environmental / carbon impacts & benefits

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Sustainability
Report 2023
Fiscal 2022 Results
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Hitachi Energy rated among top 5% of most sustainable companies

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TXpert™ Ecosystem

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TXpert™ Ecosystem overview

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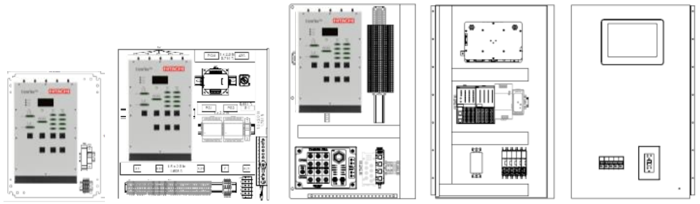
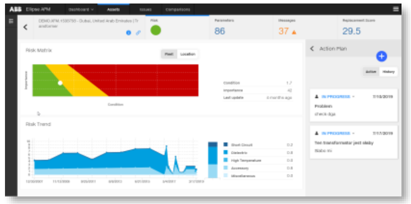


TXpert™ Hub
Transformer Monitoring System
powered by CoreTec
DRY | DTR | PT

Lumada APM
Asset Performance Management
Edge | On-premise | Cloud



TXpert Ready Sensors

Temperature,

Dissolved gases,

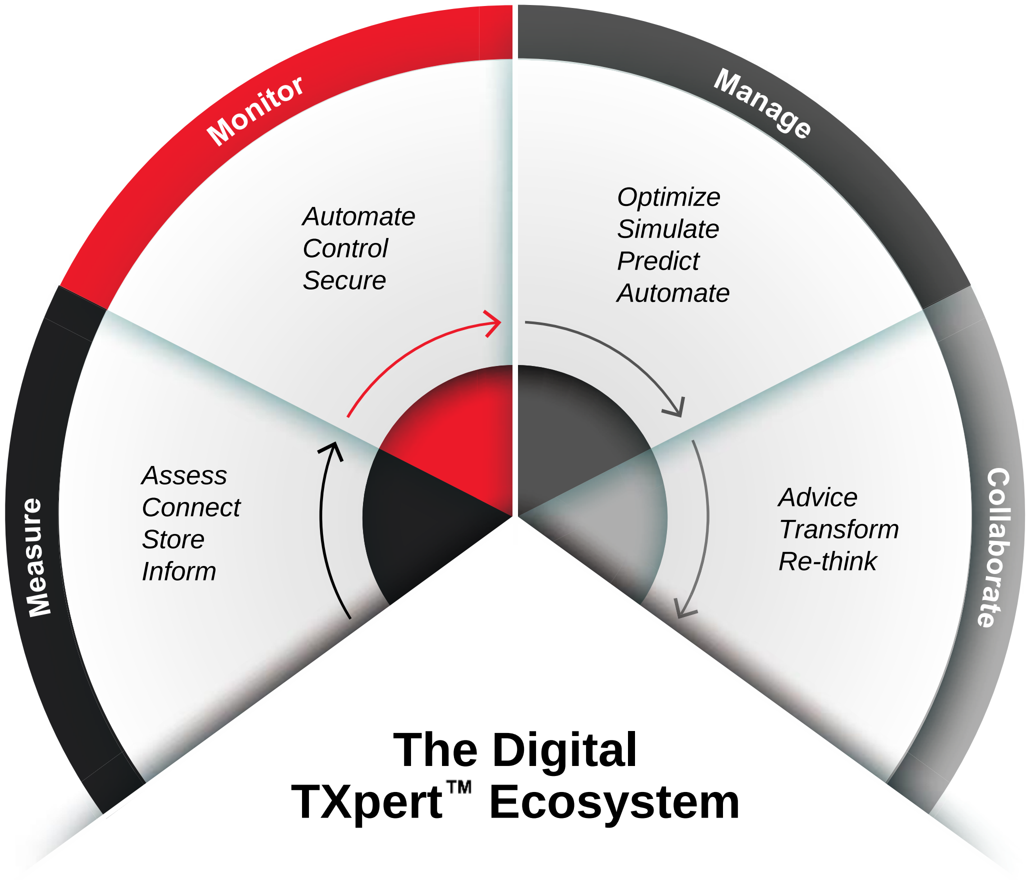
Power quality,

Partial discharges,

Bushing Tan-delta,

tap changer contact wear,

And more…



TXpert Services

Transformer Care
Service Agreements

TXpert OnDemand
Device hire

And more…

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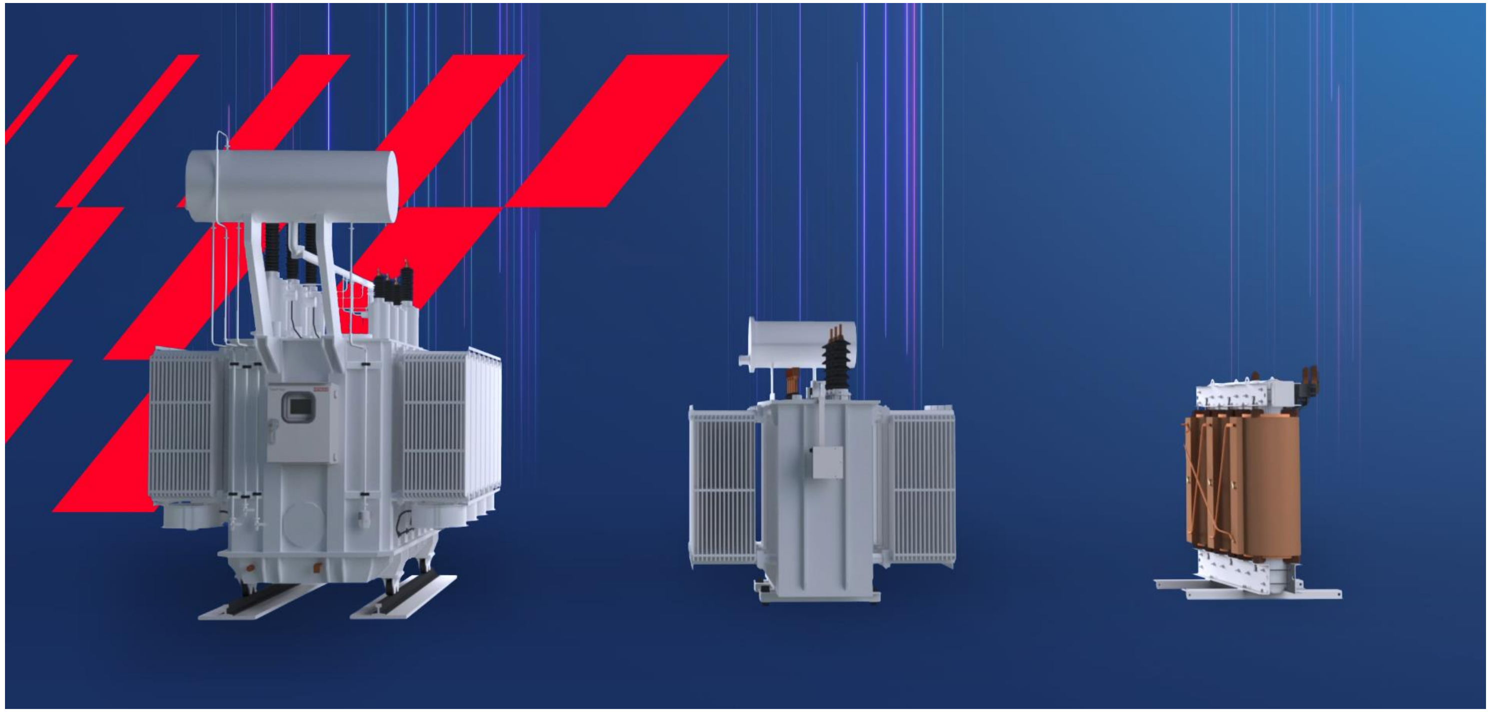
