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Hitachi Energy

Circularity Practices in Transformers

2025

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1. Transformers circularity: Framework
2. Circularity by Design
3. Circularity by Service
4. Circularity by Partnerships
5. Summary: KPIs to advance transformers circularity

Hitachi Energy Circular Economy Concept

5R

5Rs adapted from the EU Circular Economy Action Plan and Waste Framework Directive

RETHINK

Rethink the way we deliver value to customers to design waste out of the equation.

REDUCE

Reduce reliance on virgin resources and reduce waste generated throughout our value chain

REUSE

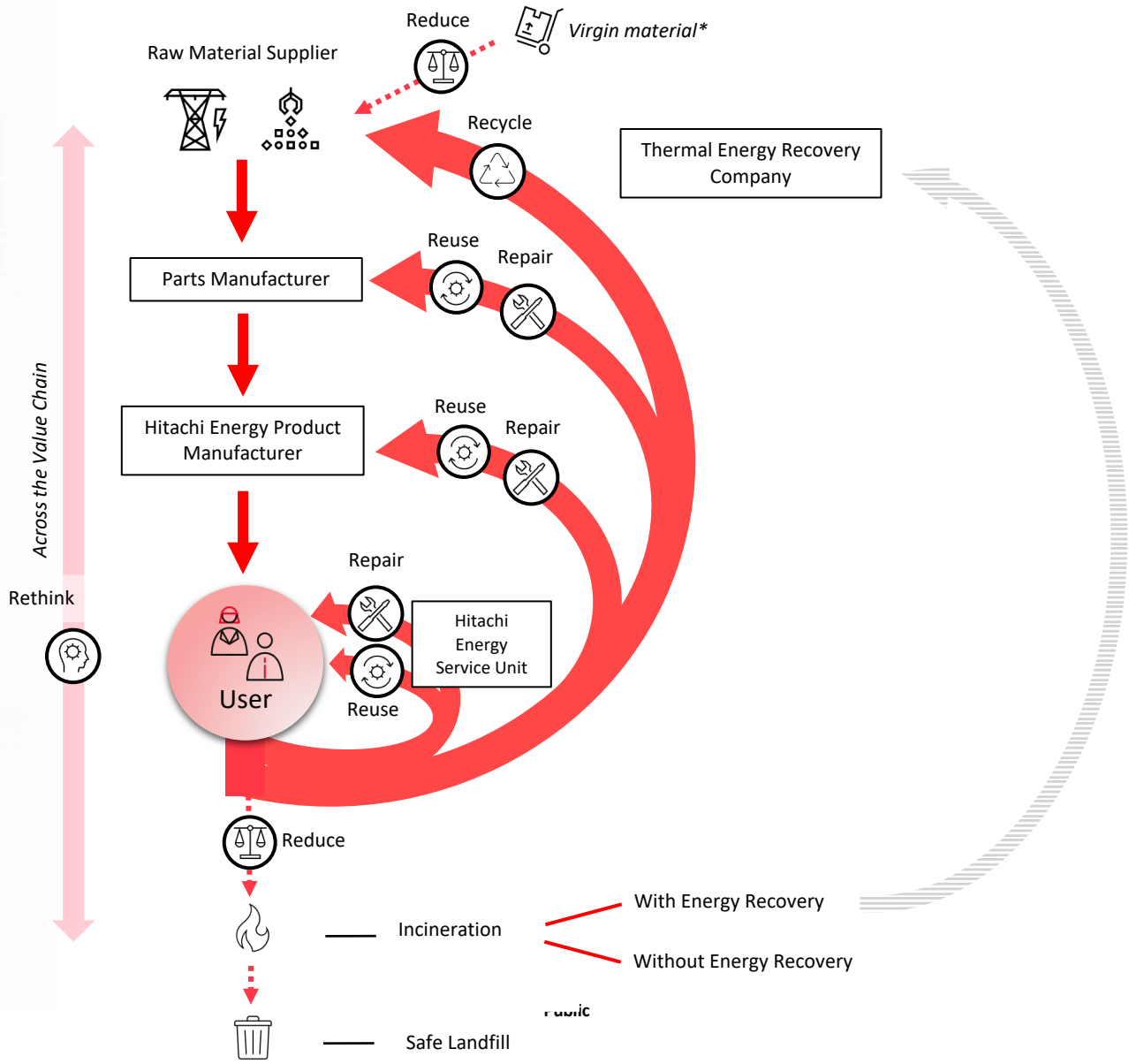
Reuse products, components and materials where possible. Design for reuse and modularity.

