

Chemical recycling: Closing the loop for complex waste

In collaboration with industry leaders such as BASF and DOMO Chemicals, Siemens is actively shaping the future of the plastics and plastics processing industry through circular approaches. By leveraging flexible process control systems and advanced digital twins, Siemens empowers the production of **high-quality recycled materials**. These innovative materials are then seamlessly integrated as raw materials in Siemens products or premium applications like outdoor clothing, creating a closed material loop in which waste plastics re-enter production as secondary raw materials.

A recent study by Plastics Europe [1] reveals that in 2023, around 54 million tons of plastics were produced in Europe alone, with only about 20 percent of input materials coming from recycled sources. Among the key reasons for this low recycling rate are the insufficient sorting capacities needed to separate different types of plastics. Sorting is essential to ensure the quality of products obtained through mechanical recycling methods. Plastics with additives or composite materials also pose challenges, as they are difficult to separate and thus hard to recycle using conventional methods. **Manufacturers of plastic products are increasingly under pressure to adapt their processes and materials**, as future requirements will stipulate that their plastics must contain a certain percentage of recycled content.

Chemical Recycling of Plastics: Solution and Challenge at the same time

Against this backdrop, **chemical recycling of plastics is emerging as a pivotal technology.** This innovative process deconstructs plastic waste, often through methods like pyrolysis, into its basic components. The recovered substances

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such as oil and gas can directly substitute virgin fossil raw materials in the production of new plastics or be utilized for energy generation.

By effectively reintegrating these materials into the value chain, chemical recycling plays an important role in closing the plastics material loop - transforming discarded plastics into a secondary raw material that can substitute virgin fossil feedstock in new plastic production.

However, chemical recycling is still slow to gain traction - not only due to market conditions but also because of the inherent challenges of the technologies and processes involved. The main issue is **adapting and optimizing recycling and processing workflows** to ensure that the final product consistently meets high quality standards.

Flexibility in Engineering, Operation, and Scale-Up

Addressing these complex challenges head-on, powerful support is found in Digital Twin technology and flexibly adaptable process control systems. The **Digital Process Twin revolutionizes plant development** by enabling engineers to simulate and scale the entire process layout in a virtual environment. This proactive approach systematically identifies and rectifies potential errors before they manifest in the physical world, dramatically reducing implementation risks for new plants, upgrades, or expansions. It ensures seamless future scalability, particularly enhancing reproducibility and modularization. Furthermore, for operational plants, parallel engineering of changes allows for data-driven planning without disrupting ongoing production.

"In recent years, many plants have been developed that use innovative chemical recycling methods to recover valuable raw materials from what was previously considered waste. The companies we support are primarily focused on transferring their processes from lab scale to commercial maturity, then scaling them up and implementing them at various locations," explains Jürgen Giegerich, Head of Sales for the Chemical Industry in Germany at Siemens Digital Industries.

"We support these companies with the Digital Twin, which enables continuous process optimization and integrates automation, simulation, and process control technologies."

On the control system level, many projects use the **web-based and intuitively operable control system Simatic PCS neo.** It features an open architecture in which **modular engineering** is firmly integrated with support for the open **Module Type Packages (MTP)** standard. This approach significantly simplifies the integration of diverse plant modules into the overall process control system, allowing for manufacturer-independent engineering and enhanced flexibility. The system is highly scalable and suitable for automating both small process modules and large-scale plants.

This is underpinned by the **reusability of engineering solutions**, which facilitates seamless scale-up and flexible adaptation across diverse plant configurations. Moreover, the web-based architecture enables **secure remote access** to globally distributed sites. This capability, coupled with integration with a virtual twin, offers the opportunity for comprehensive **operator training** and advanced process familiarization.

Sustainability Along the Value Chain

Continuous control and monitoring of the process are key to ensuring consistent quality of recycled materials. An innovative example showcasing this principle is the Thermal Anaerobic Conversion (TAC) technology developed by the British company Plastic Energy. This process heats plastic waste in an oxygen-free environment, converting it into TACOIL - a high-value synthetic oil. TACOIL is crucial for closed-loop recycling, as it can directly replace virgin fossil raw materials in petrochemical plants, even meeting the stringent requirements for manufacturing food-grade packaging. Plastic Energy operates commercial facilities in Spain, France, and the Netherlands, closely collaborating with petrochemical partners to tailor the output quality of these synthetic oils to the requirements of modern cracking units.

A critical success factor for the quality of recycled plastic feedstock, as well as the efficiency and scalability of TAC plants, is the integration of **automation and control solutions from Siemens**. The control system not only enables seamless plant operation but also predictive analysis of input materials, which can vary significantly in composition. Intelligent control strategies help detect and prevent disruptions early, significantly increasing **operational safety**. Additionally, software modules for field device management and maintenance help optimize plant availability.

Another example illustrates how SIMATIC process control technology supports material recovery and process efficiency at two points in the recycling value chain:





- At **Pyrum Innovations AG**, which uses pyrolysis to recover secondary raw materials from old car tires.
- At **BASF**, which feeds Pyrum's pyrolysis oil into production alongside conventional raw materials and, using the **mass balance approach**, assigns high-quality plastic materials to products such as those made by textile manufacturer VAUDE (see info box).

"A Digital Twin and smart process control technology also support chemical companies that increasingly use circular, recycled, raw materials," explains Jürgen Giegerich.

