TRANSFORMERS MAGAZINE'S
INDUSTRY NAVIGATOR

Measuring Transformer Life Cycle Impacts in Practice

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Hitachi Energy

AGENDA

- Why should we measure Transformer environmental life cycle impacts?
- How do we measure life cycle impacts: overview on our LCA & Carbon Footprint Tool
- From life cycle impacts to insights for optimizing your Transformer design
- Our offering: Integrating life-cycle impact assessment into tendering and engineering processes

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Why should we measure Transformer environmental life cycle impacts?

Better know your product

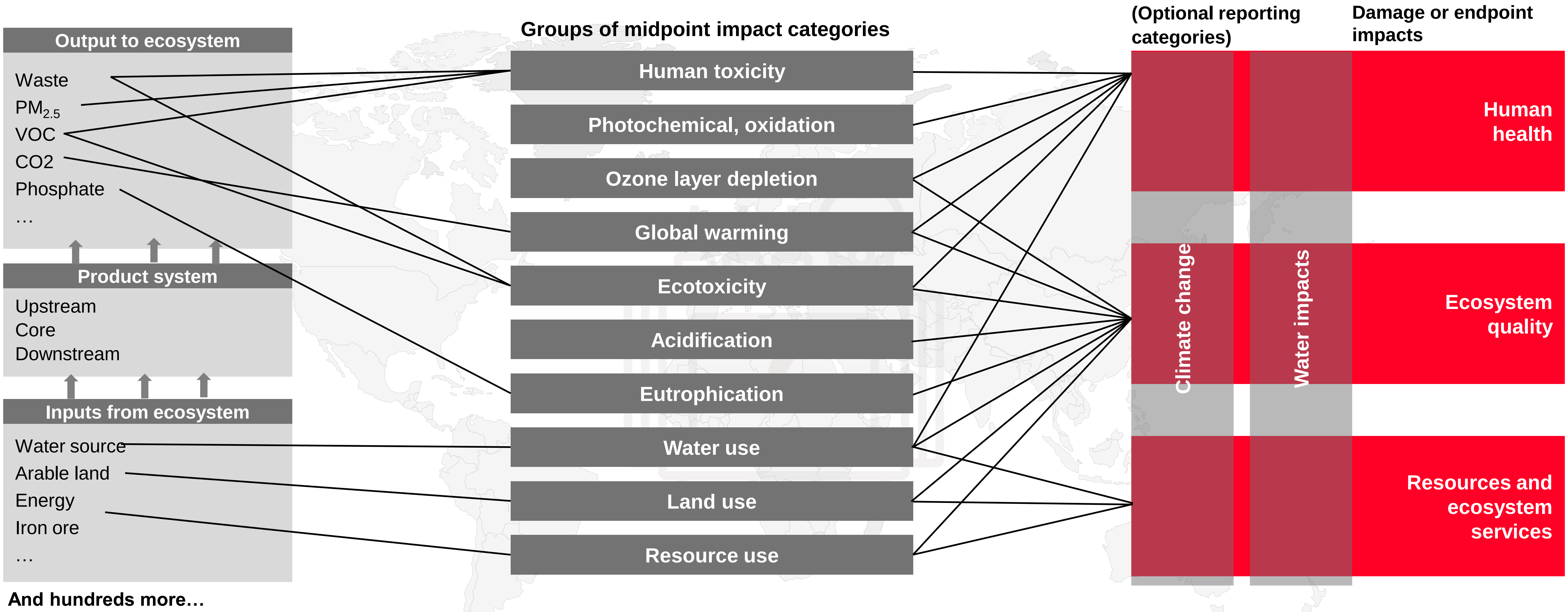
- Transformers are highly energy efficient devices, but no-load and on-load losses add up over their long life-time.
- They are also material-intensive, and all materials have an environmental impact (at materials extraction, processing, product use and end of operational life stage)
- Your transformers life-long operational performance, materials and components (BOM) decide its-
- Carbon emissions over life cycles
- Any potential health and safety issues
- Impacts on eco-systems
- Consumption and depletion of natural resources