REPAIR

Repair equipment and parts to extend the valuable lifetime for as long as possible.

RECYCLE

Recycle materials from products that no longer can be reused or repaired. Strive for closed loop recycling where possible, else open loop recycling.



5Rs Circularity Framework and Transformers

Lever	Objective	Hitachi Energy approach & solutions
RETHINK	Rethink the way we deliver value to customers to design waste out of the equation.	• Potential in future with product as service business model • Rethink traditional products as DRY transformers e.g. **CompactCool™** • Increase durability with concepts as **TVP®**
REDUCE	Reduce reliance on virgin resources and reduce waste generated throughout our value chain	• Compact and lower weight transformers by superior transformer design (with advanced design and engineering capabilities and tools & use of advanced materials (most advanced e-steel grades, higher temperature insulation… compact and lower weight transformers • Sourcing of materials with higher share of recycled content
REUSE	Reuse products, components and materials where possible. Design for reuse and modularity.	• Transformers have a very long life (20 to 40+ years) this does not seem very feasible… because of evolving specifications/regulations: energy efficiency, noise…(few exceptions: re-rewinding by keeping same core, components: e.g. bushings as spare parts but very limited options for direct reuse in new units: logistics, liabilities, guarantees…) • Old Power Transformers cores could be reused in/adapted to Distribution Transformers (with lower energy efficiency requirements)
REPAIR	Repair equipment and parts to extend the valuable lifetime for as long as possible	• Complete suite of services including life cycle extensions
RECYCLE	Recycle materials from products that no longer can be reused or repaired. Strive for closed loop recycling where necessary, else open loop recycling.	• End of Life guidance document (materials recovery guidelines) • Potential to participate in closed loops material value chain in collaboration with other players

Recyclability rates – Basis to compare “apples with apples”

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Recyclability of Transformer

- Material classification according **IEC 62474**
- Recyclability rates given by EN50693 “grouped” to align with the **IEC 62474** material classification
- Providing end of life guidance on demand to customer

Mineral oil recycling

- Comprehensive research and R&D performed on oil reclaiming and recycling
- Fully accepted recycling technologies commercially available on the market
- Possible to extract up to 95% mineral oil from the tank with no separation needed – 100% is possible by also separating oil impregnated in paper
- IEC 60296: “Any blend of unused and recycled oils is also considered recycled.”

Material Classification (ISO22628)	Recyclability rate	Recyclability rate based on	Material examples
1.1 Aluminium based metals	70%	EN50693	Aluminium sheet, other aluminium parts
1.2 Copper based metals	60%	EN50693	Winding conductors, other leads
1.3 Ferrous based metals	80%	EN50693	Core steel, tank steel, coolers, other small parts
2.1.3 Polyethylene (PE)	20%	EN50693	Different plastic parts in control cabinet etc.
2.2 Thermosets	0%	EN50693	Bushing epoxy insulation
2.3 Glass fibre reinforced plastics	0%	EN50693	Fiberglass insulation in active part
3.3 Silicone rubber	0%	EN50693	Bushing insulator
4.1 Oil	90%	Comprehensive research on available technologies on transformer oil recycling	Mineral oil insulation of active part
5.2 Organic boards and paper based materials and insulation	0%	EN50693	Pressboard and paper insulation in active part