*"The inherent variability and distinct chemical properties of these **alternative feedstocks** impose unique demands on process control compared to traditional petroleum-based products. To address this, process adjustments can be rigorously tested and validated within a **comprehensive Digital Twin environment** before their deployment in the physical plant. Moreover, **energy consumption can be directly and precisely optimized** as part of these simulations"*.

Electrical Switching Components Made from Recycled Plastics

Siemens supports circularity in the plastics and plastics processing industry not only through automation and digitalization, but also **as a consumer of recycled products**. This commitment primarily involves electrical switching components manufactured by Siemens Smart Infrastructure's Electrical Products business unit across its global facilities.
To meet the rigorous safety standards inherent in electrical switching and installation technology, many of these products incorporate housing and functional parts fabricated from high-performance engineering plastics, such as polyamides (PA) and polybutylene terephthalate (PBT).

In June 2024, Siemens Smart Infrastructure and BASF jointly introduced the first electrical safety product containing components made from **biomass-balanced plastics**.
The Siemens Sirius 3RV2 circuit breaker, widely deployed in industrial and infrastructure applications, now integrates partially flame-retardant, UL-certified plastics from BASF's Ultramid® BMBcert™ (PA) and Ultradur® BMBcert™ (PBT) product families. BASF replaces fossil raw materials at the beginning of the value chain with **bio-methane from renewable sources**, including agricultural waste. Both materials maintain the identical quality and performance characteristics of the conventional BASF plastics previously specified for Sirius 3RV2 components. This production shift saves approximately **270 tons of CO_2 equivalents per year**.[2]

In February 2025, Siemens followed up with the SENTRON 5SV3 residual current circuit breaker Type A/AC, the first product to use **TECHNYL® 4EARTH® from DOMO Chemicals**. This high-performance polyamide consists of **50% recycled raw materials**, including chemically recycled PA6 from various post-industrial and post-consumer sources such as fibers and textile filaments. The material is also flame-retardant and UL-certified, offering the same quality and performance as conventional plastics — a paramount requirement for a critical safety product.

Sustainability at Siemens

The SIRIUS 3RV2 circuit breaker and the SENTRON 5SV3 residual current circuit breaker Type A/AC meet the strict criteria of the **Siemens EcoTech label**, introduced in 2024. This Siemens self-assessment label gives customers a structured overview of product performance against a defined set of environmental criteria. The applicable criteria and methodology are publicly available at siemens.com/ecotech. Looking ahead, Siemens plans to gradually **expand the use of recycled-content and bio-based plastics across its product portfolio.**

This approach is complemented by concrete strategies for **end-of-life management of plastic products.** To improve the recyclability of plastic components from electrical and electronic devices, Siemens initiated a study in 2023 at the **IKK – Institute for Plastics and Circular Economy**. The study contributes to enhancing **design for recycling** methodologies and increasing the circularity of numerous electrical and electronics (E&E) products.

Collectively, these efforts underscore Siemens' commitment to its overarching **decarbonization and resource efficiency goals**. In addition to product design, functionality, manufacturing, and supply chain processes, **material selection** plays a crucial role in further reducing CO_2 emissions and conserving natural resources. Siemens is pursuing a science-based 1.5°C decarbonization target, including a goal to **reduce Scope 1 and 2 emissions by 90% by 2030**, and to apply **robust eco-design principles** to 100% of relevant product families by 2030.

Building on its **Environmental Portfolio** introduced in 2008, the **Robust Eco Design** approach launched in 2020, and the **DEGREE framework** introduced in 2021 - which offers a 360-degree approach to key sustainability values with clear goals in six areas: Decarbonization, Ethics, Governance, Resource Efficiency, Diversity, Inclusion & Community, and Employee Empowerment - Siemens continues to translate sustainability commitments into measurable targets and concrete product decisions.

Practical Example: Circular Economy in Action

Pyrum Innovations AG, recycles used tires using a patented thermolysis process. When expanding a recycling plant already automated with Siemens technology, Pyrum chose the Simatic PCS neo control system. Since then, this state-of-the-art system now orchestrates the daily conversion of rubber components of around 2,000 to 3,000 used tires. Via thermolysis, these materials are transformed into recovered carbon black, pyrolysis oil, and pyrolysis gas – each serving as secondary raw material with diverse applications.

BASF, for example, feeds the pyrolysis oil into its integrated production process, replacing fossil resources. The resulting Ultramid® Ccycled® product line includes PA6 and PA6.6 materials. These mass-balanced Ccycled® products are certified by independent auditors using recognized methods and have identical properties to products made solely from conventional raw materials.

The Ultramid® Ccycled® materials are processed into high-quality yarns, which, can be woven into durable fabrics and then made into backpacks and clothing. VAUDE, the first outdoor brand to adopt this innovative recycling method, now offers pants and backpacks made from this material.

Further information:
siemens.com/recycling
More information on cooperation with BASF

Sources:
[1] "Plastics – the fast Facts 2024" (accessed July 29, 2025) – https://plasticseurope.org/knowledge-hub/plastics-the-fast-facts-2024/

[2] The product carbon footprint of the materials is calculated using the TfS (Together for Sustainability) methodology. The CO_2 reduction of the biomass-balanced BASF product is compared against that of the conventional BASF product.

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