Sustainability
when using insulating oils in accordance with IEC 60296 in power transformers

STARKE & SOHN GmbH
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(translation of a presentation given at the)
7. Fachtagung
„Isoliersysteme in der Hochspannungstechnik“
5. & 6. Juli 2023
Technische Universität Graz
Institut für Hochspannungstechnik und Systemmanagement

Dipl.-Ing. Dirk Flor
Managing Director
Starke & Sohn GmbH

- Content

Brief overview of Starke & Sohn GmbH

Sustainability - what does that actually mean and what does it have to do with insulating oils?

“Milestones” for sustainability in the transformer family
(IEC, energy producers / network operators / OEMs)

Objektive review of different “sustainable insulating oils”

Acceptance & outlook

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STARKE MINERALÖLWERK

Brief overview company Starke & Sohn GmbH:

- Owner: Manfred Starke
- Employees / Sales: 35 / > 10 Mio €

- Operating locations: Niebüll, Aue & Hannover
- Products / Markets: naphthenic base & transformer oils / / EMEA

- Core competence: selective adsorption / re-refining
- Raw material / feedstock: used transformer & turbine oils

- Capacity: 20.000 t/a re-refining capacity
  - 14.000 t/a naphthenic base oil
  - 6.000 t/a transformer oil
  - > 3.000 t storage capacity (bulk & packed material)

- Certificates & permissions: ISO 9001, ISO 45001, EfB*, WHG

- Our passion: specialized mineral oil processing & providing services to the energy industry

(* & approved waste oil treatment plant according to BImSchG & specialist waste disposal company according to KrWG & specialist company according to WHG & regular system monitored without problems by the LLUR according to § 3 of the 4th BImSchV)

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Raw material procurement:

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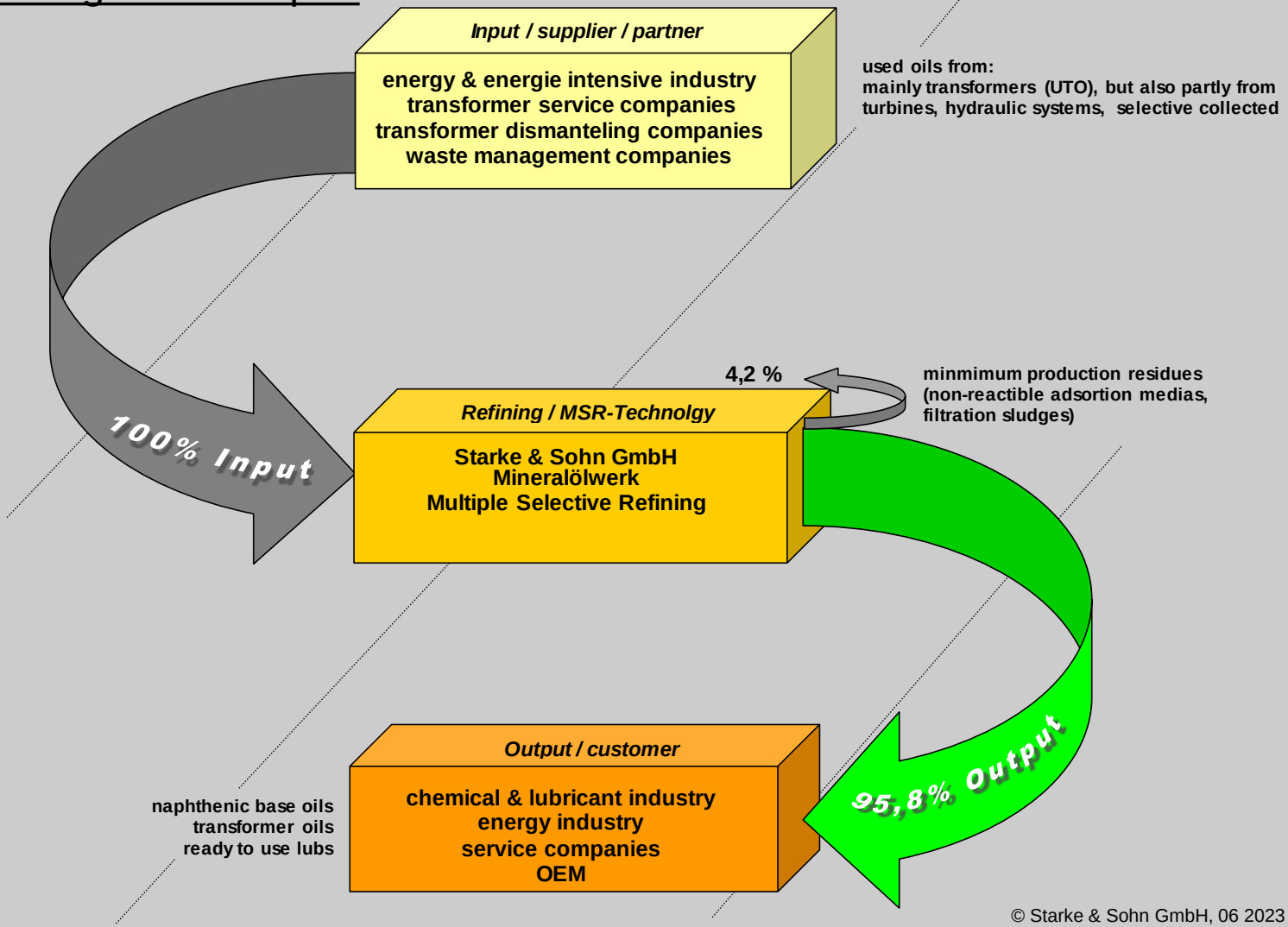
Input / Refining rate / Output:



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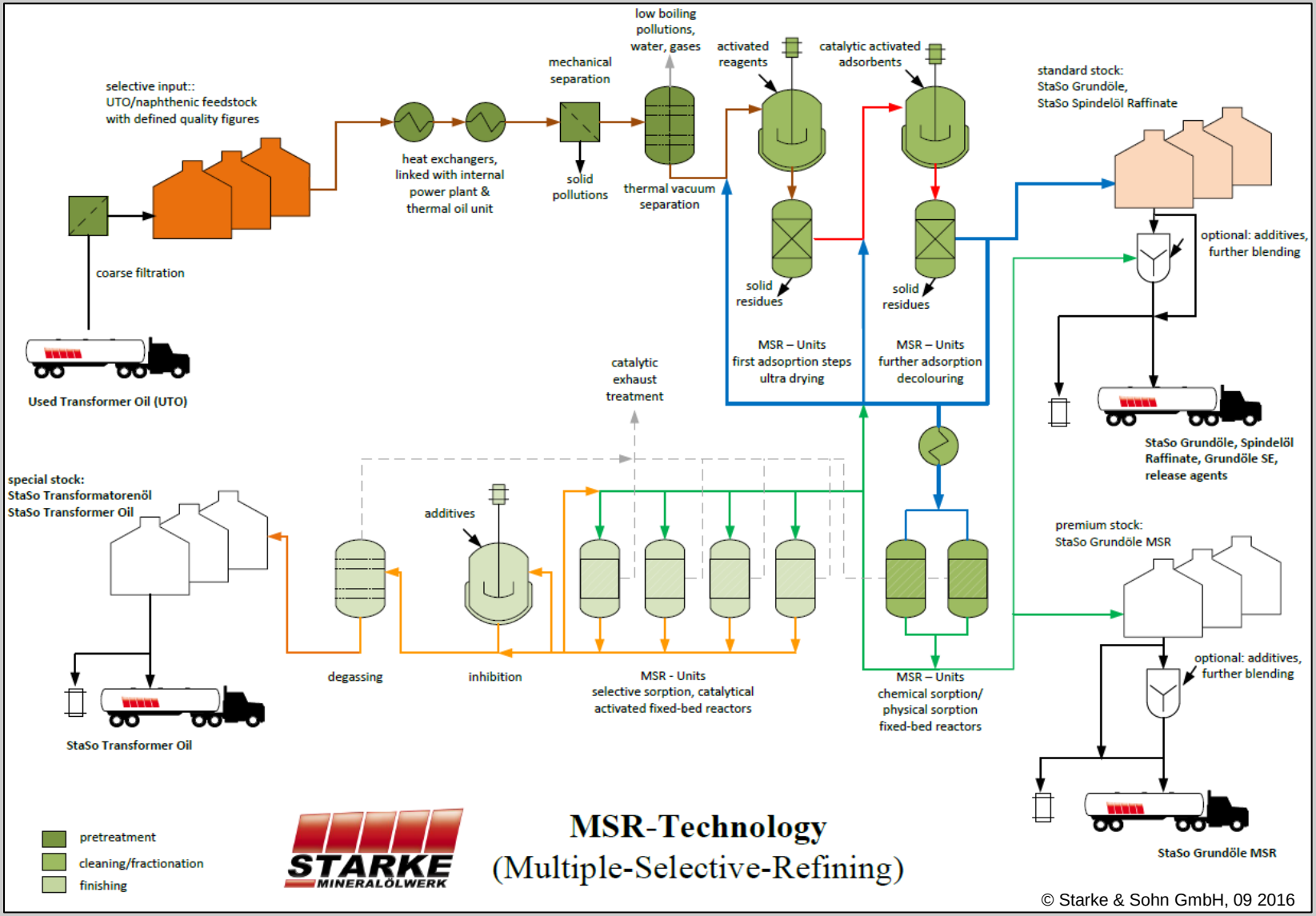