Better know your product's impacts

Make informed decisions to-

- Ensure compliance with existing and upcoming product life-cycle related regulations
- Optimize your product specifications by assessing the life-cycle economic and environmental impact of different design options
- Identify impact areas for future improvements in your operations and supply chain (e.g., reducing carbon emissions)
- Strenghthen the credibility of your mandatory and voluntary sustainability reporting with quantitative and scientific data
- Identify co-creation and collaboration opportunities across your value chain for improving environmental value

Life cycle impact assessment: Typical environmental impact framework



The methodology and output impact categories of our environmental impact tool is aligned with the Transformer Product Category Rules of EPD International. Scope to customize if required.

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Environmental impact/Carbon footprint and TCO calculator: Input data (1/2)

1 *Enter transformer specifications & bill of materials*

1. Rated Power
2. Losses: no-load (P0), load (Pk)
3. Specify means and distance of transportation – suppliers to factories, and factory to customer site
4. Transformers components/materials mass
5. Transformer lifetime in years *(just select air, ship, rail or truck)*
6. Capacity utilization
7. Electricity mix carbon intensity [kg CO2eq/ KWhr]: *just select installation country*

General Information

1 Specification

Total mass (kg)	62'622
Rated power (MVA)	36
Losses P0 (kW)	15
Losses Pk (kW)	171
Mean of transport	Truck
Distance (km)	1'200

1 Operation phase/ Active phase

Lifetime (years)	40
Capacity (%)	30
Electricity mix*	EU - European Union (28)

*Choose the suitable energy mix from the table on the right (EU-28 is recommended for Europe)

Loss evaluation

P0 (€/kW)	
Pk (€/kW)	
Total transformer price (€)	-
Current carbon price (€/tonne CO2e)	50

1 Bill of Material

Core steel

	Mass (kg)	Distance (km)	Mean of transport
Core steel	20'874	9'000	Ship

Conductor

	Mass (kg)	Distance (km)	Mean of transport
Winding conductor (kg)	6'126	20	Truck

Insulation

Core insulation kit	Mass (kg)	Distance (km)	Mean of transport
Active part insulation kit - pressboard	326	1'200	Truck
Active part insulation kit - wood	364	65	Truck

Active part insulation kit	Mass (kg)	Distance (km)	Mean of transport
Winding insulation kit - kraftpaper	345	20	Truck

Oil

	Mass (kg)	Distance (km)	Mean of transport
Oil type	Midel 7131		
Oil (kg)	16'630	1'200	Truck

Inactive core parts

	Mass (kg)	Distance (km)	Mean of transport
Core inactive parts	2'046	400	Truck

Radiator

	Mass (kg)	Distance (km)	Mean of transport
Radiator	4'848	85	Truck

Tank, Cover, Conservator

	Mass (kg)	Distance (km)	Mean of transport
Tank	10'363	90	Truck
Tank shunts	700	1'800	Truck

LCA considerations

Consider biogenic CO2 capture	No *
Consider EOL credits	No

* Applicable just to natural esters (Midel eN 1204, 1215 and Cargill FR3)

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Environmental impact/Carbon footprint and TCO calculator: Input data (1/2)

2 ***Enter economic evaluation data***
(according to IEC standard: IEC TS 60076-20:2017)

1. Capitalization of no-load losses (A-Factor) & load losses (B-factor) are typically estimated by customer (as sensitive to operational scenario, energy market pricing…)
2. Total transformer price (initial transformer cost)
3. Current carbon price (if applicable or for sensitivity analysis)

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Environmental impact/Carbon footprint and TCO calculator: Input data (2/2)

3 *LCA (methodological) Considerations*

1. **Biogenic Carbon Capture: applicable in case of natural Ester**

   The biogenic carbon captured or absorbed by their original source (soybeans or sunflower seeds) can be considered as negative carbon emissions entering our manufacturing process: reducing CO2 footprint at the manufacturing stage.

