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Digital Capabilities to Advance the Circular Economy

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Overview

The circular economy aims to eliminate the extraction of new raw materials and design a circular lifecycle with each step in the process being fully integrated. Waste is systematically eliminated, and emissions are reduced throughout the entire process by efficiency gains and with the incorporation of renewables. A recent ARC study conducted of chemicals industry manufacturers indicate complex supply chains, a lack of proven technologies, inconsistent regulatory policies, and a lack of economic viability are the most significant barriers to achieving circular economy goals. However, 75 percent of respondents believe digital capabilities are essential.

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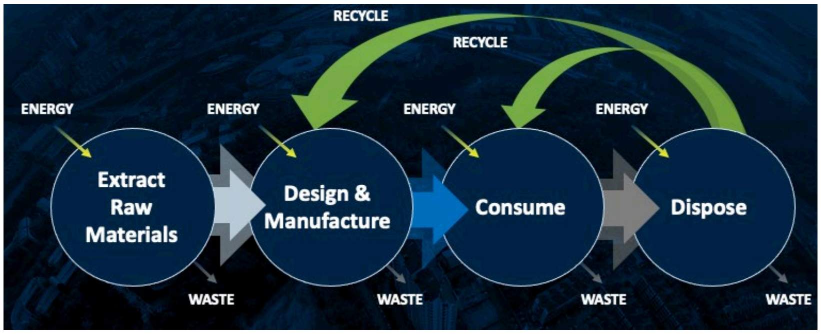
This report addresses how industry leaders in the chemical and petrochemical industries are leveraging digital technology as key component of the transition to a circular model of production and consumption and as part of an overall path to sustainability of operations. digital twin and process engineering simulation tools, supply chain management and predictive maintenance tools are valuable digital capabilities to help advance the circular economy. Key findings of this research include:

- Chemical companies are transforming value chains and services to meet customer demand for sustainable products.
- Digital solutions are instrumental for the advancement of circular economy.
- Partnering across the value chain will reduce supply chain complexities and drive down costs of circular solutions.

- Circular economy is not just about recycling plastics but applies to all segments of the chemicals production value chain.

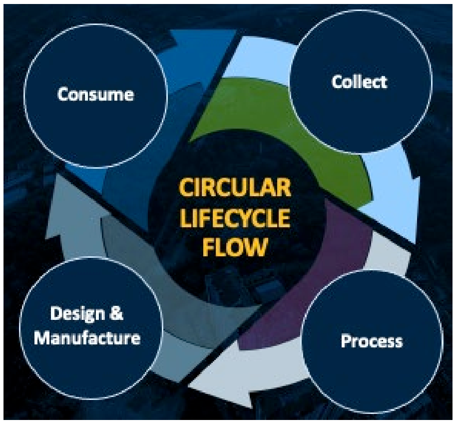
What Is the Circular Economy?

Sustainability goals and environmental, social, and governance (ESG) mandates have taken the forefront of almost every business sector. Sustainability at the highest-level means fulfilling the needs of current generations without compromising the needs of future generations while ensuring a balance between economic growth, environmental care and social well-being. For the chemical industry sector, this challenge impacts the entire value chain, including raw materials, manufacturing products materials and components and consumption by consumers and disposal.



The Linear Lifecycle Flow

The chemical lifecycle today is linear, where raw materials are extracted, products are designed and manufactured, then consumed by customers, and disposed of as waste. Each step of the process consumes energy and creates waste products. A circular economy, however, is a model of production and consumption which involves reusing end products as feedstocks or re-manufacturing, recycling and reducing waste and emissions considering the complete material flow. Circular economy aims to eliminate the extraction of new raw materials and design a circular lifecycle with the extraction, design and manufacturing, consumption and disposal being fully integrated. Waste and emissions are systematically reduced or eliminated throughout the entire process.



Circular Economy Impacts the Entire Value Chain

Challenges in Advancing the Circular Economy

Beginning in the first quarter of 2022, ARC Advisory Group conducted research surveys and interviews of industry leaders to analyze and benchmark the current state of circular economy initiatives across the chemical, polymers and specialty chemicals industries. A global audience of more than 200 industry professionals from R&D, operations, technical management, supply chain, and other roles provided valuable data to provide insights into the top challenges, the relative importance of initiatives, key drivers and importance of digital solutions.