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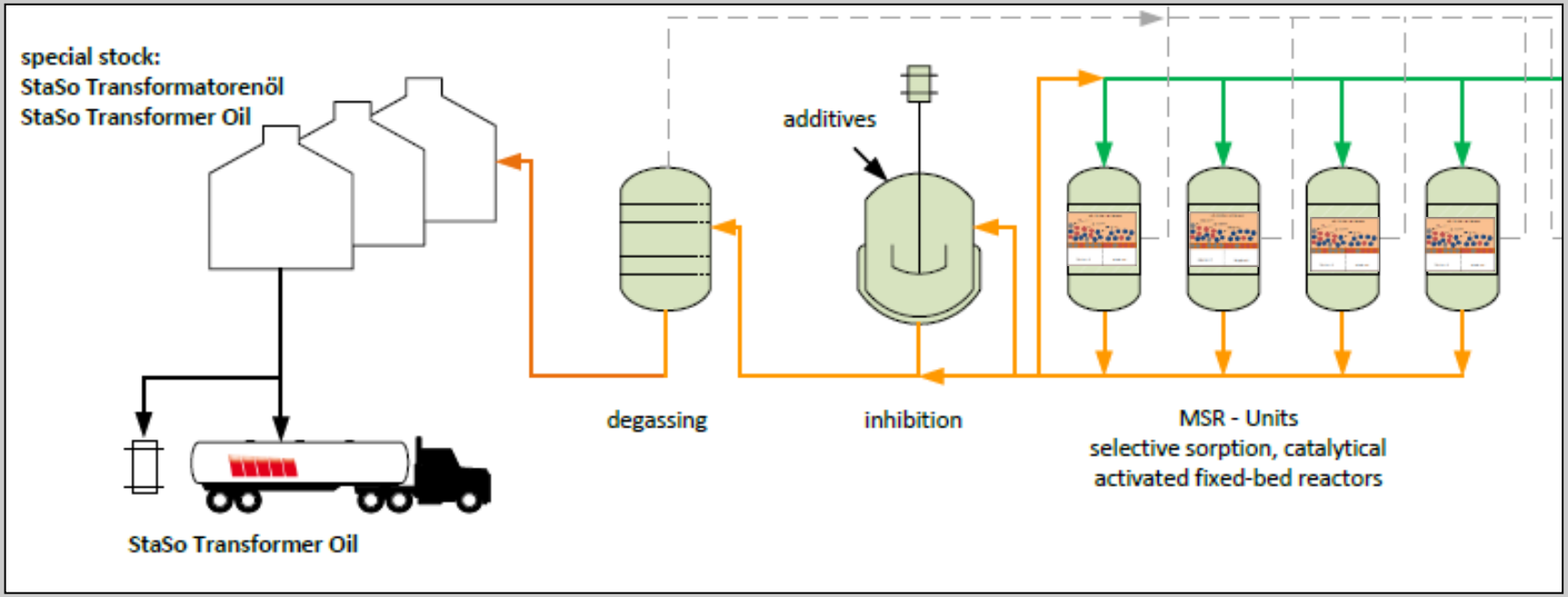
Process - MSR-Technology: **M**ultiple - **S**elektive - **Re**fining

- StaSo Grundöle MSR = base for StaSo Transformatorenöl
  (acc. IEC 60296, Typ A)



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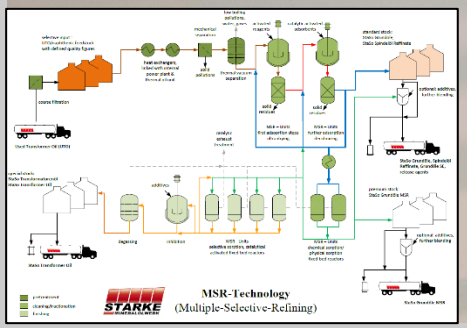
…a picture sometimes says more than a thousand words…:



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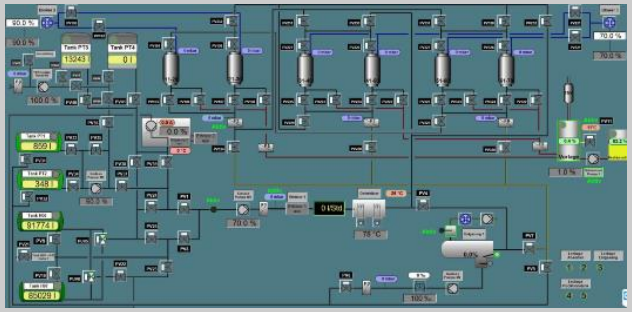
Important technical equipment:

- Specially equipped logistic - 7 trucks for Input- & Output-streams
- 3 Mobile-Regeneration-Assets for services according IEC 60422
- Verry well equipped analytics (incl. GC, IR, RFA, HPLC), consistent process control
- Own engineering know how (MSR- & MRA-Technology)
- Property for further expansion (in production & storage)