   Considering biogenic CO2: reducing GHG emissions from manufacturing by 32% and life-cycle GHG emissions by 1%
   (40 MVA, Stands losses, Ester filled)

2. **End of Life Credits: Default "No" (more conservative)**

   Methodological consideration of whether materials at end-of-life stage are recycled and used (as secondary materials) to substitute the production of new (primary) materials.

   With EOL credits: life cycle GHG emissions are reduced by 1.2% (95 tCO2 eq.)
   (40MVA, Standard losses, Mineral Oil)

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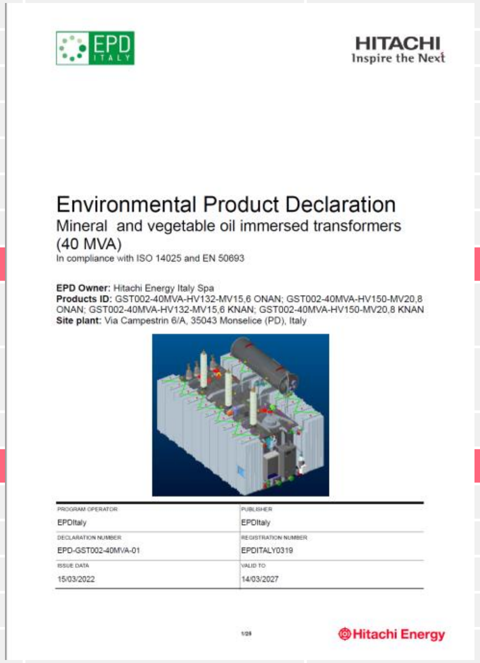
From impacts to insights: Impact by life cycle stage

(EPD on 40 MVA, HV132-MV15.6 Mineral Oil, ONAN)

Life cycle stage	Upstream	Core	Downstream			
	Manufacturing		Distribution	Installation	Use	End of Life
Environmental impact						
(Total) Global Warming Potential (GWP)					**99.30%**	
Depletion Potential for stratospheric ozone layer (ODP)					**99.35%**	
Acidification Potential (AP)	1.60%				**98.37%**	
Eutriphication Potential (Freshwater) (EP)	3.38%				**96.61%**	
Formation Potential of stratospheric Ozone (POCP)	2.54%				**97.41%**	
Abiotic Depletion (ADP) - Minerals and metals	**46.98%**				**52.82%**	
Abiotic Depletion (ADP) - Fossil fuels					**99.28%**	
Water Depriviation Potential (WDP)					**98.85%**	
Resource use						
PENRT (Total use of non-renewable primary energy resources)					**99.28%**	
PERT (Total use of renewable primary energy resources)	2.16%				**97.26%**	
Use of net fresh water (FW)	1.04%				**98.75%**	
Waste production and output flows						
Hazardous Waste Disposed (HWD)	**24.33%**				**75.63%**	
Non-Hazardous Waste Disposed (NHWD)	6.94%				**92.32%**	
Radioactive waste disposed (RWD)					**99.13%**	
Material for energy recover (MER)						
Material for Recycling (MFR)		5.77%			2.31%	**91.93%**
Component for Reuse (CRU)						