TXpert^{TM} HUB

Solution for Transformer Operators

TXpert Enabled Transformer (new or old)



Integrated in an existing control cabinet or stand-alone:

- Unified approach for distribution oil, dry and power transformers
- Multi-vendor open system
- Remote monitoring
- Cyber secure

TXpert™ Ecosystem-CoreTec: more sustainable, flexible and secure

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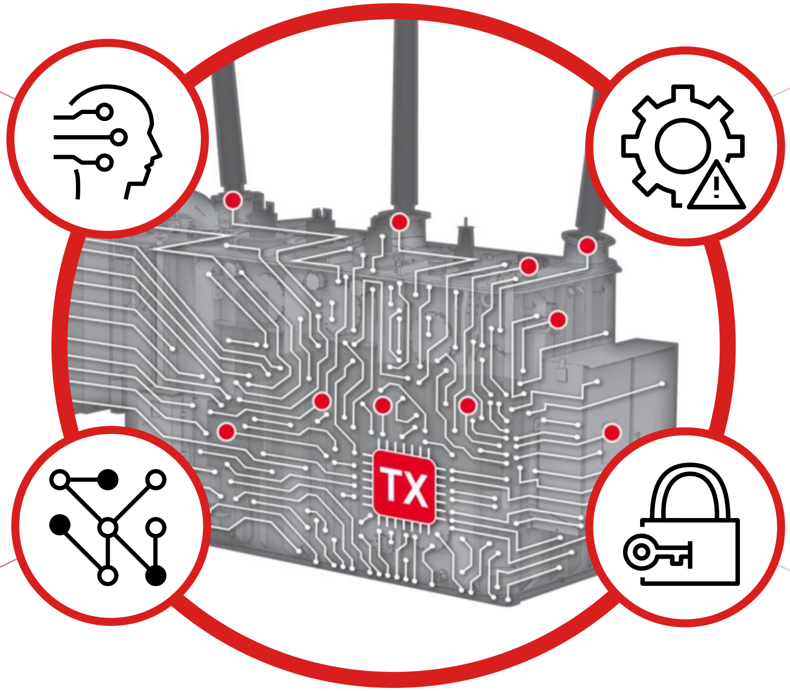

Hub of the TXpert™ Ecosystem

Actionable intelligence to increase asset life and operational performance

Remote Monitoring

Removes the need to visit the transformer on a routine basis

Fully customizable

Vendor agnostic, scalable and configurable to almost all transformer models, new or old

Cyber-secure

Higher level of protection with 3rd party certification for IEC62443-4-2 and compliance with IEEE1686

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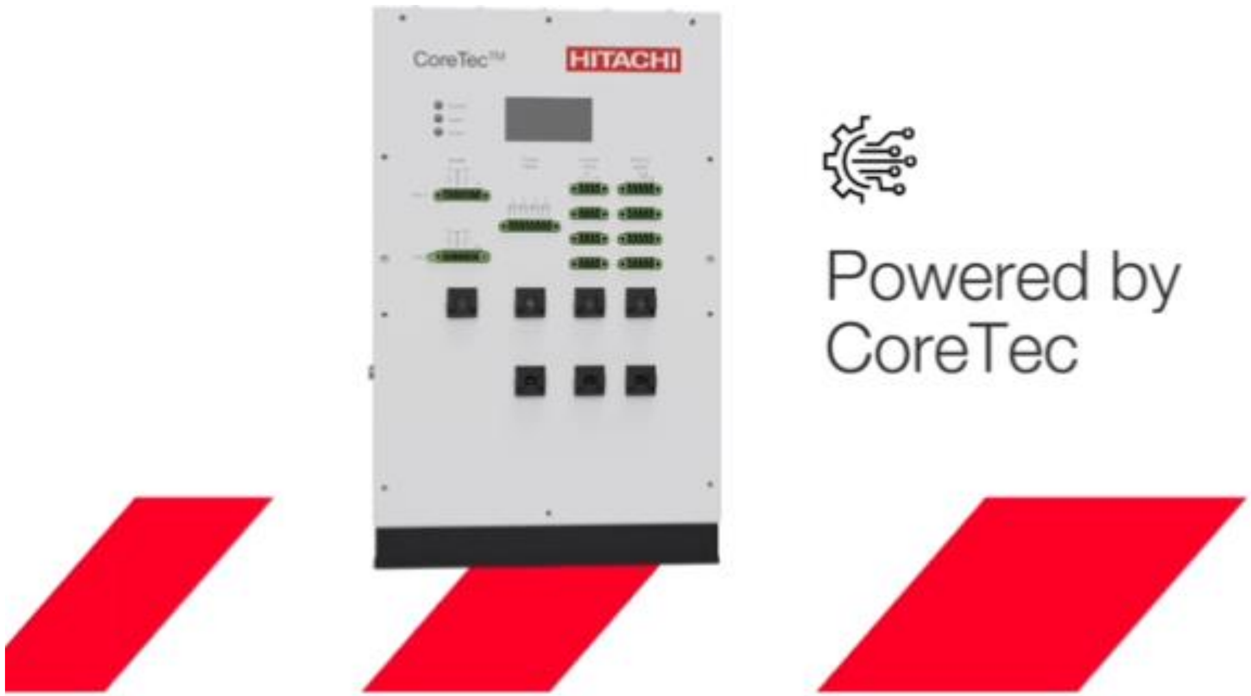
CoreTec™, TXpert™ Hub – Transformer Monitoring Platform