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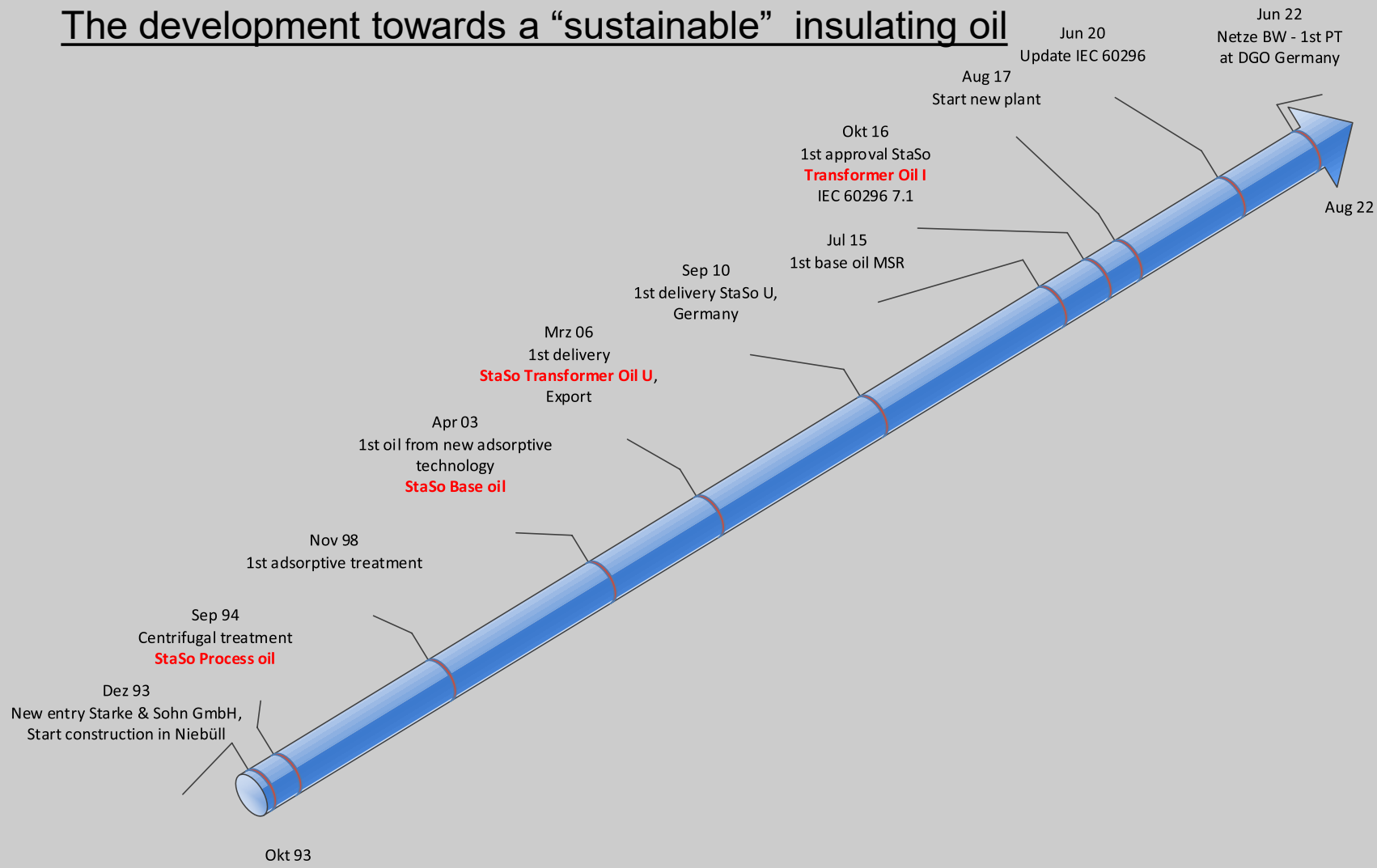
The development towards a “sustainable” insulating oil



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Sustainability - definition: what does that actually mean?

- *“Sustainability is a principle of action for the use of resources in which long-term satisfaction of needs is to be guaranteed by preserving the natural regenerative ability of the systems involved (especially living beings and ecosystems).””*

  source: https://de.wikipedia.org/wiki/Nachhaltigkeit (translated)

- *“Principle according to which no more may be consumed than can grow back, regenerate and be made available again in the future” “*

  source: https://www.duden.de/rechtschreibung/Nachhaltigkeit (translated)

- *“When considering other definitional approaches… further overlaps can be identified. The most common things to notice are:*
  - *Sustainability is always focused on the present and future and therefore has a temporal reference.*
  - *Resources, material/intangible goods, economic/ecological units, etc., should be protected, especially if they are not renewable.*
  - *The continued existence of a reference object should be secured in the short and long term.””*

  source: https://www.nachhaltigkeit.info/artikel/definitionen_1382.htm (translated)

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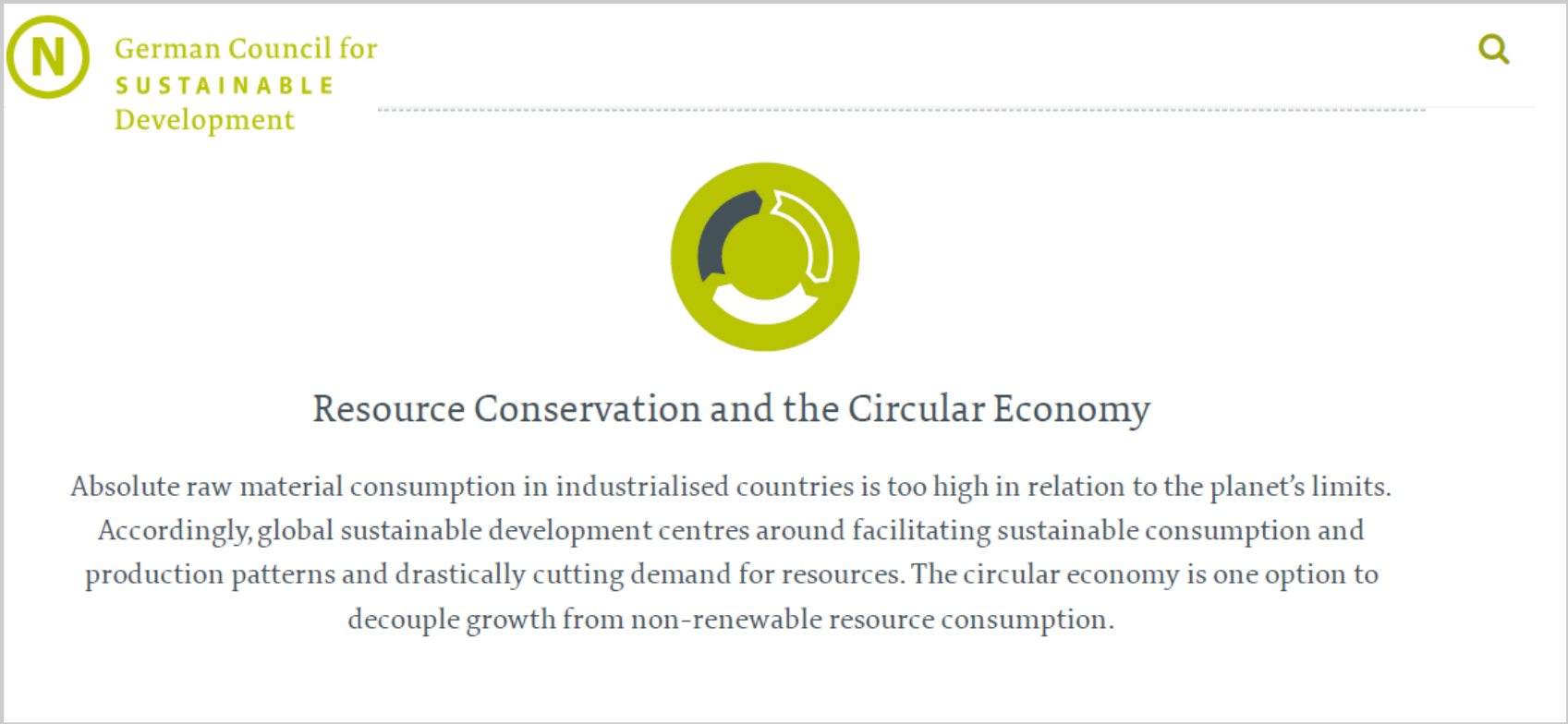
Sustainability goals – acc. the German Council for Sustainable Developmant?