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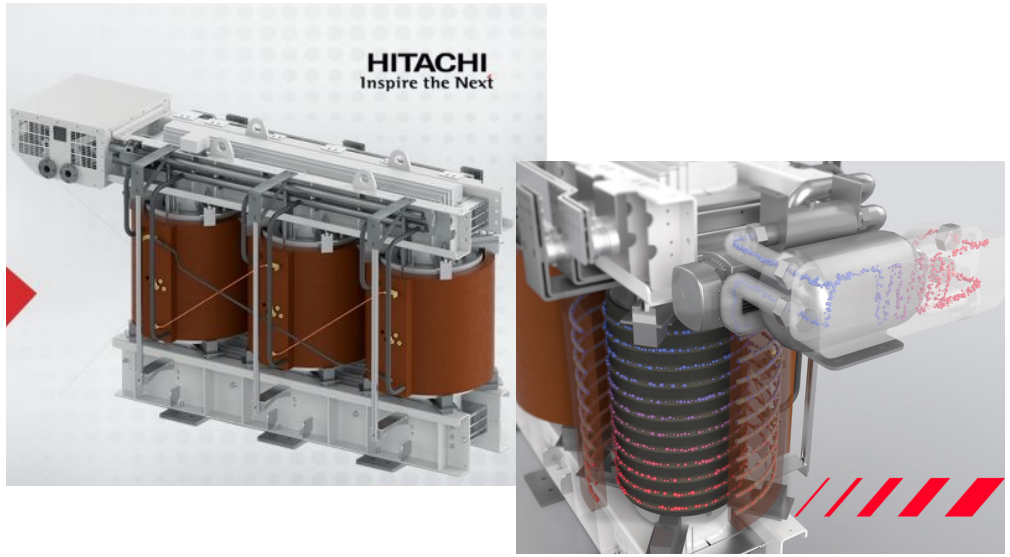
Circularity by Design – Technology for material use efficiency

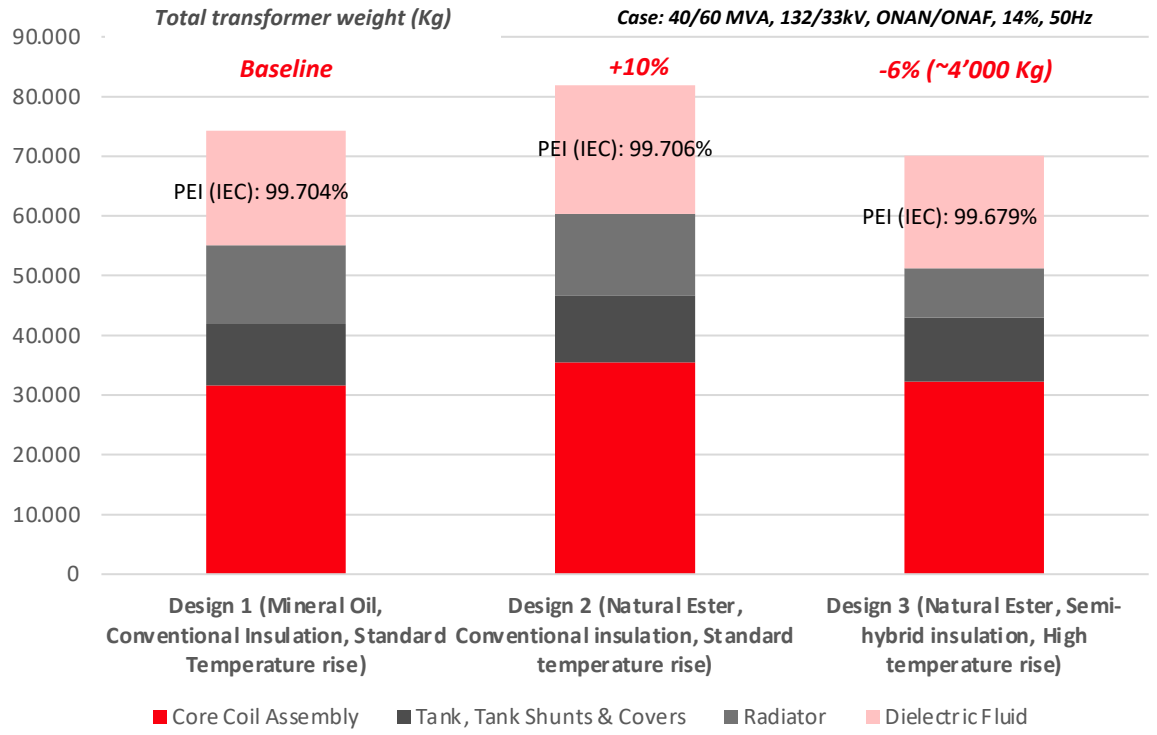
Example 1 – CompactCool™ dry-type transformer