Solutions

- Hotspot & Aging Models (IEC60076-7 or IEEE C57.91-2011)
- Load Ratio
- Overload Capability Model
- DGA & Moisture Integration and Analysis
- Bushing Monitoring (Capacitance, Tanδ,Partial Discharge)
- Cooling Efficiency&Control
- OLTC Monitoring
- OLTC Contact Wear Calculation

TXpert™ Ready Sensors

TXpert^{TM} Ecosystem

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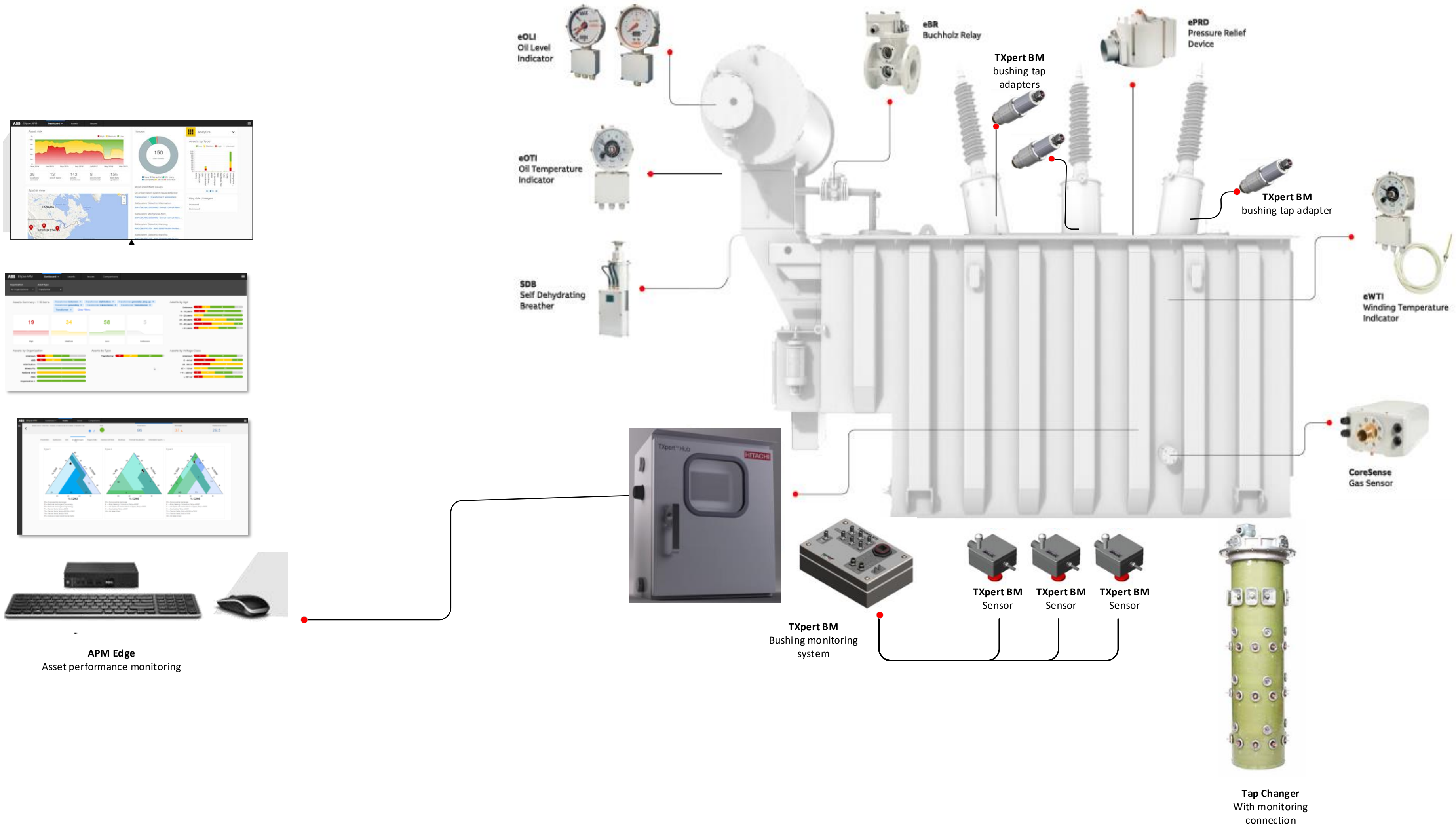
TXpert^{TM} solutions using TXpert^{TM} ready smart components



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CoreSense™ – hydrogen & moisture sensor

Engineered simplicity & robustness

Flag incipient faults

Hydrogen and moisture in oil are important indicators that can alert you to a developing condition. These indicators will not give you a precise diagnostic of the underlying condition, rather indication that something is happening in the transformer.

No moving parts, no consumables

Robustness was a key design parameter during the product development process. We eliminated weak points such as the membrane that separates dissolved gas from oil and removed consumables. To ensure oil circulation we implemented a forced convection thermal pump with no moving parts.

