



# Sustainable power starts with smarter maintenance

How Siemens Energy DRY, REG, and CLEAN technologies extend transformer lifespan and cut CO<sub>2</sub> emissions

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Bruttogewicht

7.500 kg

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## Advanced on-site oil treatment technologies DRY, REG, and CLEAN go beyond conventional degassing and dehumidification methods

Power transformers are essential to the reliability of energy systems, yet many are operating beyond their intended lifespan. Environmental pressures, aging insulation, and oil degradation are accelerating failure risks and increasing maintenance costs. Siemens Energy addresses these challenges with a modular suite of advanced on-site oil treatment technologies: DRY, REG, and CLEAN, which go beyond conventional degassing and dehumidification methods. These solutions are specifically designed to extract moisture from solid insulation, regenerate oil to near-new quality, and optimize critical oil parameters, thereby extending transformer life, reducing CO<sub>2</sub> emissions, and supporting sustainable asset management.

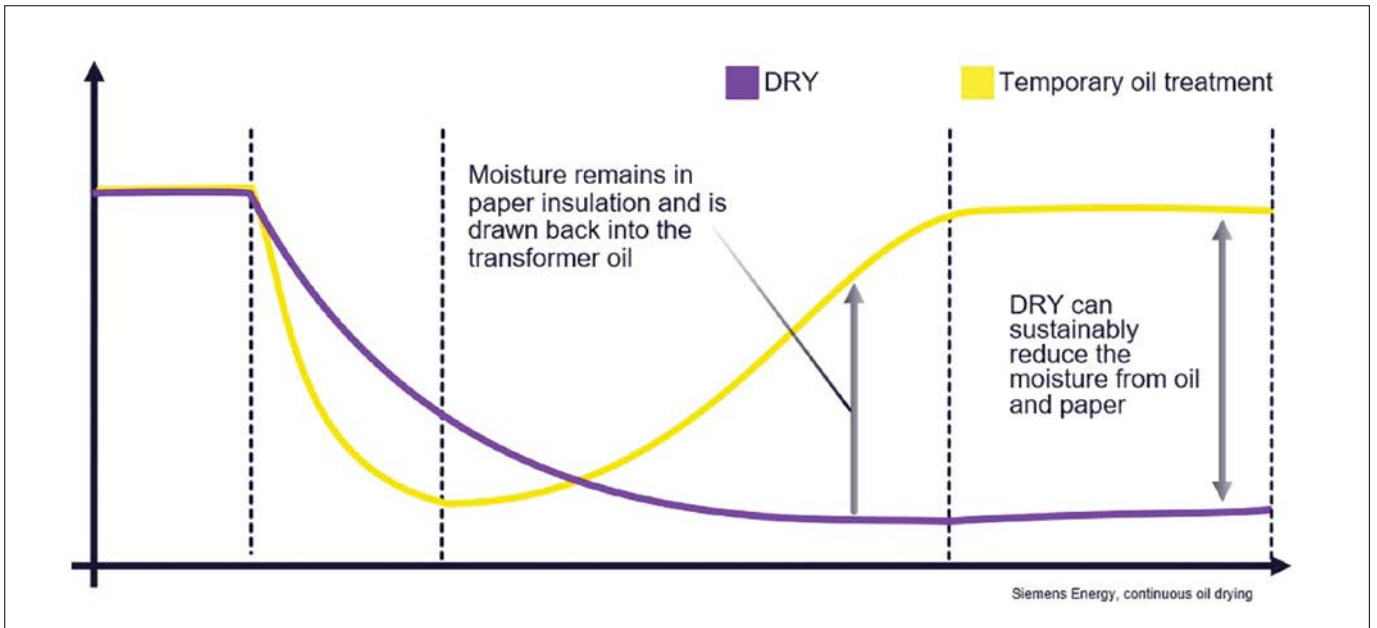
### DRY – Extending transformer life through advanced online drying

DRY is a continuous, online drying system designed to remove moisture not only from the insulating oil but, more importantly, from the cellulose-based solid insulation of power transformers. Moisture is a key factor in accelerating insulation aging, reducing dielectric strength, and promoting chemical degradation. Unlike conventional oil treatments such as degassing or basic dehumidification, DRY targets the core of the insulation system. It uses the oil merely as a transport medium to extract moisture from the soaked paper insulation. This is a gradual process

that typically takes several weeks to months, depending on the transformer's condition and operating temperature.