source:
https://www.nachhaltigkeitsrat.de/en/sustainable-development/resource-conservation-and-circular-economy/

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Sustainability - re-refining of waste oil - fundamentals - study ex IFEU

*“In summary, the processing of waste oil to recover base oils leads to significant resource conservation and relief for the environment.” ***

This study reinforces the 2005 findings and complements the previous conclusions by stating that advanced treatment technology should be the preferred route to keep waste oil as a high-value material in the circular economy for as long as possible..

In brief:
This LCA supports the higher ranking of
re-refining versus energetic use
in accordance to the waste hierarchy required by
the EU policy.“

* source:
Updating the study Ecological and energetic assessment of re-refining waste oils to base oils,
ifeu – Institut für Energie- und Umweltforschung Heidelberg GmbH, Nabil Abdalla, Horst Fehrenbach, 2017, translated by google,
https://bva-altoelrecycling.de/files/uploads/2017/10/oekobilanz_ifeu_2017.pdf

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Sustainability - regarding the use of recycled insulating oil in transformers?

- Is the use "…always focused on the present and future…" *?
  - Is the current and safe use possible?
  - Is the capability and performance also possible in the future, i.e. also over the lifetime of the transformer?
- Could the use *„…protect non renewable resources…"* * ?
  - E.g. the absolutely finite oil and gas resources?
  - Are agricultural areas for the cultivation of native raw materials used in technical products renewable and/or limited ? And can these also be protected?
- Is the use, means *„…the continued existence of a reference object be secured in the short and long term …" * ?*
  - Is there enough recycled insulating oil available?
  - Can recycled insulating oil be recycled "infinitely"?

* Quelle: https://www.nachhaltigkeitsrat.de/nachhaltige-entwicklung/ressourcenschonung-und-kreislaufwirtschaft/

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“Milestone“ - Sustainability - insulating oil in power transformer - new IEC 60296

IEC 60296:2020
Type A - fully inhibited "high grade" insulating oil

In June 2020 the International Electrotechnical Commission (IEC) published a revised version of the standard for "Fluids for electrotechnical applications – Mineral insulating oils for electrical equipment”: the IEC 60296:2020

A novelty of the new IEC 60296:2020 is the focus on the specification of technical quality and performance parameters of insulating oils.

The origin of the oil molecules (crude oil, gas or used oil) does not longer matter regarding specification, classification and performance.

This standard is undoubtedly a very positive and innovative milestone within the "conservative transformer family" and we are proud that our company could participate in the revision of this standard within the Technical Working Committee MT 38.

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“Milestone“ - Sustainability - power generator in DE / 600 MVA transformer

600 MVA power transformer: already filled with 84 t of StaSo Transformer Oil I in August 2016 at today's Lausitz Energie Kraftwerke AG (formerly Vattenfall AG) - the first power transformer of its kind in Germany

source: Trafodaten: Michael Lukas, LEAG, Prüfergebnisse: StaSo LAB-ID 66670

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““Milestone“ - Sustainability - power generator in DE / 600 MVA transformer

600 MVA power transformers from the reserve filled with 84 t at today’s LEAG with StaSo Transformer Oil I in 08 2016

- large VDE analysis in March 2022 shows perfect values
- the performance of the oil is as expected and flawless after 6 years of “storage”.

Entnahmedatum	15.03.2022	**Standort**	KW Jänschwalde
Eingangsdatum	22.03.2022	**Geräteart**	Transformator
Prüfdatum	22.03.2022	**Fabriknummer**	642158
Entnahmetemperatur	8 °C	**Typ**	TRO
Probenmenge	1,2 Liter	**Leistung**	600 MVA
Probengefäß	Metall	**Übersetzung**	20/0,4 kV
Probennehmer	Buss		

Prüfergebnisse

Analyseart	Norm	Analysenwert	Einheit
Äußere Beschaffenheit	visuell	Blank, frei von Feststoffen	
Farbe (FZ)	ISO 2049	L0,5	
Dichte bei 20°C	DIN 51757	871	kg/m³
Neutralisationszahl	DIN EN 62021-1	<0,01	mgKOH/g
Durchschlagspannung	IEC 60156	93,5	kV
Wassergehalt (KF)	DIN EN 60814	1	mg/kg
Dielektrischer Verlustfaktor 90°C	IEC 60247	0,0009	
Grenzflächenspannung	ISO 6295	41,1	mN/m
Antioxidations-Additiv	IEC 60666	0,34	w.-%

Bewertung Das Isolieröl entspricht in den untersuchten Parametern den Anforderungen der IEC 60422.