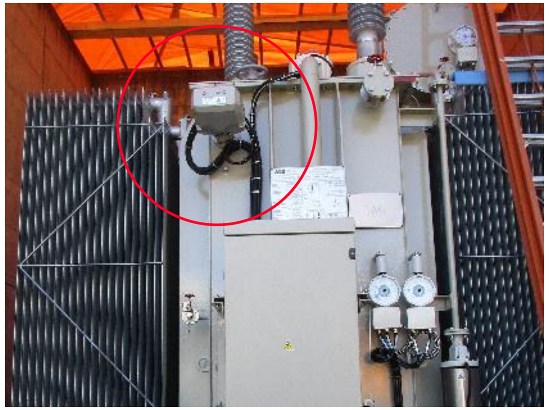
Universal oil support

DGA for mineral oils, ester fluids and silicon fluids supported with correct alarm settings for each type of oil

Public

CoreSense™ – hydrogen & moisture sensor

Installation – versatility



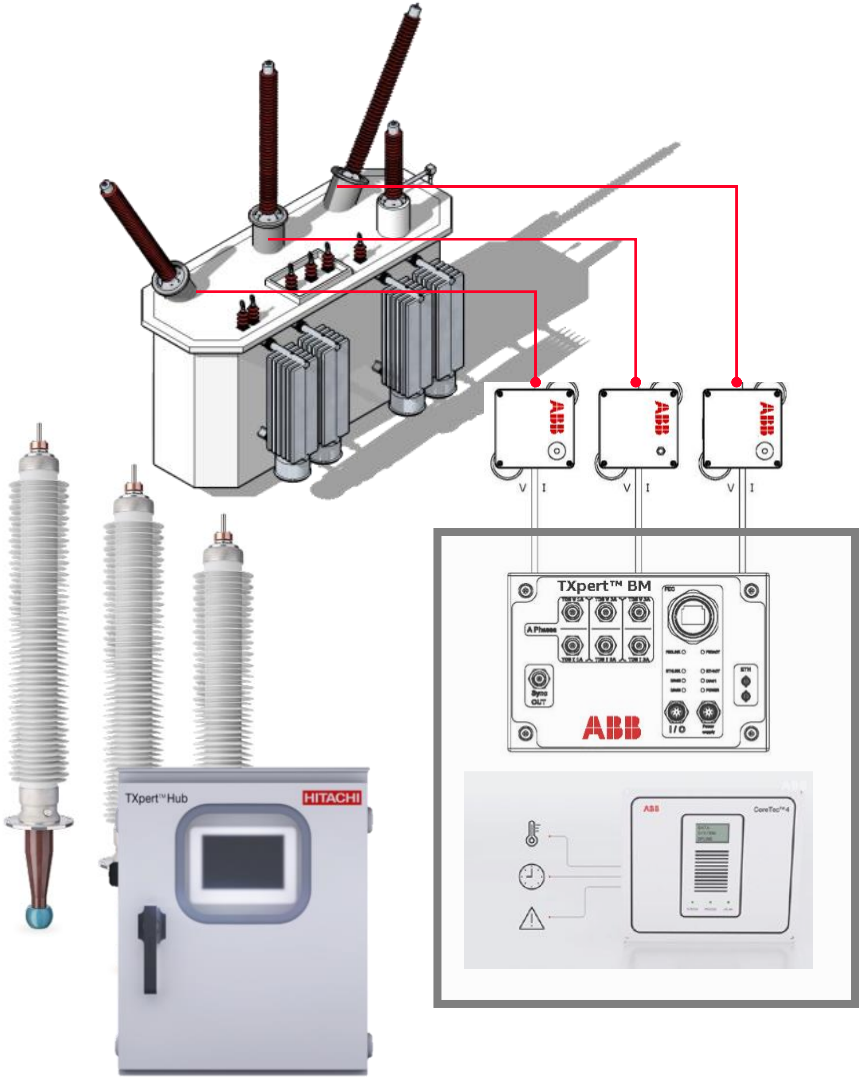
Public

TXpert™ BM bushing monitoring solution

Details

- Support 3 or 6 bushing
- CoreTec is designed to monitor the vital signs for transformer bushings:
  - Capacitance
  - Dissipation factor
  - Leakage current
- CoreTec support both the industry standard sum of currents algorithms as well as the advanced voltage reference method