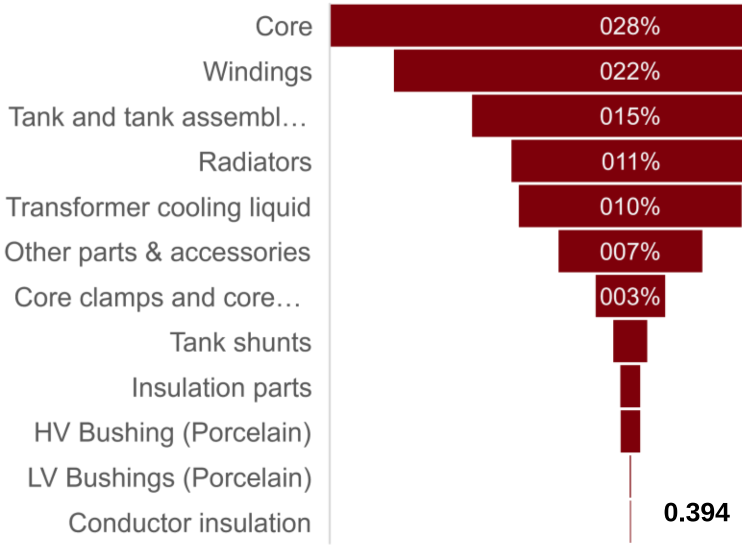
1. **Product use stage**: dominating environmental impact assessment (basically: life cycle impact of the electricity consumed due to energy losses)
2. **Manufacturing upstream**: also relevant from a resource consumption and (hazardous waste) disposal perspective

1. **Grid energy mix** is determining the life cycle impact of a transformer (energy mix transformation as first level for reducing impacts)
2. **Materials usage (type) and transformer weight** are also relevant for resource depletion and waste production (circularity as the next lever for reducing impacts)

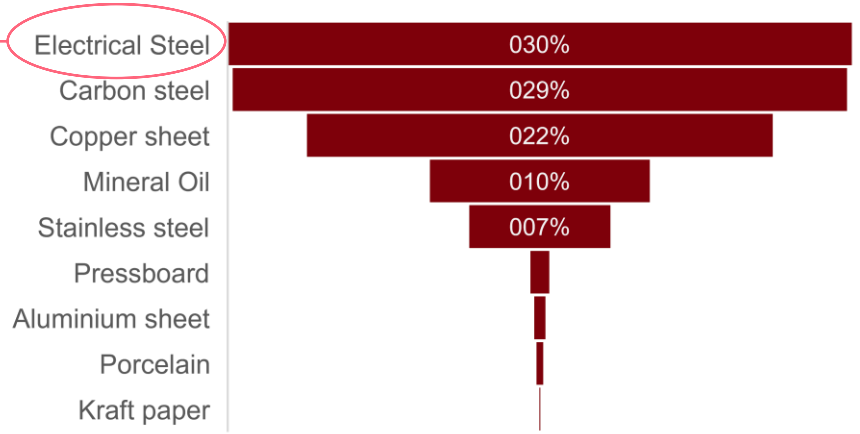
From impacts to insights: Optimizing your product carbon footprint (1/2)

(PCF on 40 MVA Liquid Filled Power Transformer, Mineral Oil, Standard losses)

Contribution by component to Global Warming Potential (GWP) from Manufacturing-Upstream stage