The CompactCool™ technology combines dry-type solid insulation with direct liquid cooling to deliver:

- Total material use reduction: up to -25% (when compared to a conventional dry-type)
- Footprint reduction: up to -30%
- Volume reduction: up to -35%

Example 2 – Optimizing transformer weight with advanced solid insulation in ester-filled power transformers



Insulation class as per IEC 60076-14

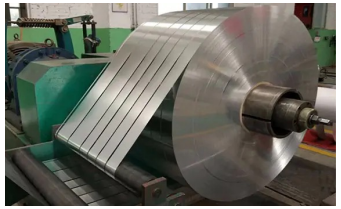
Circularity by Design – Reducing virgin raw materials

E-Steel/Carbon steel

- Recycled content in e-steel/carbon steel:
  - BF/BOF Smelters: up to 25% scrap input possible (today: 10-20%)
  - EAF: up to 100% scrap input possible? (today: >75%)
- Traceability challenging in case of sourcing finished tanks vs. in-house tank production

Conductor materials (Copper & Aluminum)

- Multi-tier supply chain (from raw materials extraction to finished conductor) challenging traceability of % recycled content
- Copper recyclability: potential up to 100%, depends on purity level of scrap (EU: market average today: 30-40%)
- Cu: Mass-balanced alternatives available (100% recycled copper)
- Al recycled content market average today: 15-20%. Higher share impacting conductor technical specifications (conductivity requirements for transformers)



Mineral oil

- Recycled mineral oil (from old transformers) commercially available in Europe
- Specifications as per IEC 60296 for new transformers
- No specifications/design rules changes required (compared to new mineral oil)
- RMOs available are inhibited by technology
- 99.6% share of recycled content.

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Circularity with Transformer services

1. Windings: Condition can be assessed and reused in case of healthy status.

2. Magnetic Core: Health condition can be verified and reused in case of healthy status / or retrofitted damaged silicon steel laminations

3. Bushings and Insulators: Bushing condition can be verified and replace damaged bushings and reuse intact insulators & Bushings.

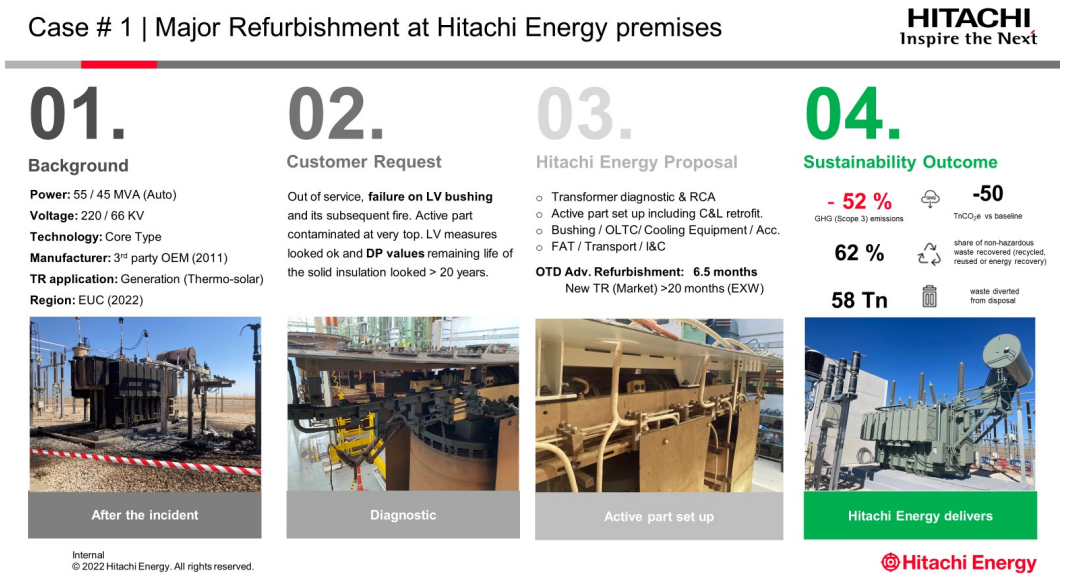
4. Gaskets and Seals: In case of leakages, transformer can be regasketed or welding pores fixed.

