Accelerate decarbonization and sustainability transformation with smart manufacturing

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For process manufacturing companies in the downstream refining, chemicals, and materials industries, decarbonization and emissions reduction are critical for the path to net-zero. Due to their position in the value chain, reductions in their scope 1 (direct energy and process emissions) and scope 2 (indirect purchased energy and steam) emissions have impacts on the scope 3 emissions of various other industries, such as consumer goods, transportation, and construction, to name a few.[1] Many step-change reduction levers involve technologies and supply chains that are still evolving (e.g., carbon capture and storage, clean hydrogen).[2] There are, however, critical steps companies can take now to reduce their scope 1 and 2 emissions from existing assets and operations that will set them up for greater success when they can implement the larger transition levers that will achieve step-change reductions.

The industrial sector plays a large role in global energy consumption and, in turn, is responsible for a large portion of emissions. Per the IEA, "The industry sector in 2022 was directly responsible for emitting 9.0 Gt of CO2, accounting for a quarter of global energy system CO2 emissions."[1] While emissions have declined from 2020 levels, the IEA also reports they are not in line with the net-zero target of 7 Gt CO2 by 2030.[2] Of the industrial sector, the chemicals industry is the largest consumer of energy and the third-largest emitter of direct CO2 emissions, coming in at 935 MtCO2 in 2022.[3]

In addition, these industries are known as "hard to abate" due to the challenge and cost associated with reducing their emissions. Their scope 1 emissions can come from multiple sources, such as fuel and the process itself, requiring a robust strategy. The fuel is often used to achieve high temperatures that are not yet achievable with electricity. Despite these challenges, process manufacturing companies are setting emissions reductions targets and developing strategies to achieve their goals.

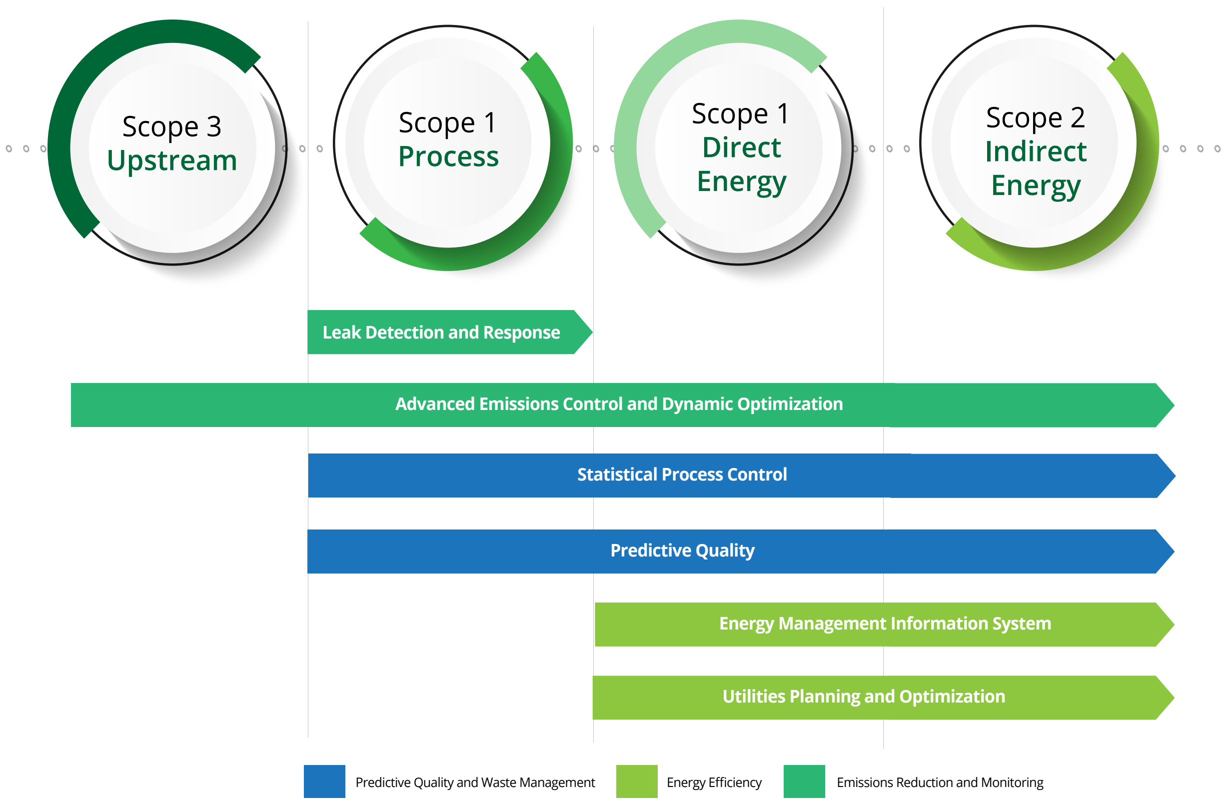
Our recent CxO study reveals that 68% of business leaders say that their company feels pressure from stakeholders to a large or moderate extent to act on climate change. [4] They acknowledge the urgency of sustainability but are often hindered by the complexities of integrating sustainable practices into their operations. While measuring, monitoring, and reporting greenhouse gas (GHG) emissions is an initial step in determining the environmental, social, and governance (ESG) performance baseline and identifying improvement opportunities, this step must be followed with actions to reduce the measured emissions from input energy (fuels and electricity), feedstocks, and the process. The same CxO report notes that 59% of companies are taking steps to increase energy efficiency, and 54% of companies are using energy-efficient or climate-friendly machinery, technologies, and equipment.[5]