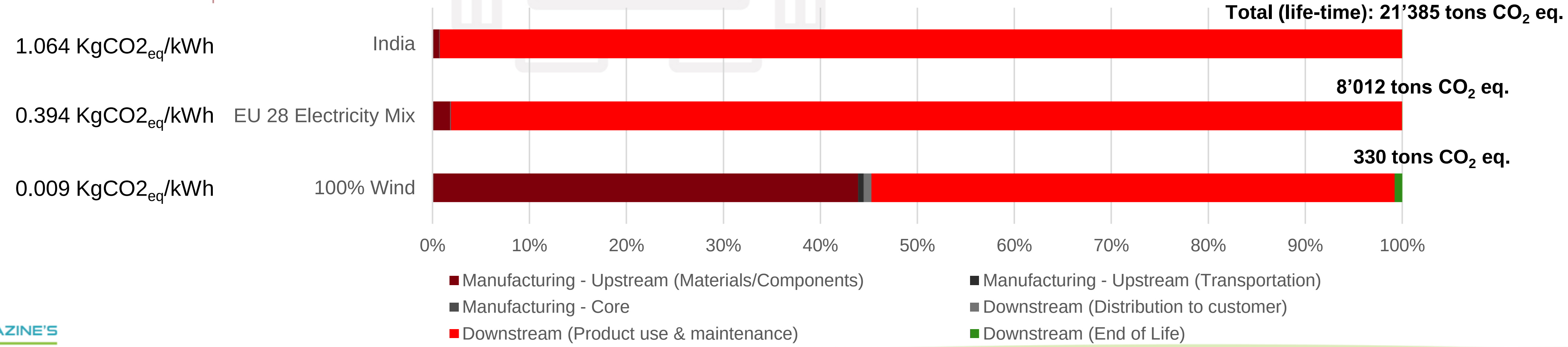


Contribution by material to Global Warming Potential (GWP) from Manufacturing-Upstream stage



	GWP (from Materials only)	GWP (Total Life-Cycle)
E-Steel Grade 1		
E-Steel Grade 2	+10.52%	-11.53%
E-Steel Grade 3	+13.04%	-11.42%

Impact of the energy mix (Grid EF) on share of GWP impact by life cycle stage



From impacts to insights: Optimizing your product carbon footprint (2/2)

(PCF on 40 MVA Liquid Filled Power Transformer – Different Designs, EU 28 electricity mix)

	TRANSFORMER A (Standard losses; Mineral Oil)	TRANSFORMER B (Lower losses; Mineral Oil)	TRANSFORMER C (Standard losses; Ester filled)	TRANSFORMER D (Lower losses; Ester filled)
Transformer total weight		15.3%	16.4%	26.4%
Transformer cooling liquid weight		17.4%	33.4%	41.2%
GWP Manufacturing Upstream		33.0%	29.2%	44.1%
GWP Product use & maintenance		-23.0%	-5.5%	-21.3%
GWP End-of-Life		10.2%	7.1%	14.1%
GWP Total		*-22.0%*	*-5.0%*	*-20.1%*
Peak Efficiency Index (IEC)	99.73%	99.80%	99.76%	99.80%
TCO* (A= €/kW 7’500, B=€/kW 2’500, €8000/MVA for baseline transformer) without CO2 costs		-12.4%	3.8%	-3.62%
CO2 costs (50 €/ton, 35 years)		-23.0%	-5.5%	-21.3%

** Potential additional economic benefits from ester and alternative, biodegradable fluids: impact of O&M costs, reduced operational risks resulting into lower insurance costs… are not considered in the TCO calculation.*

PEI is key to lowering life cycle GHG emissions and TCO…
PEI and Bio-degrabdable Fluids increasing materials intensity, but lowering environmental impact on remaining assessment categories

From impacts to insights: Optimize your design & TCO by including carbon costs* into your loss capitalization (A & B factors)

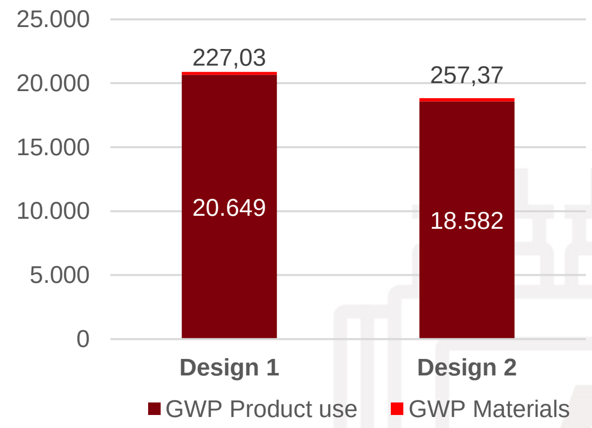
**** Worldwide, 68 carbon pricing instruments (CPIs), including taxes and emissions trading systems (ETSs), are operating and 3 more are scheduled for implementation (**World Bank, State of Carbon Markets 2022**).***

Transformer: 62.5 MVA, 154kV/33.6kV, Mineral Oil, ONAF, TCO @ $8000/MVA, load factor: 57.7%, 40 years