TX BM custom tap adaptor and TX BM sensor



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TXpert™ Cooling Control

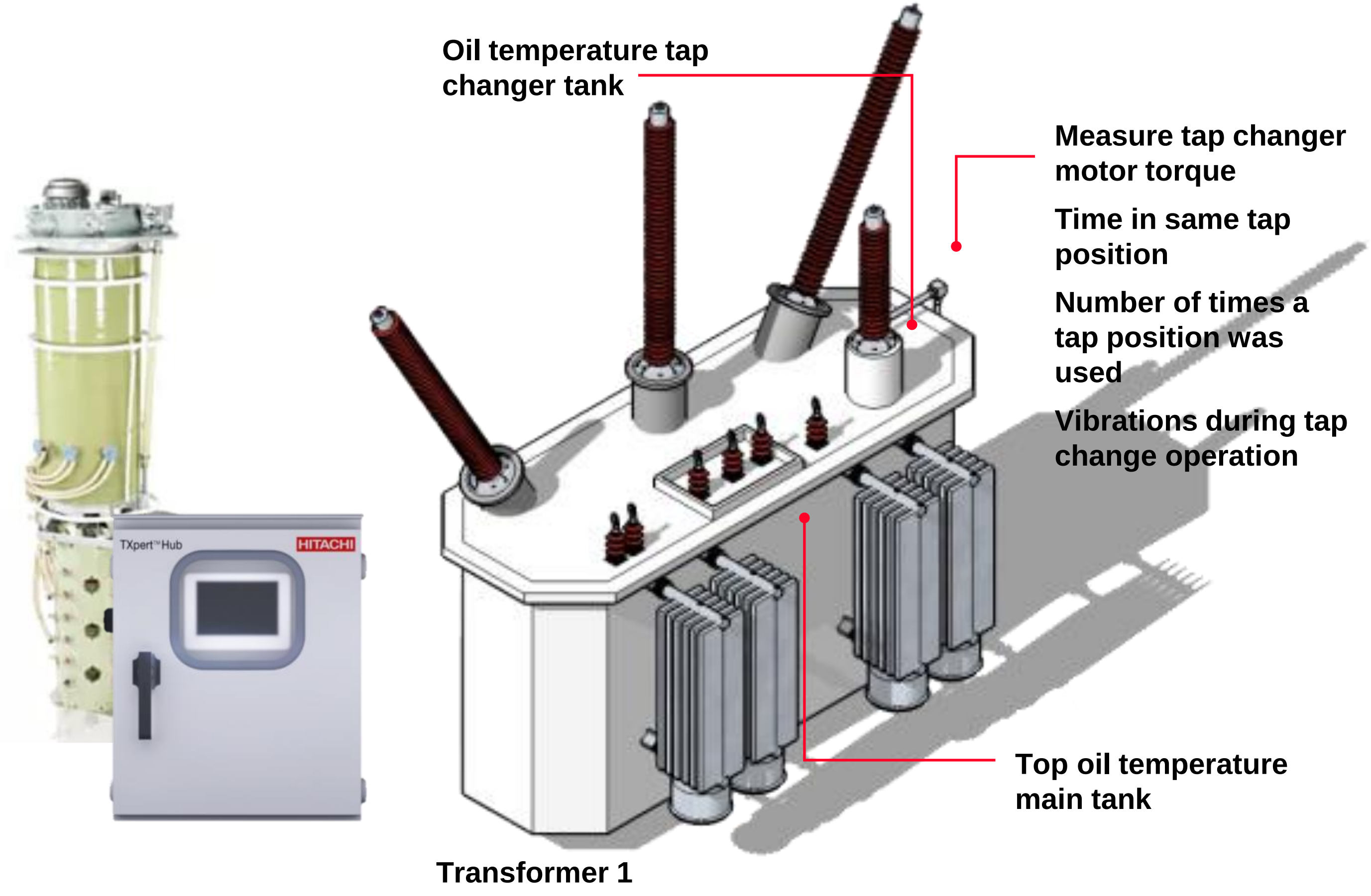
Details

- CoreTec uses thermal and electrical data to calculate cooling demand and control the fans and/or pumps based on that demand
- Cooling demand logic is based on IEC 354 1991-09 and IEEE Std C57.91-1995 Standards
- Requires top oil, ambient temperatures and load
- Option: Monitor the status of the cooling stages through digital inputs
- Algorithm provides
  - Automatic reduction of short on-off cycles
  - Independant control of up to 6 cooling banks
  - Automatics bank rotation for even wear
  - Automatic excercising of unused cooling banks
  - Tracking of total run time for maintenance recomendations
- Fail-safe installation turns on cooling banks if digital control fails

TXpert™ Tap Changer Monitoring Solution

Details

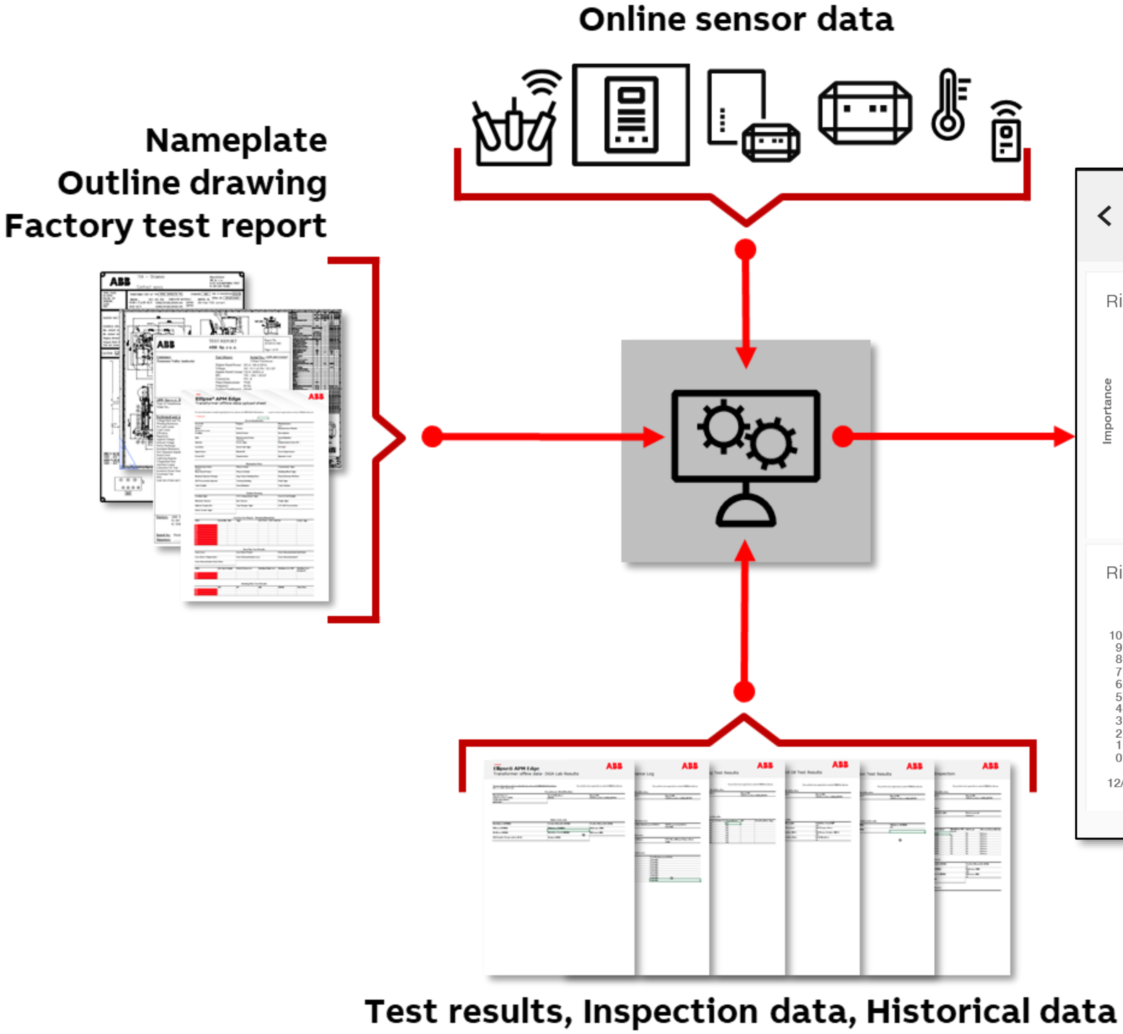
- Tap changer failure cover most important percentage of transformer faults
- Temperature in Tap Changer tank
- Tap position, number of operation, duration of tap switch
- Motor drive current
- Contac wear for ABB/Hitachi Tap Changer
- DGA on Tap Changer tank
- Results are shown in a dashboard