1. Smart manufacturing for decarbonization and sustainability

According to a recent report from the US Department of Energy, process and energy efficiency technologies have a negative cost to implement (better than $100/ton CO2 based on a 10% return) and could abate up to 5 MtCO2 for the US chemicals industry.[6] Efficiency capabilities can optimize existing assets for lower emissions, energy, and waste by incorporating sustainability in their operational excellence programs.

Operational excellence has been traditionally focused on improving efficiency and effectiveness by improving overall equipment effectiveness (OEE) and its contributing components—availability, productivity, and quality. Now, that same operational improvement can and should be applied to decarbonization and sustainability transformation. According to the IEA's Net Zero by 2050 Roadmap, "energy intensity falls 4% on average each year between 2020 and 2030."[7] This improvement in energy efficiency, higher than that of the previous decade, is achieved partly through "a push to pursue all energy and materials efficiency opportunities."[8] With these goals in mind, sustainability should be incorporated as a key focus of operational excellence via reductions in emissions, energy usage, and waste generation. This can be achieved by adopting and scaling smart manufacturing capabilities oriented toward decarbonization. Our earlier study revealed that 86% of US manufacturers believe smart factories will be the main driver of competition by 2025.[9] Yet, only 5% have fully converted at least one factory to "smart" status, indicating a vast untapped potential.[10]

Figure 1: Mapping smart manufacturing technology capabilities to carbon sources



In the following sections, we will explore three key areas in which smart manufacturing capabilities can accelerate the decarbonization and sustainability transformation of process manufacturing companies. These capabilities and technology solutions address many sources of carbon—emissions, energy, and waste (figure 1). The unique operations profile of a process or facility should be considered when determining which of these capabilities and technologies to employ.

2. Improved emissions monitoring and management

Emissions monitoring and management can be applied to various emissions sources. GHG emissions can come from the fuel that is burned to heat the process, the process itself (e.g., CO2 exiting a wet gas scrubber or leaking equipment), or from the feedstocks used. Organizations must first determine which of these emissions sources will be addressed by the relevant technologies and then select the suitable available solution that can integrate with existing infrastructure. There are multiple technology providers using Internet of Things (IoT), drones, first principles, and digital twins, among other capabilities, to measure emissions and provide comprehensive emissions monitoring and management.

One prevalent capability combines leak detection via sensors with artificial intelligence (AI) and analytics to enable quick detection, isolation, and mitigation of the leak. This technology is applicable to a wide array of use cases, including fenceline and tank farms monitoring for Leak Detection and Repair (LDAR), providing early warning of leaks using gas sensors, wireless and IoT capabilities, and AI/machine learning (ML)-based analytics. Previously, leaks could go undetected for a long time, until a routine manual inspection was scheduled. As stated in one account of a refinery implementation, identifying the leaks and their sources and responding quickly to mitigate them could potentially reduce emissions by as much as 70 Mt per year for a typical refinery or chemical facility.[11] These solutions also support streamlined reporting for regulatory compliance.