Empfehlung Fortsetzen des Routine-Prüfintervalls.

Quelle: Trafodaten: Michael Lukas, LEAG, Prüfergebnisse: StaSo LAB-ID 66670

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“Milestone“ - Sustainability – grid operator NL / international tender

In 2017/2018, for the first time, an international tender was held by a grid operator consortium (Alliander Group/NL) for power transformers in Continental Europe, in which the use of “recycled” insulating oil also had a highly positive impact on the transformer OEM's bid evaluation (evaluation not only related to economical & technical point but 50% evaluation based on CSR (Company Social Responsibility, Sustainability, Circularity)

source:
Alliander Annual Report 2018:
https://2021.jaarverslag.alliander.com/FbContent.ashx/pub_1030/downloads/v190321144050/Alliander_Annual_Report_2018.pdf

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“Milestone“ - Sustainability – grid operator NL / international tender

- In 2018 long-term supply contracts have been concluded with transformer manufacturers of power transformers, who had included the use of StaSo Transformer Oil I in their offers.

„Sustainable agreements with suppliers are possible “

Making sustainable agreements with suppliers is possible

Sustainable agreements with suppliers are possible: we successfully concluded an eight-year agreement for the supply of power transformers, for instance, in which previously used oil is reused. We have also drawn up a plan of approach with the suppliers for working with them in the years ahead on further sustainability improvements to the transformer. The power distribution losses attributable to these new transformers are around 10% lower than those of our existing transformers. Based on the current order volume and the load on the transformers, this translates into an appreciable reduction in CO_2 emissions and a cost saving of €1.2 million over a useful life of 40 years.

source:
Alliander Annual Report 2018:
https://2021.jaarverslag.alliander.com/FbContent.ashx/pub_1030/downloads/v190321144050/Alliander_Annual_Report_2018.pdf

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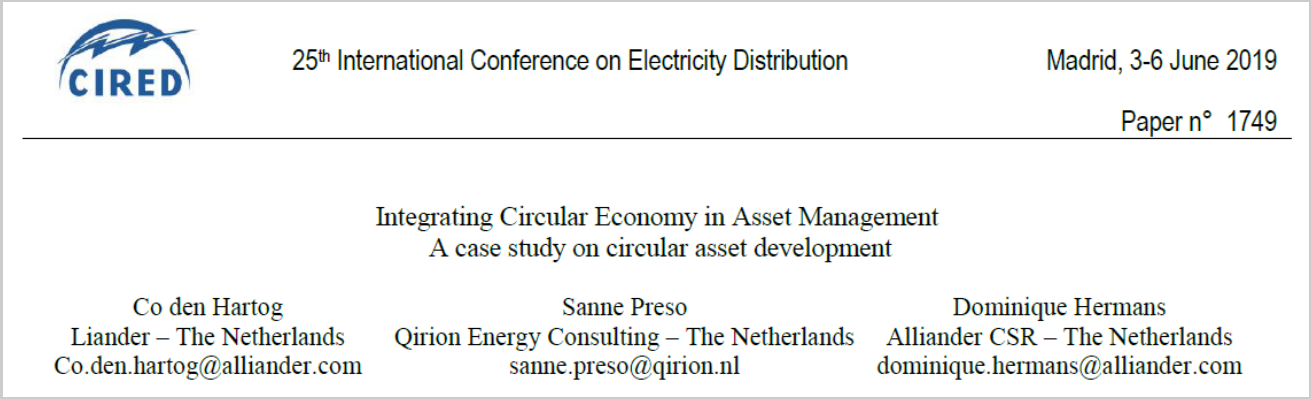
“Milestone“ - Sustainability - circular economy - in asset management

„The Laborelec-LCA compares the environmental impact of new mineral oil with re-refined oil. The result shows that the environmental impact of re-refined oil is lower than new oil...

However, it is important that the re-refined oil is refined within Europe...

The conclusion is that it is both technically and sustainably justified to use a re-refined oil…

*Liander piloted a re-refined oil in 2018. In 2019, re-refined oil will be the standard….“ **



CIRED 25th International Conference on Electricity Distribution Madrid, 3-6 June 2019

Paper n° 1749

Integrating Circular Economy in Asset Management
A case study on circular asset development

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“ source:
Integrating Circular Economy in Asset Management A case study on circular asset development,
Co den Hartog (Alliander), Sanne Preso (Qirion), Dominique Hermans (Liander), Cired 25th International Conference on Electricity Distribution, Cired, Madrid, 2019,
https://www.cired-repository.org/handle/20.500.12455/553

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Sustainability – circular economy - LCA & CO2-emissions

StaSo – MSR-Technologie (Mehrfach-Selektiv-Raffination):
Abschätzung der CO2-Equivalente für StaSo-Produkte auf Basis externer Analysen (2018) und intern aktualisierter Berechnungen (2021), produkt- & produktionsbezogen