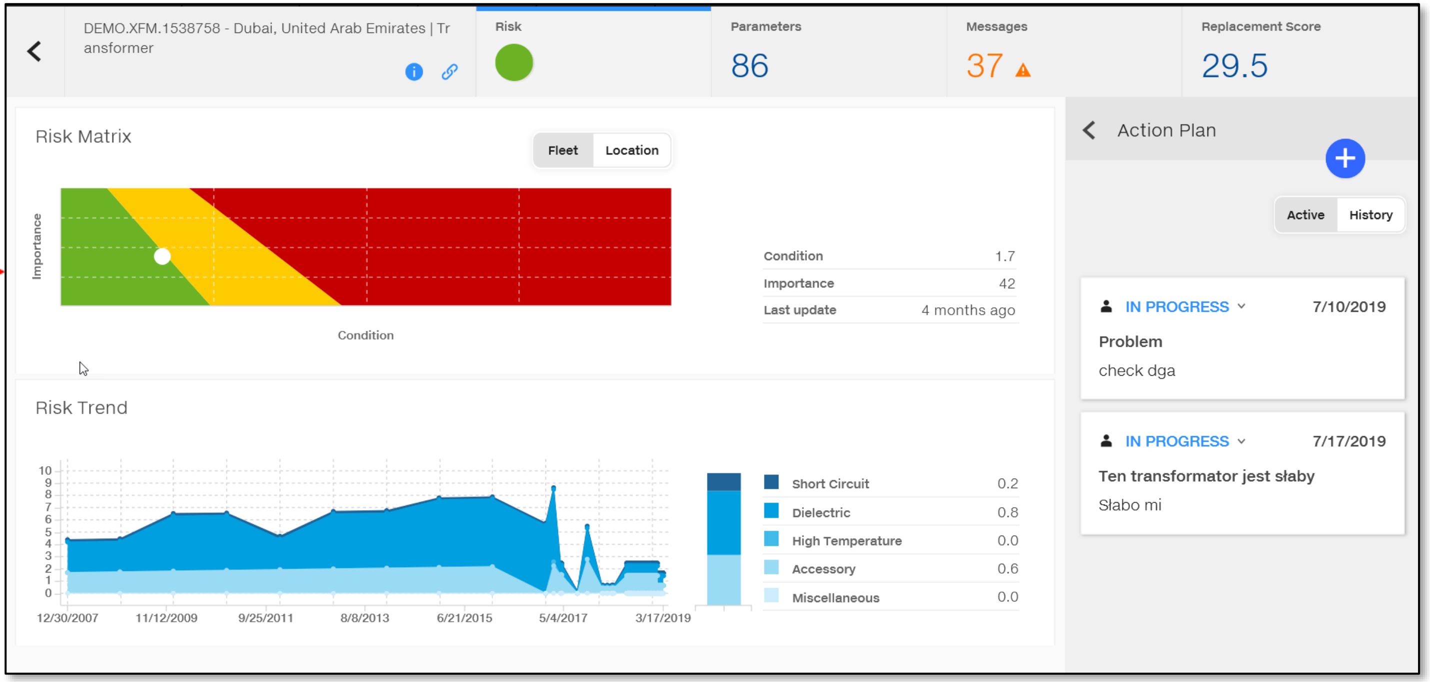


APM Edge

Powered by Lumada APM

Fleet Management using TXpert™ APM Edge





Probability of failure & Risk Assessment
Expert Recommendations

APM Edge - Asset Management Solution

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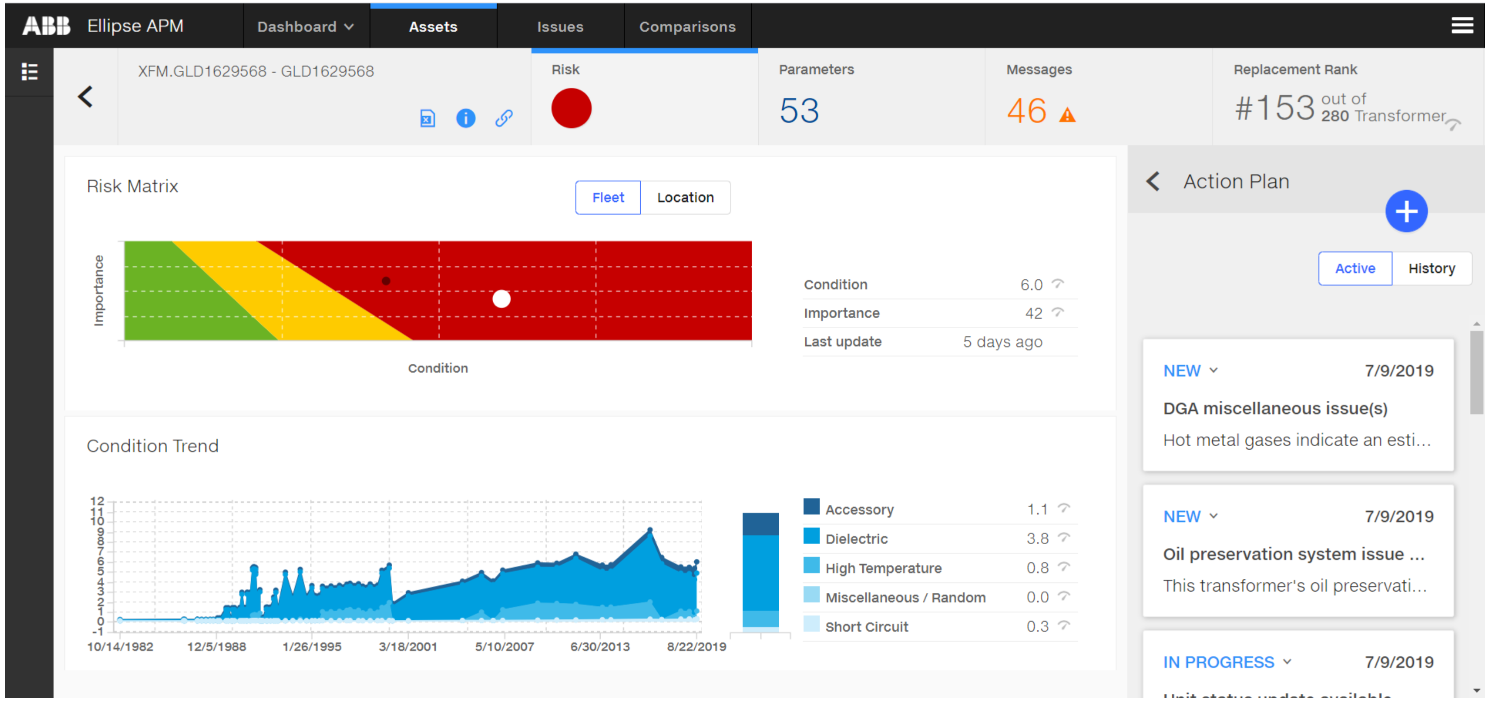
What will you get?