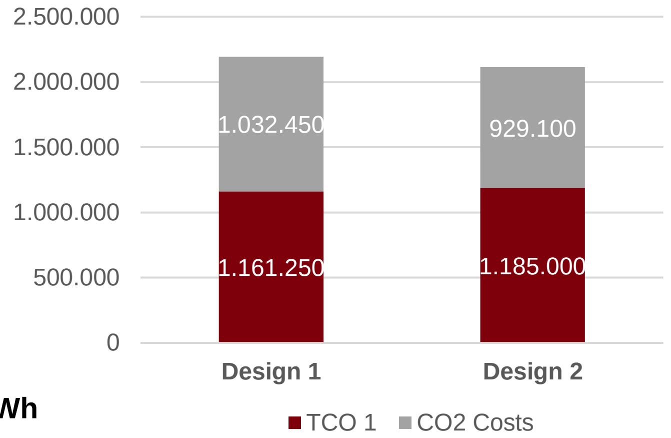
Conventional TCO approach
A = $7500/kW; B = $2500/kW;
Cost of Electricity w/o CO2 costs: $0.05/kWh

Design 1:
optimized for lowest TCO @ natural peak efficiency load factor (derived from A/B Factors): 57.7% (baseline design)

Design 2:
optimized for load factor close to desired load factor @ peak efficiency (+18% transformer price; +12% total weight)



Avg. grid EF: 0.670 $KgCO2_{eq}$/kWh

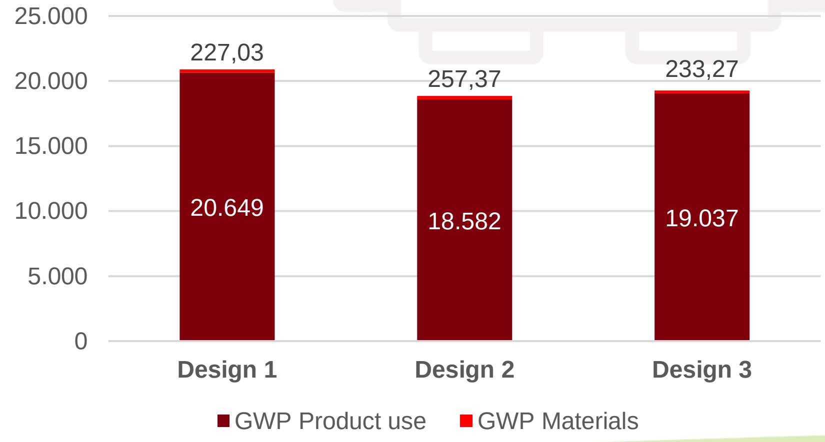


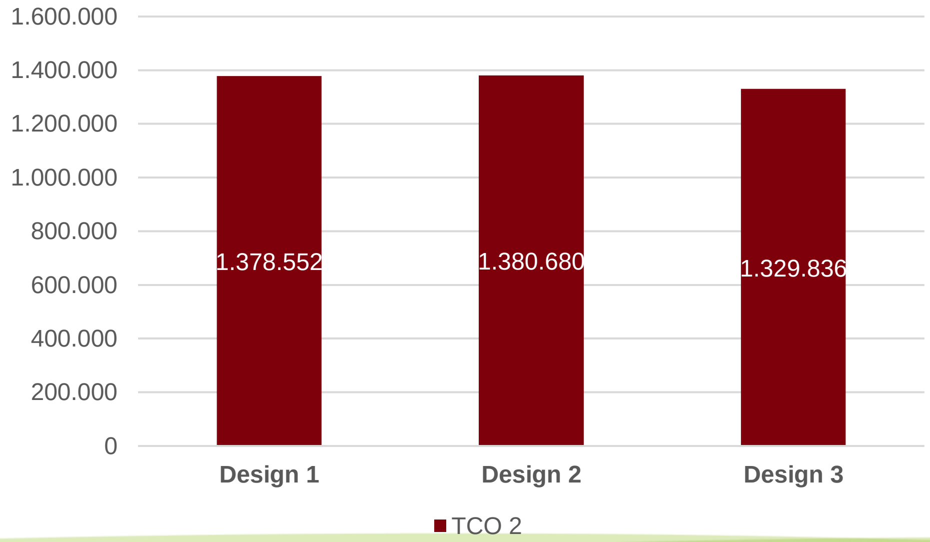
CO2 cost: $50/ton

Recommended TCO approach
A = $9'980/kW; B = $3'320/kW;
Cost of Electricity incl. CO2 costs: $0.066/kWh