The system operates by circulating transformer oil through adsorption cartridges filled with a hygroscopic material that captures dissolved water. As the oil dries, a moisture equilibrium shift occurs, drawing water from the paper insulation into the oil, which is then adsorbed by a specific reactant and filtered out. The entire process is non-invasive and performed while the transformer remains energized, ensuring uninterrupted operation. DRY is offered as a product that customers can purchase and install permanently on their transformers, making it ideal for transformers with chronic moisture problems. It achieves a reduction in water content in oil and paper, restores breakdown voltage to over 60 kV within just a few days, and gradually reduces paper moisture by 1%, significantly extending insulation life. The graphic shows how DRY extracts moisture from





transformer insulation by creating a gradient that draws water into the oil. Over time, this continuous cycle significantly reduces the moisture content in the solid insulation, thereby improving dielectric strength and extending

**The entire process is non-invasive and performed while the transformer remains energized – ensuring uninterrupted operation**



## REG restores aged transformer oil to near-original condition. It effectively removes sludge, oxidation by-products, and corrosive sulfur compounds like DBDS

transformer life. The water content in both oil and solid insulation represents a complex system with interdependencies that must be carefully considered. Therefore, it is recommended to maintain the drying process even after improvements in oil values are observed. This approach ensures that any residual moisture in the solid insulation is adequately addressed, promoting the overall health and longevity of the system.

### REG – A strategic solution for aging oil and corrosive contaminants

REG is a mobile, on-site oil regeneration system that restores aged transformer oil to near-original condition. It removes oxidation by-products, sludge, and corrosive sulfur compounds such as, but not limited to, dibenzyl disulfide (DBDS), which are known to cause copper sulfide formation with conducting properties,

causing insulation failure. According to CIGRÉ, several catastrophic transformer failures in the past have been linked to copper corrosion caused by this specific corrosive sulfur compound (DBDS). Improper process execution or poorly designed regeneration systems can even lead to the formation of new high and low-molecular corrosive sulfur species. Siemens Energy ensures that this risk is eliminated by applying a precisely controlled process and leveraging deep expertise in the selection and combination of different types of fuller's earth, tailored to each oil condition.

During the regeneration process, the oil is passed through columns filled with activated fuller's earth, which reacts with polar contaminants, acids, and aging products. The fuller's earth medium, if saturated by impurities, can be thermally reactivated directly on-site and reused up to 300 times, thereby minimizing waste generation and environmental footprint. The process is fully closed-loop, preventing exposure and preserving oil integrity through several safety measures. REG achieves a reduction in neutralization number to below 0.01 mgKOH/g, restores interfacial tension to above 40 mN/m, and removes sludge that could otherwise block cooling ducts. It is ideally suited for transformers with dark, acidic, or sludge-laden oil, especially those showing signs of corrosive sulfur or requiring long-term stabilization of the insulation system.

### CLEAN – Sustaining performance through continuous oil conditioning

CLEAN is an online oil conditioning system that enhances oil quality by removing oxidation by-products and improving

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critical parameters such as acidity, interfacial tension (IFT), dissipation factor, and color. These parameters are essential for maintaining dielectric integrity, reducing energy losses, and ensuring long-term transformer reliability. CLEAN is particularly effective as a preventive measure for smaller transformers up to 5000 liters of oil or as a follow-up to DRY or REG treatments, where moisture or corrosive sulfur has already been removed but the equipment continues to age naturally over time. Its ability to fine-tune oil properties makes it a valuable tool for maintaining compliance with IEC 60422 standards.

The system operates continuously while the transformer remains energized,

using specialized filtration cartridges to remove varnishes, acids, and polar compounds. CLEAN has demonstrated impressive results, such as reducing acidity from 0.1 to 0.05 mgKOH/kg, improving the loss factor from 0.0258 to 0.0094, and increasing IFT from 22 to 28 mN/m. It also significantly improves oil color, indicating reduced oxidation. As a relatively low-cost solution, CLEAN

offers a highly efficient way to preserve transformer performance and extend service life over the long term, making it a strategic asset for operators focused on preventive maintenance and long-term reliability. Existing DRY systems can be easily converted into CLEAN systems, and both approaches can be combined as needed to meet each customer's specific requirements.