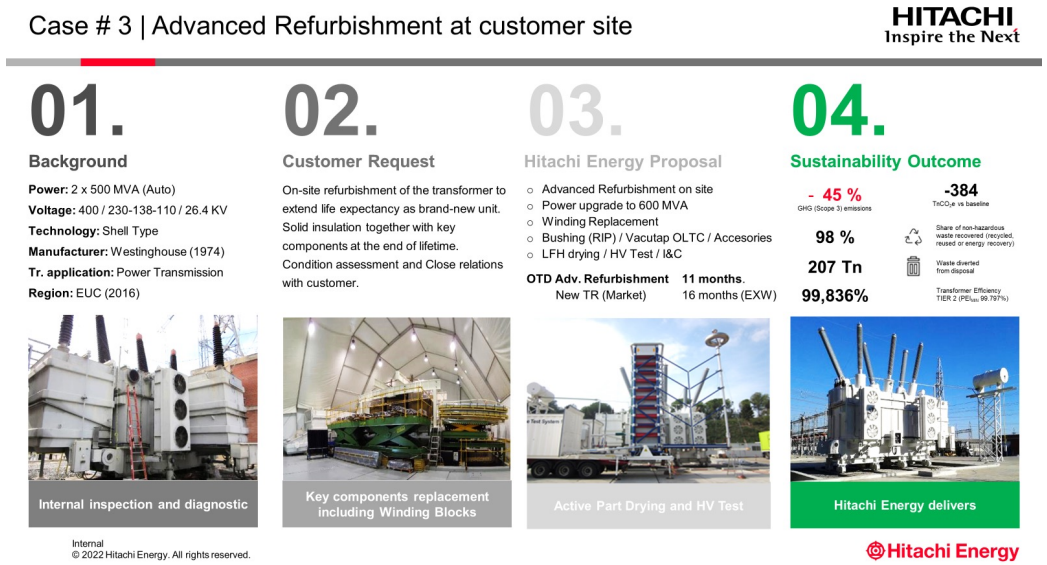
5. Tap Changers: Reuse / upgrade existing OLTC / DETC.