Design 3:
optimized for new A & B Factors (+4% transformer price; +3% total weight)

[TCO Tool: A Guide to Using Total Cost of Ownership When Purchasing Distribution Transformers - United for Efficiency (united4efficiency.org)]





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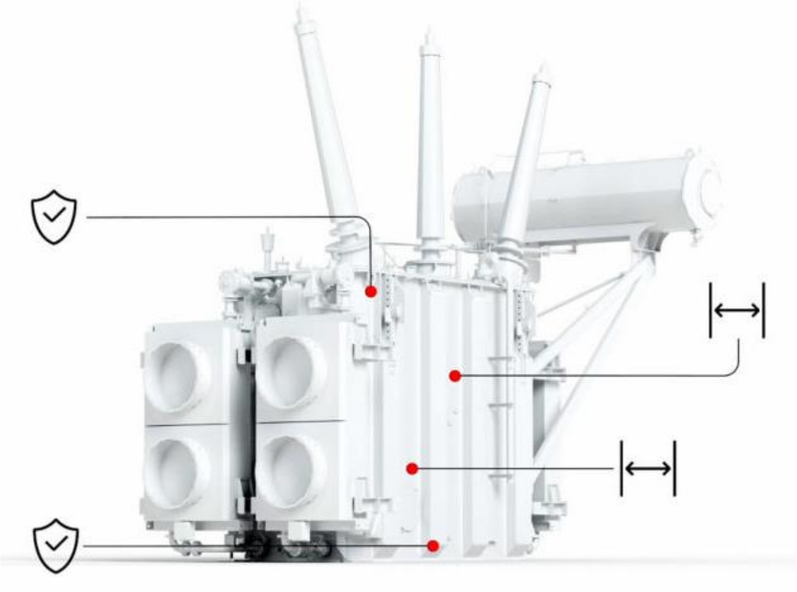
Life Cycle Impact Assessment: When and Why

Collaboration & Specification → **Engineering/Procurement/Manufacturing**

LCA Models



→ **Life Cycle Impact Assessment Tool**

Preliminary assessment and comparison of economic/environmental impacts of different design options

→ **Your Transformer specific LCA Report**

Detailed LCA study for selected design (*optional on-demand*)

→ **Your Transformer Environmental Product Declaration**

Disclosure and 3rd party verification according to ISO/EPD Standards (*optional on-demand*)

Sustainable Design Optimization

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EconiQ™ Transformers – Our eco-efficiency excellence portfolio

EconiQ™ Transformers – Liquid Filled

(*) Use case: 40 MVA 115 kV mineral oil and standard losses vs 40 MVA 115kV Ester and optimized losses. Based on Life Cycle Assessment for Oil filled Transformers by Hitachi Energy LCA methodology as per ISO 14040/14044

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	More than 20% reduction on equivalent carbon emissions*	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	15% reduction on Eutrophication and water toxicity*	Biodegradable and higher flash point fluids, reducing impacts of eutrophication, fresh- water toxicity and minimizing fire hazards.
Enhanced safety	Avoidance of fire risk or environmental impact of oil leakages.	Additional EconiQ solutions like, TXpand (explosion proof tanks), Dry bushings and noise reduction technologies.
Responsible use of resources	Full Material Compliance Ccommitment to provide support in Disassembly and recyclability	Following stringent regulations for our materials Disassembly manual at delivery of the transformers, with guidance for recycling and waste disposal

Thank you!

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