## Oil treatment technologies such as DRY, REG, and CLEAN offer not only technical and economic advantages but also significant environmental benefits

Solution	Thermo-Vacuum	DRY	REG	CLEAN
<b>Main goal</b>	Degassing and dehumidification of insulating oil.	Continuous removal of moisture from oil and solid insulation.	Reconditioning of all oil parameters from aged to new values. Capable of <b>removing</b> corrosive sulfur compounds, incl. DBDS.	Enhances oil parameters and removes aging, oxidation products and moisture.
<b>Technical capabilities</b>	Heating, vacuum application, and filtration to remove gasses, moisture, and particles.	Operates with transformer energized, reduces water content in oil and paper. <ul style="list-style-type: none"> <li>Breakdown voltage: &gt; 60 kV</li> <li>Paper moisture: ~1%</li> </ul>	Removes acids, polar impurities, and corrosive sulfur compounds. <ul style="list-style-type: none"> <li>Neutralization: &lt;0.01 mgKOH/g</li> <li>IFT: &gt; 45 mN/m</li> <li>Removes sludge and corrosive sulfur</li> <li>DBDS content: &lt;5ppm</li> </ul>	Improves oil color, acidity, IFT, and loss factor. <ul style="list-style-type: none"> <li>Acidity: &lt;0.05 mgKOH/kg</li> <li>IFT: &lt;22 to 28 mN/m</li> <li>Breakdown voltage: &gt; 60 kV</li> <li>Paper moisture: ~1%</li> </ul>
<b>Best fit scenario</b>	Transformers with high moisture content leading to poor breakdown voltage and for gasses dissolved in oil.	Transformers with high moisture content in oil and insulation paper. Right solution for long term drying and lifetime extension.	Transformers with aged or corrosive oil, presence of DBDS, REG system instead of oil change.	Smaller transformers (max. 5,000 liters of oil volume) requiring enhanced oil quality and extended lifespan.
<b>Benefits</b>	Quick improvement (within 24 hours) of breakdown voltage of oil. Improves insulation condition and transformer reliability.	Prolongs transformer lifespan, improves oil breakdown voltage.	Long-time improvement of transformer insulation condition through excellent and long lasting cleaning effect. Preferable during operation due to better cleaning effect.	Increases system flexibility, boosts reliability, reduces maintenance for smaller transformers.
<b>Additional scenario</b>	Can be combined with DRY for long term improvement.	Depending on oil values, combination with Thermo-Vacuum or REG.	If transformer has initially high moisture levels, an installation of DRY is recommended.	The equipment of DRY and CLEAN is based on the same system. Both functions can be covered by exchange of individual cartridges.

**These solutions are specifically designed to extract moisture from solid insulation, regenerate oil to near-new quality, and optimize critical oil parameters – extending transformer life, reducing CO<sub>2</sub> emissions, and supporting sustainable asset management**

**Comparative Table: DRY, REG, and CLEAN**

The comparative table outlines the key strengths and optimal use cases of DRY, REG, and CLEAN. These solutions enable targeted transformer maintenance tailored to specific operational needs.

**Closing the loop: Safe, efficient, and sustainable transformer care**

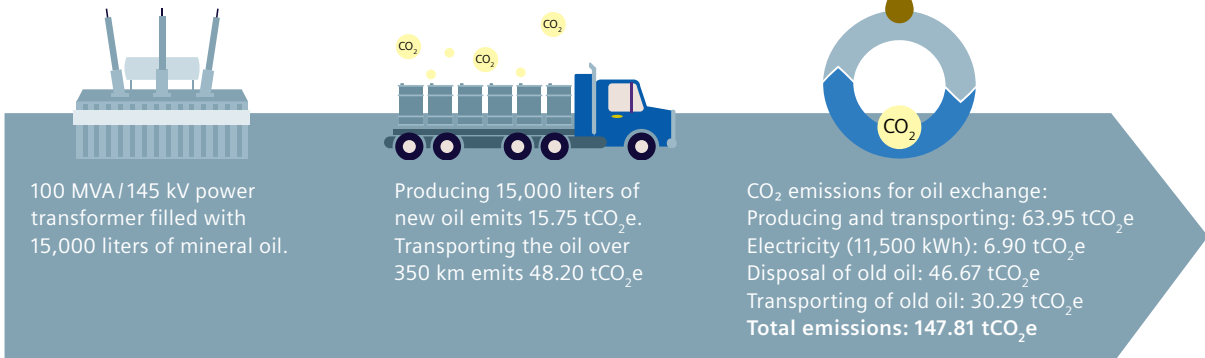
Oil treatment technologies such as DRY, REG, and CLEAN offer not only technical and economic advantages but also significant environmental benefits. One of

the most impactful is the substantial reduction in CO<sub>2</sub> emissions by avoiding the production, transportation, and disposal of new insulating oil. But the environmental responsibility of these solutions goes beyond emissions: they are also designed with robust safety features to prevent environmental hazards during operation.