6. Cooling Fans and Radiators: Reuse / Upgrade existing cooling system as per operation condition for the years to come.

7. Control and Protection Devices: Reusing / Retrofit the healthy control panels, relays, and protective devices.

8. Oil: Reusing the oil after it can be filtered and treated.





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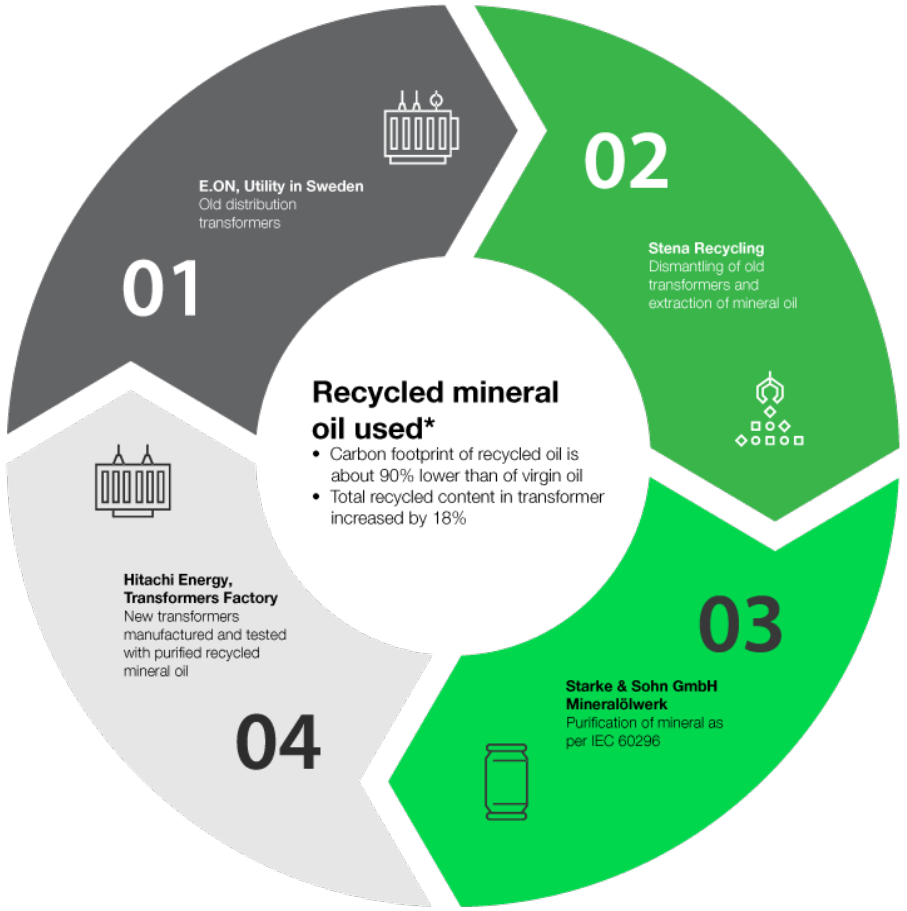
Circularity by Partnership – closed material loop value chain – mineral oil

1. Carbon footprint of recycled mineral oil is about 90% lower than virgin oil
2. Total recycled content in transformer increased by 18% (Distribution Transformer Pilots)
3. Full visibility and due-diligence of supply chain
4. Helping utilities to meet their Scope 3 carbon emissions and circular economy targets through their own old assets



* Chain of custody based on mass balance methodology.

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KPIs for measuring and advancing transformers circularity