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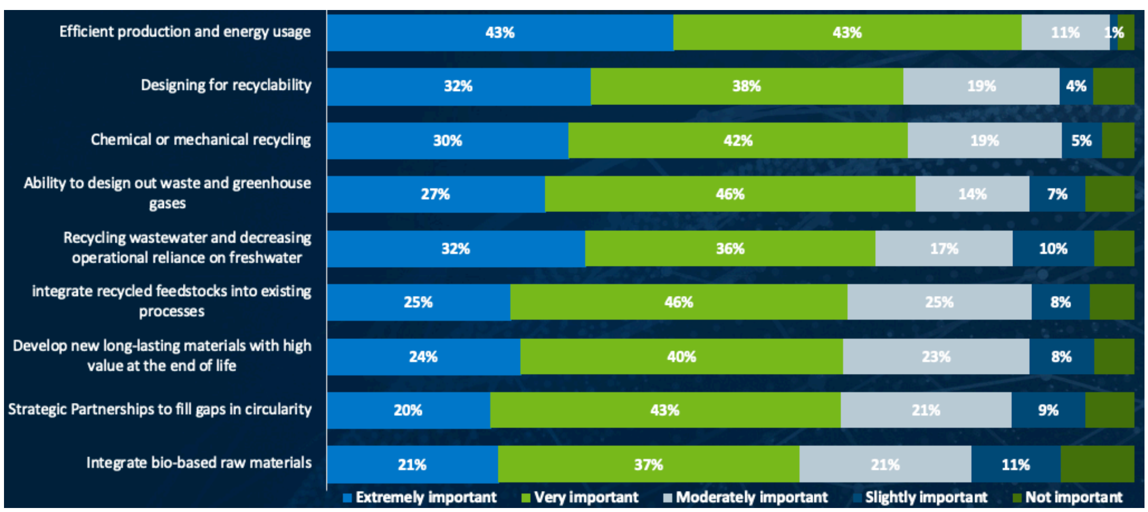
The research identified the top challenges in advancing circular economy goals as addressing complex supply chains, the lack of proven technologies, inconsistent regulatory policies, and a lack of economic viability. The supply chains for product circularity are undoubtedly complex. Turning post-consumer materials into feedstocks currently represents a complex supply chain challenge. The materials tend to be highly distributed, and the energy and carbon footprint required to move products back to the manufacturing source is costly and logistically complicated and difficult operationally. There is considerable research and development needed to address advanced recycling methods and make products cost-effective. From a regulatory perspective, government policy on recycling and waste differ significantly from country and region, with the European Union being at the forefront of policy for municipal waste and single-use plastic directives.

Important Initiatives Supporting Circular Economy Goals

Leading chemical R&D groups are now making investments in advanced chemical recycling along with the help of several smaller engineering firms (start-ups). Processes such as depolymerization and improved pyrolysis technologies to turn mixed plastic waste into naphtha or pyrolysis oil, which can be cracked into petrochemicals and plastics, will eventually decrease in cost and become more easily scaled and economically viable. Depolymerization is the process of converting a polymer into a monomer or a mixture of monomers into their raw materials for conversion back into new polymers. Over time these methods of advanced recycling will continue to be more cost effective. Key drivers for investments are to satisfy customer buying preferences and access to new markets.

An example of a company leading in circularity progress is Dow. Dow has a vision to turn the tide on plastic waste and solving challenges from designing to recyclability to encouraging local infrastructure to close the loop. The company views waste as a resource and invests in new product technology, value chain partnerships, business models and waste management infrastructure to scale sustainable solutions that extend the useful life of materials and the resources that go into making them. A few examples of how the company is collaborating to deliver solutions:

- Advanced recycling technologies and circular polymers using pyrolysis oil feedstock, which is made from plastic waste.
- Helping customers design for recyclability demonstrated that recyclable structures were possible for packaging applications that were previously considered unrecyclable.
- Working on value chains to explore regenerative business models and advance recycling technologies and infrastructure and partnering and improving waste management.



How important are the following initiatives supporting your company's circular economy goals?

Another industry leader LyondellBasell (LYB) is taking steps toward circularity by producing 2 million metric tons of recycled and renewable-based plastic polymers by 2030, zero plastic pellet loss to the environment from their facilities and tons of plastic waste diverted through the Alliance to End

Plastic Waste projects by 2030. The LYB Circulen brand of products enable customers to deliver sustainable consumer products using:

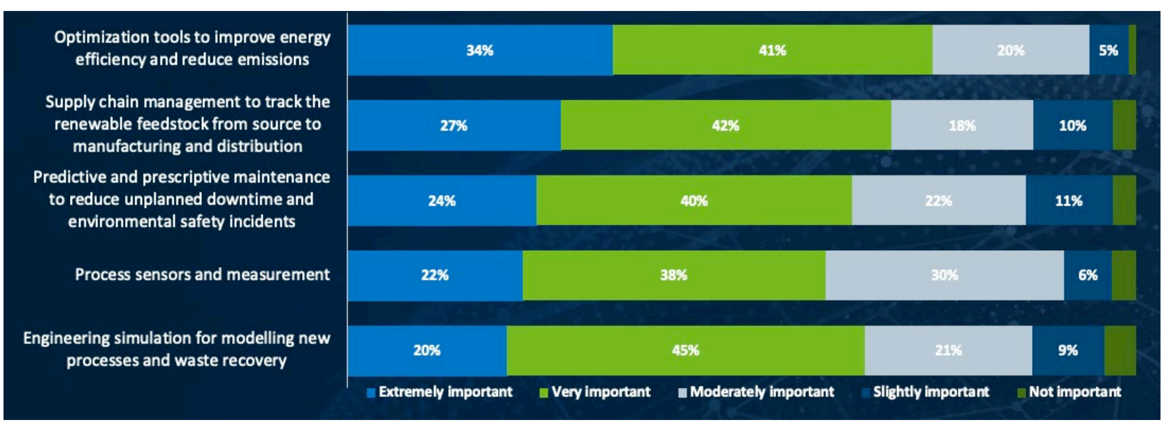
- Polymers made from plastic waste through mechanical recycling.
- Polymers made by converting plastic waste into feedstock to produce new polymers using an advanced (molecular) recycling process.
- Polymers made from renewable feedstocks such as used cooking oil.