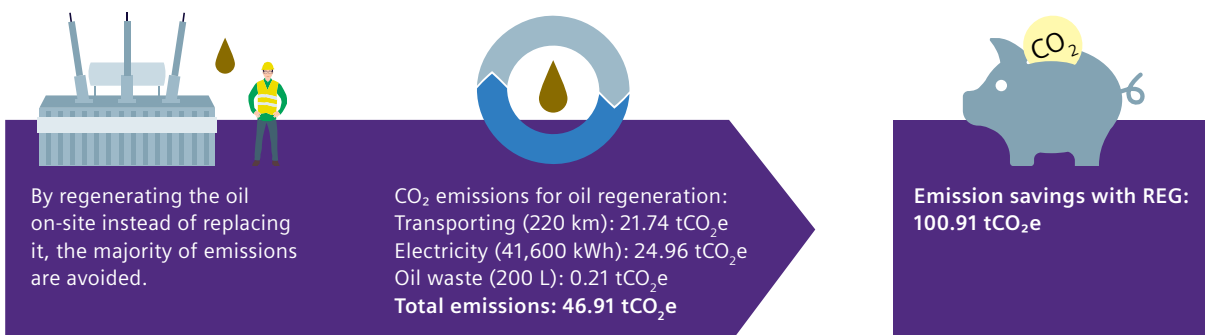
**CO<sub>2</sub>e emissions savings exercise using REG**

Let's consider a real-world scenario:

**Oil exchange**



**Oil regeneration**



These savings with REG equal to the annual energy use of 12 average households.



**Emission factor for:**  
 Producing new oil: 1.05 kgCO<sub>2</sub>e/liter  
 Electricity: 0.6 kgCO<sub>2</sub>e/kWh

Transporting <20 ton: 0.988 kgCO<sub>2</sub>e/(ton / km)  
 Transporting >30 ton: 1.377 kgCO<sub>2</sub>e/(ton / km)  
 Disposal: 74.1 tCO<sub>2</sub>e/TJ

For example, DRY, REG, and CLEAN systems are equipped with leakage detection mechanisms that automatically switch the units into safe mode in case of anomalies. REG includes additional protections such as double-walled hoses, electromagnetic valves, air traps, and integrated fire suppression systems, ensuring safe operation even under demanding field conditions. These built-in safeguards not only protect the environment from potential oil spills or fire risks but also reinforce the reliability and sustainability of on-site oil treatment as a long-term asset management strategy. To quantify the environmental benefits of on-site oil treatment, we present a practical CO<sub>2</sub> emissions savings exercise using REG. This example demonstrates how avoiding oil replacement through regeneration can lead to substantial carbon footprint reductions. The exercise is based on real-world transformer specifications and standard emission factors, offering a clear view of the sustainability impact.

## Why can't action on transformer maintenance wait

Extending the life of power transformers is not only technically feasible but also a strategic imperative in the context of the global energy transition. As utilities and industries face increasing pressure to reduce carbon emissions, optimize asset performance, and ensure uninterrupted power delivery, solutions like DRY, REG and CLEAN stand out as essential tools.

These technologies offer a modern, sustainable, and economically viable approach to transformer maintenance. By treating the insulating oil directly on-

**DRY, REG, and CLEAN systems are equipped with leakage detection mechanisms that automatically switch the units into safe mode in case of anomalies**

# Avoiding oil replacement through regeneration can save over 100 tons of CO<sub>2</sub> – the equivalent of planting a small forest the size of two football fields

site and with the transformer energized, emissions associated with the production, transportation, and disposal of new oil are avoided. This translates to up to 100 tons of CO<sub>2</sub> avoided per treated transformer, along with a significant reduction in the use of natural resources.

More than just extending asset life, these solutions increase the reliability and operational availability of transformers, reducing unexpected failures, optimizing dielectric performance, and ensuring greater predictability in asset management. This means fewer interruptions, lower total cost of ownership, and greater energy security for customers.

By adopting technologies like DRY, REG and CLEAN, electrical system operators not only protect their investments, but they also play a key role in building a cleaner, more resilient, and energy-efficient future.

For those looking to explore how these solutions can be tailored to specific operational needs, we recommend getting in touch with our expert team for further insights and guidance.

Now is the time for utilities and asset managers to rethink transformer maintenance, not just as a technical task, but as a strategic lever for sustainability, reliability, and long-term value.

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## Author



**Fernando Melo** is a seasoned professional with over 20 years of experience managing large, multidisciplinary projects within challenging, multicultural environments. Currently serving as the [Global Product Manager at Siemens Energy](#), he specializes in service lifecycle management and power transformer design. Fernando holds a master's degree in innovation and project management and a bachelor's degree in industrial engineering, and is also certified in Lean Six Sigma. Known for his strategic thinking and leadership, he is dedicated to driving innovation and delivering exceptional value to customers.