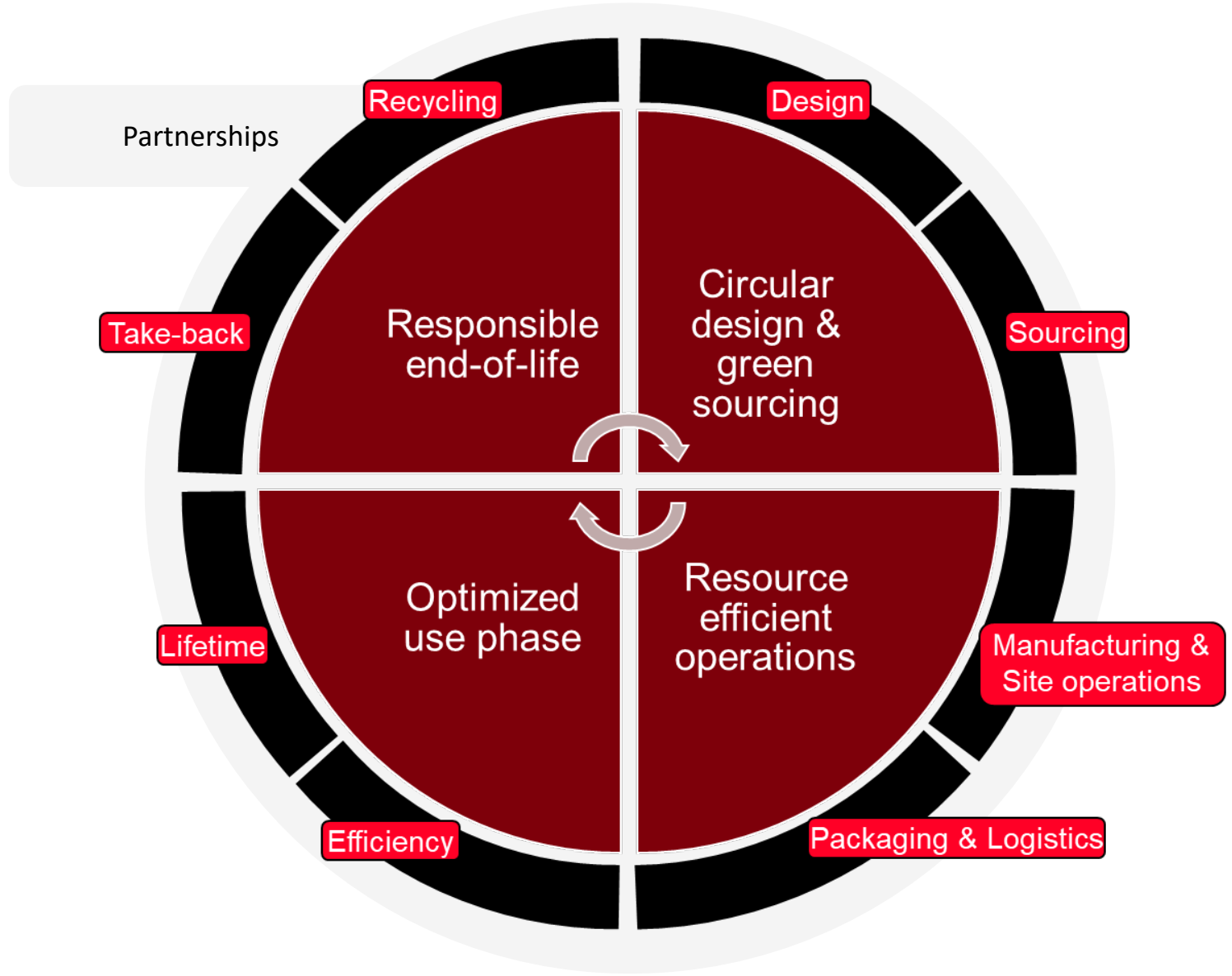
Metrics

Design & Sourcing
- Ecodesign on new products
- *Eco material sourcing: % renewable / recycled content*

Operations
- % Waste to landfill
- % Utilization of plastic waste
- *% Recycled waste*
- *% Reused packaging*

Use Phase
- *Upgradability*
- *Repairability*
- *Refurbished spare part % usage*

End-of-life
- *% recyclability of products*
- *% Reusability of products*
- *% waste divereted from landfill*
- *Take-back offering*