	CO2-Emission bei StaSo-Ölen CO2eq t/t	Mittlere CO2-Emission bei Erstraffinaten CO2eq t/t *	CO2-Einsparung on top durch Einsatz von StaSo-Ölen CO2eq t/t	CO2-Einsparung on top plus Grundeinsparung bei Einsatz von StaSo-Ölen CO2eq t/t **
Extern kalkuliert, konservativ, nur auf Basis StaSo I (Trafoöl), 2018:	< 0,35	0,955	> 0,605	> 3,245
Intern, aktualisiert, nur auf Basis StaSo I (Trafoöl), 2021:	0,128	0,955	0,827	3,467
Intern, aktualisiert, auf Basis StaSo SPR, StaSo Grundöl, StaSo MSR, 2021:	0,088	0,955	0,867	3,507
Intern aktualisiert auf Basis StaSo-Gesamtproduktion, 2021:	0,099	0,955	0,856	3,496

*(auf Basis ifeu-Gutachten, 2017, https://bva-altoelrecycling.de/files/uploads/2017/10/oekobilanz_ifeu_2017.pdf)
**(beachte: durch die stoffliche Verwertung & Re-Raffination von Gebrauchtölen werden im Vergleich zu einer ansonsten durchgeführten Verbrennung grundsätzlich mindestens bereits 2,64 t CO2 eq pro t Produkt eingespart)

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“Milestone“ - Sustainability – grid operator NL / international tender

- Since mid 2018, dozens of power transformers have been filled (in first and service fill) with StaSo Transformer Oil I in the Netherlands, as expected all are operating quiet well

Trafohersteller:

TIRONI power transformers 60 YEARS

Trafoservice on site:

FLUX Transformer Services

Trafoöllieferant on site:

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Kunde / Betreiber:

Liander Qirion

Type
20/10kV 20MVA
20/10kV 40MVA
50/10kV 20MVA
50/10kV 30MVA
50/10kV 40MVA
110/10kV 50MVA
110/20kV 80MVA
150/10kV 53MVA
150/20kV 80MVA
150/50/10kV 140MVA

source:
list of transformers: Qirion, Rory Leich,

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Sustainability - grid operator Liander NL / monitoring & quality transformer oil

- since commissioning, oil samples from the power transformers have been regularly analyzed by the operator, all results (VDE, DGA) are within typical ranges,
- see extract below & no “special features when using recycled insulating oils” are expected in the future

- Values for 50 KV-trafo ex: Qirion

50kV vermogenstransformator 2 Edam

Gebied	Locatie	Afkorting	Installatie	Type	Serienummer	Bouwjaar
Noord-Holland	50kV onderstation Edam	EDM	050kV transformatorinstallatie 2 Edam	MR - VVIII 250 D x-delig - TR	83026	2018

Inspectiedatum	Olieanalyse Analyse Conclusie		Conditiecode
20-01-2022	Monster Stazo olie monitoring.	20-07-2022	9

Inspectiedatum	Olieanalyse Dga Conclusie		Conditiecode
03-02-2022	Monster monitoring Stazo olie. Gassamenstelling normaal.	03-02-2022	9

- Values for a 150 KV-trafo ex: Qirion

150kV vermogenstransformator 1 Watergraafsmeer

Gebied	Locatie	Afkorting	Installatie	Type	Serienummer	Bouwjaar
Noord-Holland	150kV onderstation Watergraafsmeer	WGM	150kV transformatorinstallatie 1 Watergraafsmeer	MR - VMSIII 400 Y 72.5 - TR	F4525	2019

Inspectiedatum	Olieanalyse Analyse Conclusie		Conditiecode
28-01-2022	Monster Stazo olie monitoring. Goedgekeurd.	28-07-2022	9

Inspectiedatum	Olieanalyse Dga Conclusie		Conditiecode
14-06-2022	Gassamenstelling normaal.	14-06-2023	9

source:
list of analysis: Qirion, Mr. van de Kuilen, mail vom 14 07 2022

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Sustainability – quality of recycled transformer oil – analogy conclusion

- mobile oil regenerations lead to sustainably reliable oil parameters and conditions - stationary refining is even more effective and efficient

Geräteart	Transformator	**Leistung**	300 MVA	**Ölmenge**	47 to
Fabriknummer	11150188	**Übersetzung**	220 kV	**Entnahmestelle**	unten
Baujahr	1977	**Isolierflüssigkeit**	Shell Diala D	**Auftragsdauer**	17 Tage
Typ	KDOR 325000/220	**Fülldatum**	01.01.1977	**Datum**	07.06. - 24.06.2013
Hersteller	Lepper Dominit				

Eigenschaft	**Prüfmethode**	**Start Probe 1** 25669	**Ende Probe 5** 24356	after 9 years (04 2022):
Datum		07.06.2013	05.03.2013	
Farbzahl	ISO 2049	L3,5	L0,5	**1,5**
Reinheit	VDE 0370	blank	blank	**klar**
Neutralisationszahl	IEC 62021-1	0,02	<0,01	**< 0,01**
Durchschlagsspannung	IEC 60156	72,1	93,3	**79**
Verlustfaktor bei 50 Hz	IEC 60247	0,0316	0,0045	**0,011**
Wassergehalt (20°C)	IEC 60814	7	1	**2**
Dichte bei 20°C	DIN 51757	874		
Brechungszahl	DIN 51423	1,478		
Grenzflächenspannung	ASTM D971	17,7	42,6	**31**
Inhibitorgehalt	IEC 60666	<0,02	0,41	**0,29**
Ag-Silberstreifentest	DIN 51353	nicht korrosiv	nicht korrosiv	
pot. Korrosiver Schwefel	IEC 62535	nicht korrosiv	nicht korrosiv	
PCB - Gehalt	DIN 12766 -1,2	n.n.	n.n.	

