Environmental life-cycle Assessments of Transformers – Why and How?

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Decarbonizing power sector: challenges and key levers

40% Contribution of power sector to energy related GHG emissions (2020)

50% Share of electricity in total energy use by 2050 (vs. 20% today)

2040 Achieving net zero in global power sector to align with 1.5°C path (and supporting transition of other sectors to net zero)

- Changing the electricity mix towards lower carbon and renewable power sources
- Reducing GHG emissions from T&D losses (e.g. lower operational energy losses of Transformers)
- Reducing remaining emissions from the value chain (e.g. lowering embedded carbon from materials manufacturing, construction of transformers)

Source: adapted from GHG Protocol and Carbon Accounting (corporatefinanceinstitute.com)
How could transformers support transition towards net zero

**GHG Scope 1 Emissions**

*Decarbonizing the electricity mix*

- Transformers for renewable energy systems
- Powerful transformers for grid interconnections (HVDC)
- Transformers for electrifying GHG intensive industrial sectors

**GHG Scope 2 Emissions**

*Reducing GHG Emissions from T&D losses*

- 98% Global average energy efficiency of transformers installed base
- 5% Of the global electrical energy is consumed by transformers losses

**GHG Scope 3 Emissions**

*Reducing remaining emissions from the value chain*

- 90% Of total transformer weight is related to few main materials: E-Steel, Steel, Copper, Aluminum, Insulation materials
- ~40-60% Of total life-cycle carbon footprint of transformers is from materials manufacturing (in case of electricity grids with very low GHG EF)

1. Reducing GHG intensity of electricity mix
2. Reducing Scope 2 + Scope 3 Emissions by design: challenge as lower NLL/LL leads typically to higher material use – an LCA perspective is key
Transformers and the energy transition
LCA informs decision-making for future-proof transformers

Environmental life-cycle analysis quantifies impact per life-cycle stage of a product or a system from cradle to gate, cradle to grave based on material and energy flows and impacts at each stage.

- Calculating product-level GHG scope 2 and scope 3 emissions (from new transformers, lifetime extension service scenarios)
- Assessing impacts of different design choices/parameters on life cycle climate & environmental performance
- Building a baseline on impacts and identifying “hot spots” as key levers for reducing life-cycle impacts

Standardized methodology
LCA standard: ISO 14040 & 14044
PCF standard: ISO 14067

Different type of declarations (towards 3rd verified PCF and EPD)

Informing Sustainability and climate strategy, targets and progress management

Strengthening credibility of sustainability (voluntary & mandatory) reporting (& avoiding greenwashing)

Providing solid data for ESG/Green Finance funding

Supporting policy-making on shaping effective product level environmental regulations (e.g. DOE 2027...
Life cycle analysis for transformers

How it works

Input data

General information about the transformer and application is needed:

1. Rated power
2. No load and Load Losses
3. Mean of transport (from the factory location to the customer site) and distance
5. Bill of Materials (covering >90% of total weight of the unit)

Tools, databases and user interfaces

Commercially available Life cycle analysis tools (to be customized for a specific product) and life cycle inventory databases:

- Customized
  - Product specific life cycle model
    (scope, system boundaries)

- Generic (secondary data from LCA databases)
  - Life cycle inventories database
    (materials, transportation, manufacturing impacts, electricity-mix...)

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Reference standards and methodologies

- General guidance: EN 50693:2019 Product category rules for life cycle assessments of electronic and electrical products and systems (on Power Transformers)
**Life cycle carbon analysis for transformers – Insights**

**Case of a 630 kVA Liquid Filled Distribution Transformer, Mineral Oil**

Impact of the electricity-mix on share of scope 2 vs. scope 3 and life-cycle GHG emissions

US Electricity Mix

- 100% Wind: 17 tCO2/Lifetime
- 100% Wind: 290 tCO2/Lifetime

**Materials & Manufacturing**

- Transportation to customer site
- Operation
- End of Life

**Case of a 40 MVA Power Transformer, 132/15.6 kV**

Impact of energy losses on life cycle GHG emissions (Kg CO2e) for 35 years lifetime, US electricity mix)

- 40MVA, 150/20.8 kV, ONAN - Mineral Oil (Reduced Energy Losses): 20,000,000

**Impact of fluid choice on life cycle GHG emissions (Kg CO2e) for 35 years lifetime, US electricity mix)**

- 40MVA, 132/15.6 kV, ONAN - Mineral Oil (Standard Energy Losses): 22,000,000
- 40MVA, 132/15.6 kV, KNAN - Natural Ester (Standard Energy Losses): 21,000,000

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**Impact of energy losses on life cycle GHG emissions (Kg CO2e) for 35 years lifetime, US electricity mix)**

- 40MVA, 132/15.6 kV, ONAN - Mineral Oil (Standard Energy Losses): 500 Metric tons CO2e
Life cycle analysis for transformers

A key tool for informing lifetime extension investments

- Defining and modeling service vs. baseline scenarios
- Quantifying impact of different service scenarios (vs. baseline) on Scope 2 & Scope 3 emissions, material use (& cost) savings/benefits

**Asset Condition Assessment**

**Service Scenarios Impacts (financial, environmental)**

**Service Strategy at Asset & Fleet Level**

Informed decisions on alternative scenarios to unit replacement: lifetime extension alternatives and their impacts on climate & sustainability priorities, targets
Why a TF on LCA/PCF of Transformers in IEEE

Particularly for transformers being energy- and material intensive, long-lasting products, a life cycle perspective on climate/environmental impact is key for best informed specifications and policy making driving implementing effective energy transition paths.

Existing LCA ISO standards and specific guidance for Liquid-filled Transformers

Similar initiatives in IEC (ongoing: TC 111/WG 15/17), CIGRE (starting: JWG1 N° A2/C3.70)

Leveraging references to further expanding scope (all transformer types, shunt reactors, components, services)

Adapting methodology to IEEE standards (energy efficiency, default values: load factor, lifetime...)
Thank you

Advancing a sustainable energy future for all

Hitachi Energy