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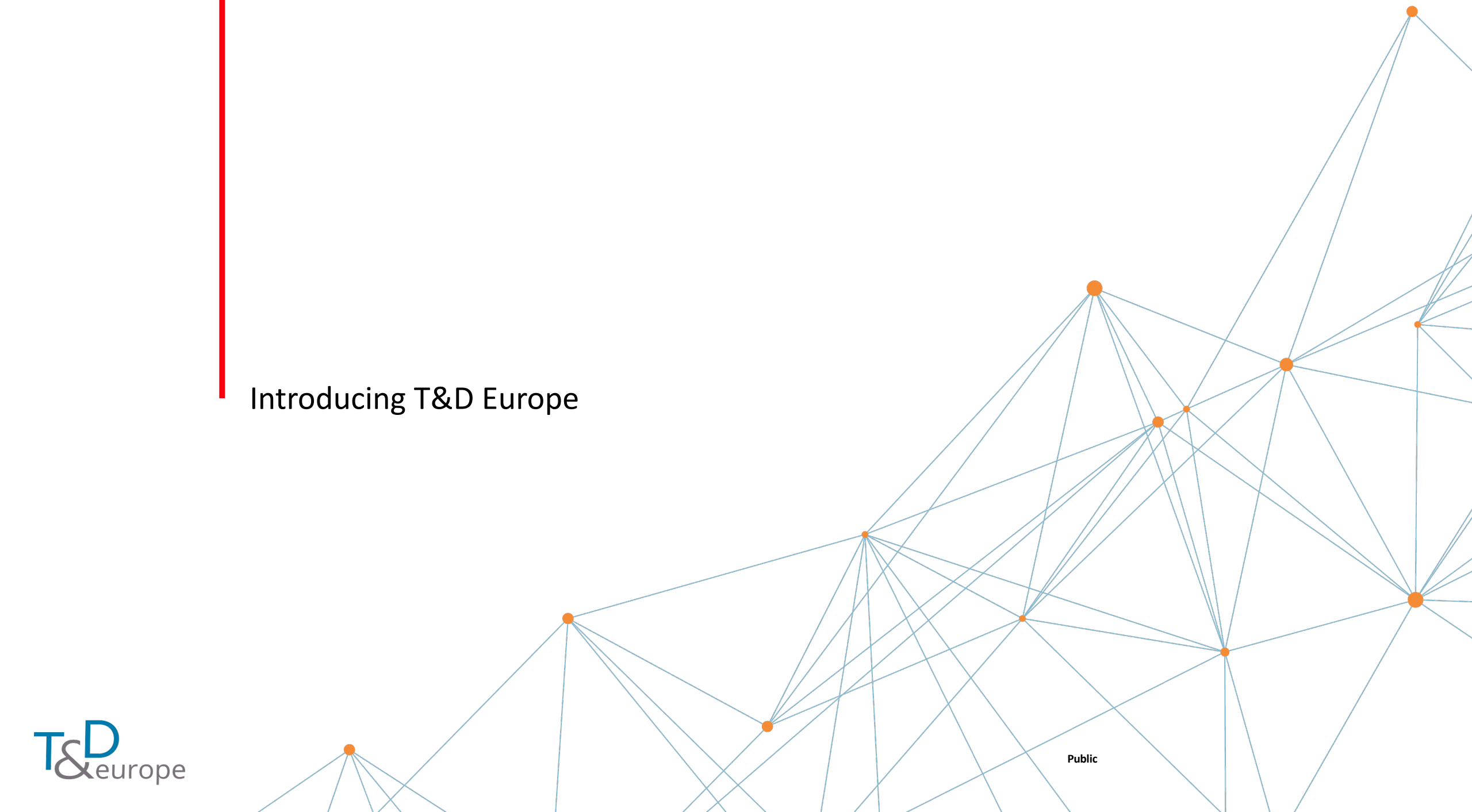

T&D europe

– Crafting a brighter, electric future

–T&D Europe’s members, representing **more than 600 companies** and **more than 450 factories** across Europe, enable the energy transition and the goal of a climate-neutral Europe by 2050.

–**Over 175,000 people** in our industry manufacture, innovate and supply smart systems for the efficient transmission and distribution of electricity.

–Our technologies and services future-proof the grid and make clean electricity accessible to all Europeans.

–We put out collective expertise to work to craft a brighter,

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T&D Europe Position Paper

–7 Key Asks

1. Recognise Europe’s grid technology sector as a vital European interest
2. Provide a clear long-term commitment
3. Transmission and distribution are equally important
4. Digitalisation and cybersecurity are a must
5. Make the most of existing capacities
6. Ensure regulatory coherence
7. **Recognise sustainability**

Recognise Sustainability

- **European leadership**: European manufacturers are aligning with Europe's leadership in advancing sustainability.
- **Balanced rules**: Regulatory frameworks should support sustainability without creating additional burdens that risk reducing global competitiveness.
- **Procurement recognition**: Procurement processes should recognise sustainability performance as an essential criterion.
- **Incentives for assets**: Policies should provide incentives and, where appropriate, requirements for sustainable asset acquisition and development rather than favouring only lowest-cost options.
- **Lifecycle assessments**: Incorporating structured life cycle assessments into procurement would enable project developers to make data-driven decisions that reflect sustainability value.

– **Thank you**

The European Association of the Electricity Transmission and Distribution Equipment and Services Industry

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