- Connect/Collect all data from transformers
- Analyze/Predict of the data
- Inform/Prescribe
- Act

Why APM Edge?

- Increases transformer reliability by identifying, prioritizing and resolving risks before materialize
- Flexible- a quick and simple way to esablish a scalable asset performance management solution that grows with you
- Reduces capital expenditures by getting longer economical life from existing assets
- Increased efficiency and storage of online and offline data



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Rupture Resistant Tank

TXpand™

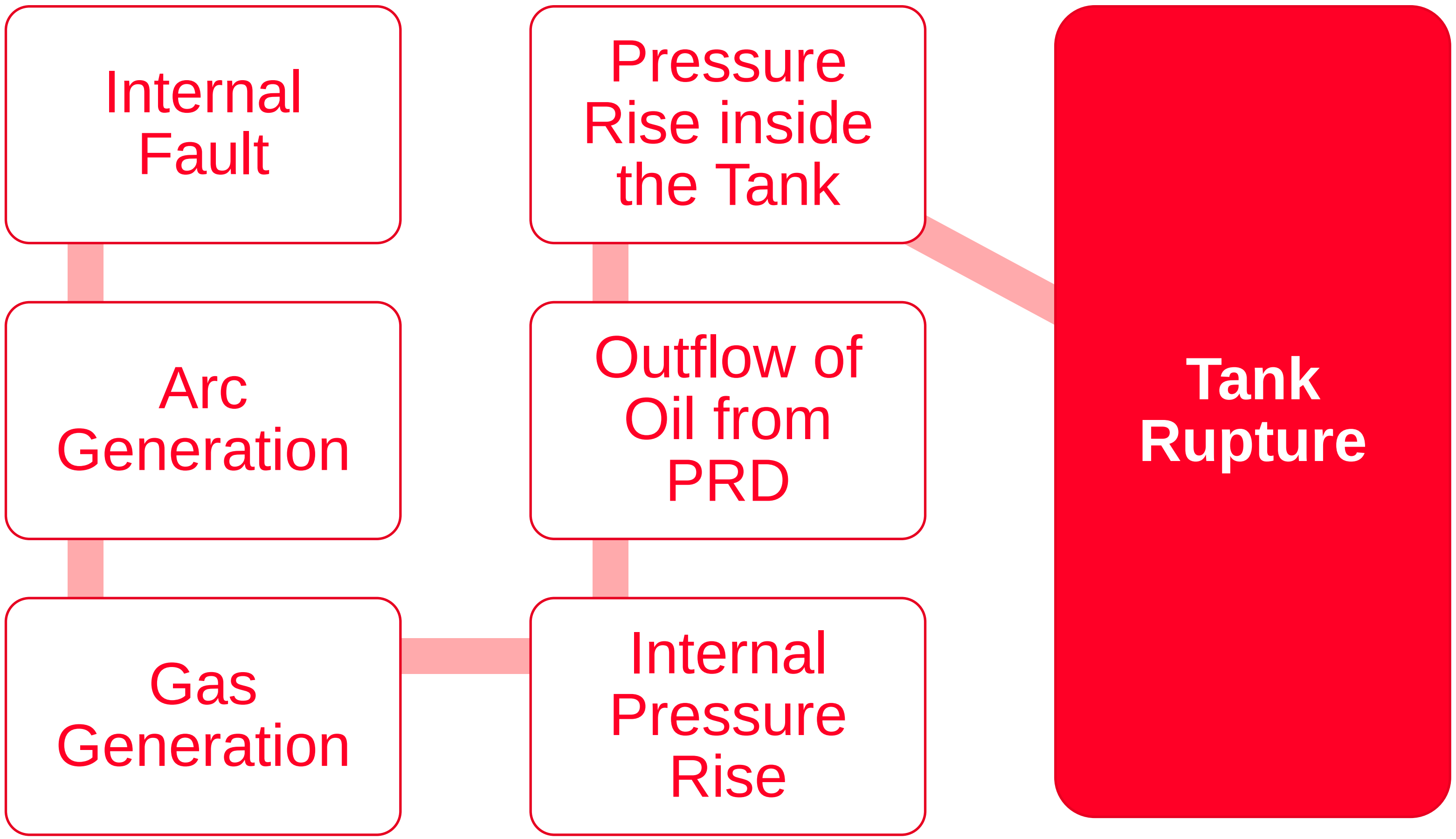
Tank Rupture Process

Tank Rupture depends on:

Arc parameters and location

Transformer tank features and associated structural weaknesses like:

- Bolted / Welded joints
- Reinforcement beams, their shapes and locations
- Bushing turrets, Cable boxes etc.