The company recently announced renewable power purchase agreements with Engie and Buckeye to provide 216 MW of wind and solar in support of the company's goal to procure 50 percent of electricity from renewable sources by 2030.

Leading industrial companies measure circular economy progress by reporting on the recyclability of products and renewable energy consumption or efficiency or circular water consumption. Another commonly used metric is limiting the use of non-virgin materials in production. It was no surprise that our research identified the most important initiatives as focusing on making production facilities more efficient and improving energy management. Two-thirds of companies surveyed believe digital capabilities are of very high to extreme importance in achieving circular economy goals.

Digital Capabilities to Advance Circular Economy Initiatives

Optimization, supply chain management, predictive maintenance and Industrial IoT tools are valuable digital capabilities to help advance the circular economy.



Which digital capabilities are valuable to help advance Circular Economy?

- Digital Twin and process engineering simulation tools: to optimize energy use and reduce carbon intensity, model new processes for waste recovery and process re-design.

- Advanced process control (APC) to reduce process variability, optimize processes against constraints, and support autonomous operations. Dynamic optimization can also coordinate multi-unit processes to help close the gap between plan versus actual production.

- Supply chain management to coordinate, manage, and improve the transparency of connected processes across different organizational silos or value chain ecosystems and to track the renewable feedstock from source to manufacturing and distribution.

- Predictive and prescriptive maintenance to improve asset utilization and return on capital by use of machine learning and advanced analytics to shift maintenance operations to predict failures and avoid process disturbances and equipment downtime.

- Industrial IoT and the use of sensors and instrumentation will accelerate circular economy by helping organizations have better visibility of supply chains, bringing greater opportunities for control and innovation, such as material tracing, reverse logistics, decentralized production, and remanufacturing. Digital enablement of new business models and finding new ways to bring products or services to market are key capabilities in sustainable manufacturing.

Case Study: Digital Solutions to Maximize CO_2 Recycle and Minimize Off-gas Production

BASF is a German multinational chemical company and the largest chemical producer in the world. BASF is an energy intensive company actively working towards sustainability goals, primarily reduction of greenhouse gas emissions and achieve CO_2 -neutral growth by 2030.

BASF identified methanol synthesis as one of the main contributors of CO_2 emissions and wanted to minimize off-gas production in methanol synthesis process and avoid usage of fired heater typically used in the process without significant technology risks. The company utilized Aspen Plus to develop and optimize CO_2 emission-free methanol production process. Aspen Plus was able to support technical feasibility of new methanol production process for carbon-free syn gas generation in alignment with BASF emission targets. The simulation models were used to evaluate optimization of methanol synthesis and methanol distillation process, helping to identify and act on several improvements. In operations, the model is used to control operations and to understand key parameters in the reactor, such as heat transfer.

Recommendations

Larger chemical companies have clear ambitions and clarity on circular targets, which have been identified in their respective corporate sustainability reports. There is a lack of clarity with the end customer and understanding of what it takes for products and materials to become fully circular and thus creating an incentive to recycle. This adds to the problem of post-consumer products and the inadequate level of infrastructure for recycling. Getting more of the end-to-end value chain engaged, no matter the company's size will help. Government subsidies and policies will help get the circular economy started and ensure proper sorting of recycled materials.

During this initial development of circular economy, Chemical companies will reduce energy consumption, optimize existing facilities, and incorporate renewable energy and feedstocks. The circular economy is not just about recycling plastics and has a broader impact on all chemicals production value chain segments. Chemical companies are transforming value chains and services to meet customer demand for sustainable products, recognizing that digital solutions are instrumental in advancing the circular economy. Customer demand for longer-lasting products and products made from recycled material will increase, as will partnering across the value chain. This will reduce supply chain complexities and drive out the costs of circular solutions.

Based on ARC research and analysis, we recommend the following actions for owner-operators and other technology users:

- Consider all segments of chemicals production value chain when developing circular economy strategies.
- Implement supply chain management tools to reduce complexity and develop new technologies to overcome the lack of economic viability and inconsistent regulatory policy.
- Begin by looking at existing plants and facilities: Identify major emitting units and define efficiency strategies to lower emissions, including

process control and use of renewable energies to lower GHG emissions incorporating renewable energy.

- Use energy simulation tools to analyze energy usage and determine recyclability of products.

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