* Grenzwerte nach IEC 60422:2005 (DIN VDE 0370/2:2007-2)

after > 9 years: values still better as given limits according to IEC 60422

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“Milestone“ - Sustainability - grid operator DE / 40 MVA power transformer

- 40 MVA power transformer filled with approx. 20 t of StaSo Transformer Oil I at Koncar in Zagreb and delivered in 06 2022 to Netze BW GmbH, Neckarsulm substation
  - as expected, successful FAT in Zagreb, including warming test
  - the first transformer of its kind in the German distribution network, initiated by the departments of Electricity & Gas Networks & Environment/Energy Management and supported by the Network Development Management
  - another step for Netze BW to become a sustainable network operator

KONČAR Inspired by challenge

Netze BW

source: https://www.netze-bw.de/News/75-tonnen-nachhaltigkeit

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Sustainability - remarks/comparison - mineral oil - esters - re-refined

"The results from the LCA study showed that from a cradle-to-gate perspective, mineral oil has a lower environmental impact than ester-based transformer oils…

...The re-refining of used mineral transformer oil further reduces the environmental impact…

..The results from the business case showed that a small scale re-refining facility is financially feasible but highly dependent on the supply and demand of used transformer oil…" *

Our remark:

This is understandable and we agree with it and derive a "sustainability hierarchy" for different insulating oils as follows:

"Sustainability Hierachy" for insulting oils:

1. Re-refined oils

2. Mineral oils

3. Ester oils

" source::

The Sustainability related opportunities and challenges with various transformer insulation fluids and business case on re-refining, Gharib Ali Jalal, Ibrahim & Abdulbasit Abdulaziz, Ali, KTH, School of Chemical Science and Engineering (CHE). 2017 http://kth.diva-portal.org/smash/get/diva2:1178578/FULLTEXT01.pdf

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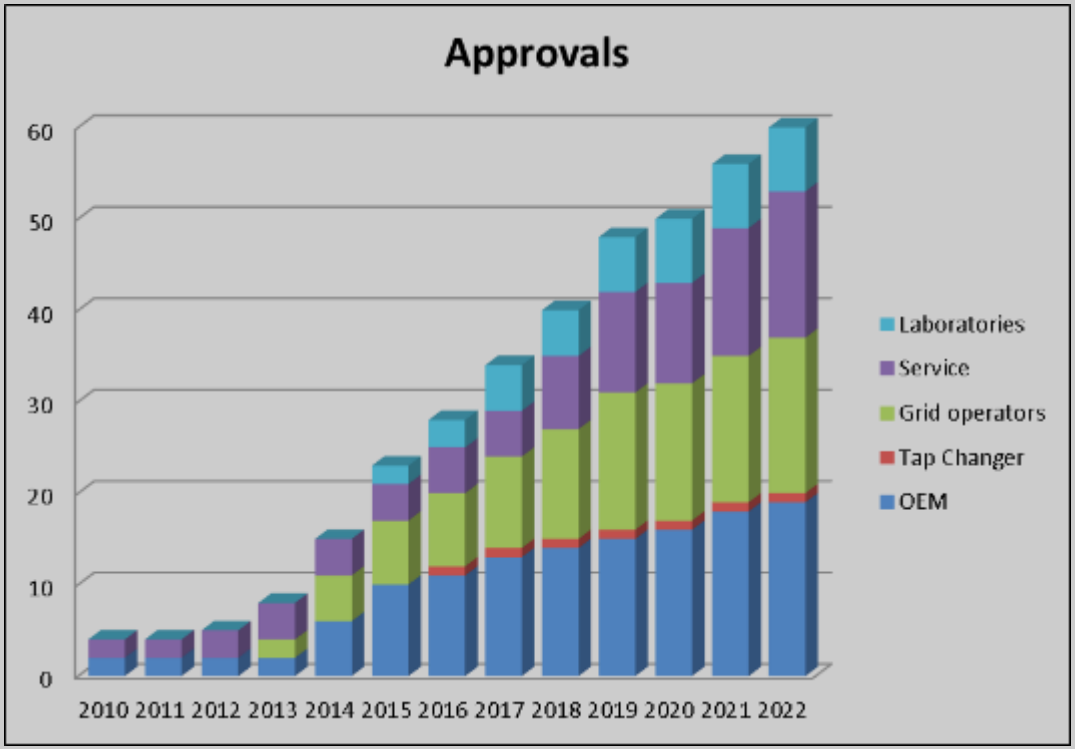
Sustainability – re-refined - StaSo Transformer Oil I – increasing acceptance

The further increasing acceptance of StaSo Transformer Oil I is based on an increased awareness within the “transformer family” regarding

- the resource-saving use of materials and systems,
- an economic approach, designed for sustainability
- a promotion of circular economy,
- and the use of ecological and economically valuable alternatives



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Sustainability – re-refined - StaSo Transformer Oil I - outlook

- Demand from transformer manufacturers (OEMs) and network operators will increase
- The procurement of raw materials and the amount of usable, used transformer oil will remain a limiting factor
- Single-variety collection/recycling remains a constant challenge (mixtures with ester and silicone oils limit usability)
- The development of new input sources and capacity adjustments and enlargements are of strategic importance

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Thank you very much

for your attention !

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