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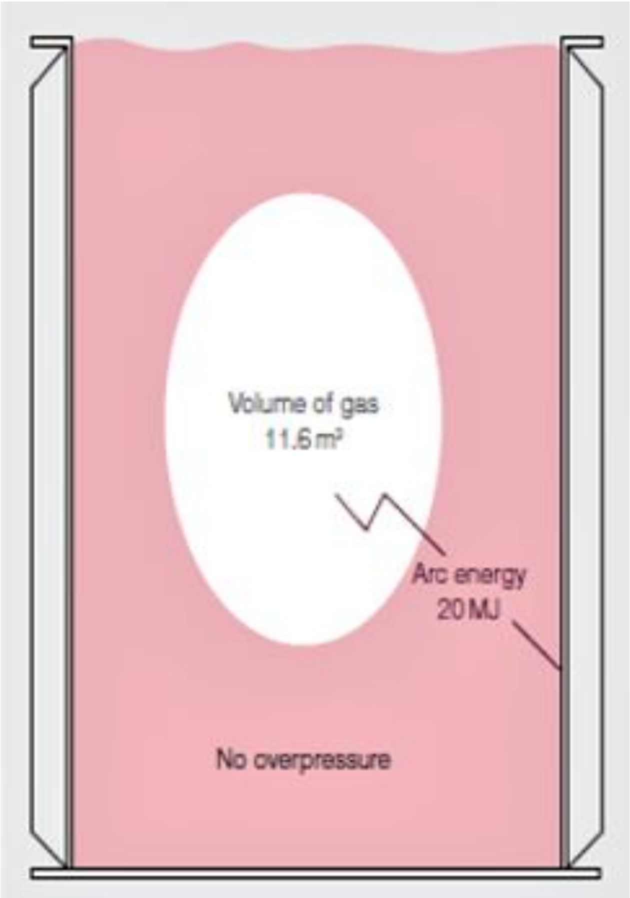
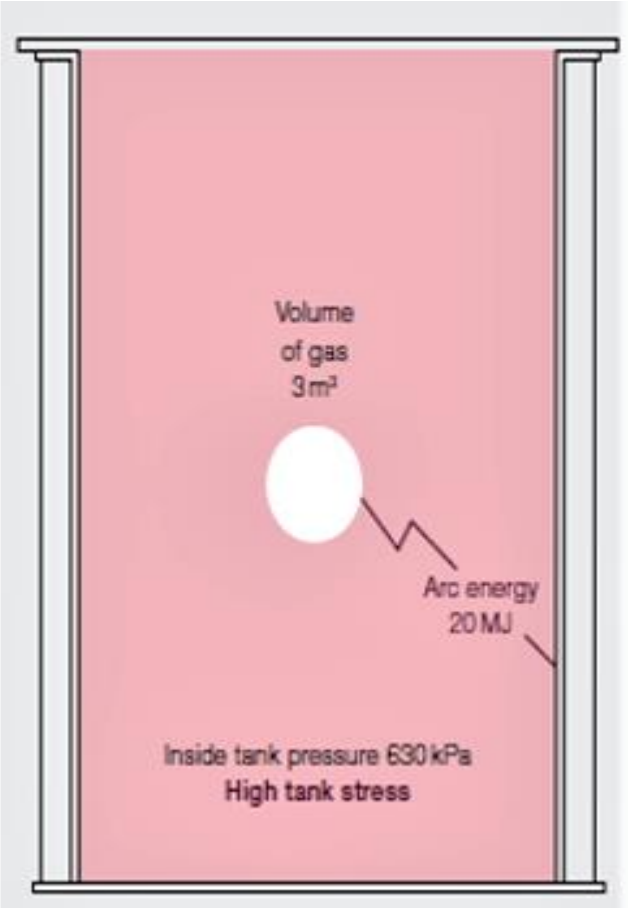
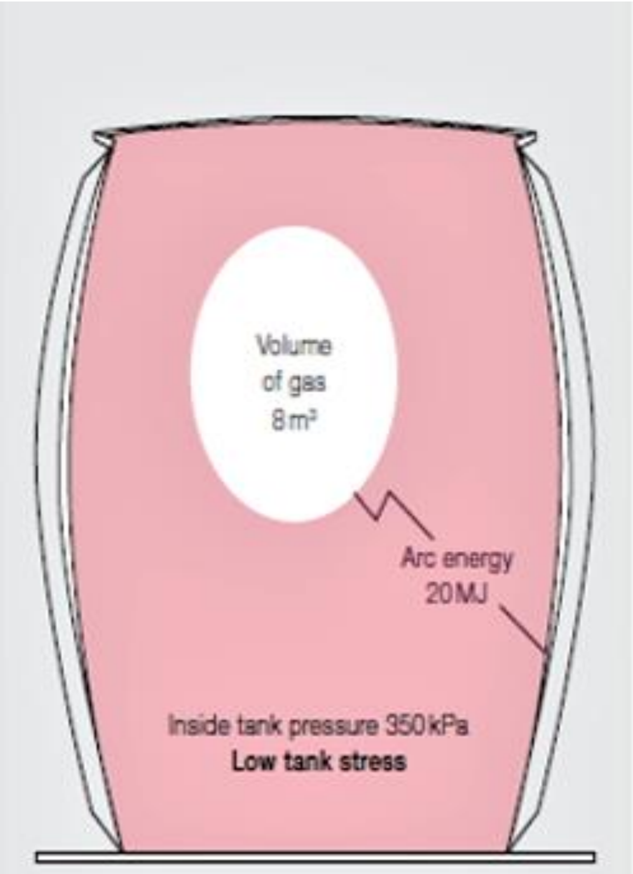
Open Top (Illustration)



Rigid Tank (Conventional)



Flexible Tank (Innovative)



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Rupture resistant tank concept - TXpand™

The combination of desired strength and flexibility is achieved by advanced engineering simulations, material selection and precise manufacturing process.

Absorb a certain arc energy in a deformation of the tank, designed to rupture above this energy level

↓

For safety reasons, the point of rupture is typically arranged to be at the edge of the cover, making dangerous ejections and major oil spills less likely

↓

Flexible tank solution is better than a pressure venting approach. Even a large venting area of 1~1.5 m2 would reduce the peak pressure by only 10~30% during an internal arcing fault an is insufficient to mitigate the tank rupture risk under normal circumstances

Design validation through Finite Element Analysis (FEA)

- **FEA includes nonlinear material properties, large deflection, proper element type and mesh size ensures reliability, accuracy and convergence of the results**
- **Stress, strain and displacement results are then analyzed by the team of experienced engineers**

TXpand™ Step 3: Beyond Tank - Rupture Resistant Turrets

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TXpand solution is now more comprehensive with special rupture resistant bushing turret design

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