Another capability is end-to-end emissions monitoring, control, and optimization. These solutions go beyond reactive leak detection and monitoring to allow for process visualization and optimization of emissions, including feedstock, energy source choices, and operational efficiency. A leading global cement manufacturer utilized plant data management and analytics capabilities to monitor, optimize, and control emissions and energy usage to reduce nearly 140,000 tons of CO2 in a year.[12] Some emissions management platforms even allow facilities to accurately report carbon emissions with a mass-balance carbon accounting approach as well as accurately predict emissions and carbon intensity.

Currently, process operations implement and adhere to safety and operability limit envelopes, alarms, and alerts for critical process variables. With the addition of emissions monitoring and reporting technologies, these operability constraints can be further enhanced to incorporate sustainability limits for emissions and energy usage. Based on these limits, alerts and alarms can be generated to identify emissions and leaks carrying environmental consequences with associated recommended mitigation actions to reduce the scope 1 emissions from operations

Proactive emissions reduction

Beyond emissions monitoring using Industrial IoT (IIoT) sensors, drones, and reactive response to incidents, organizations can utilize existing advanced process control and optimization solutions to proactively reduce emissions by defining the ESG "costs" of GHG emissions from manufacturing operations. This can be achieved by incorporating the costs and the constraint limits for emissions into the objective functions of the advanced process control and plant automation solutions, so that the sustainability criteria are considered along with the economic optimization. Ideally, the plant would have emissions targets and limits, as well as a plan for advanced control solutions to be implemented during manufacturing execution along with the production targets, so that the operating conditions are within those limits.

In addition, by mining historical plant data and process operations knowledge, AI/ML models can identify the operating conditions and patterns correlated with emissions and incident data from the past. Using insights learned from the data, plants can develop intelligent advisory models to determine and recommend the optimal operations parameter setpoints to run the process units with reduced emissions. Once trained and tested, such AI-based emissions reduction models can be integrated with existing process control solutions to enable autonomous operations.

3. Improved energy efficiency

For hard-to-abate chemicals and materials industries that burn fuels to achieve high-temperature operations, energy requirements are intrinsically linked to emissions. Multiple technologies and applications have arisen from the need to find energy efficiencies to achieve net-zero emissions and decarbonization targets.

Utilities optimization with opportunity identification is one such technology focused on optimizing plant processes, allowing operators to manage and optimize balancing energy across the production site. This capability is currently being used by a leading multinational chemical manufacturing company and has enabled it to reduce carbon emissions by 60,000 tons per year, as well as to minimize steam losses and reduce GHG emissions.[13]

Another capability is more suited toward management of the energy system rather than optimization of plant processes. Energy management and information systems (EMIS) monitor, schedule, and optimize in real time to provide insight into emissions, cost-effective energy production, distribution, scheduling, and trading. This type of technology has been implemented by the largest Latin American petrochemical company.[14] By incorporating the EMIS into its processing unit operations, it was able to automatically select the most appropriate energy source for its equipment, thus increasing efficiencies and stability.

Depending on regional availability of support, it may be beneficial to implement different fit-for-purpose vendor EMIS at various global facilities. A metals manufacturer was experiencing rapid growth and needed to implement a solution to contend with stricter emissions regulations, increased gas costs, and improved energy intensity. To meet these goals, the manufacturer looked to implement a solution to dynamically reoptimize inputs based on real-time data and optimize energy usage through a control system. Further, the manufacturer wanted to increase the transparency of the operations by increasing visibility into energy usage at each step.

Deloitte identified opportunities to improve efficiency and energy usage through a combination of process improvements and software solutions. Within these opportunities, Deloitte provided multiple options for EMIS that would allow the company to choose from selected EMIS that fit each site's needs. The Deloitte team also provided physical process improvements to reduce downtime and energy losses that coincided with the EMIS to achieve sustainability and energy savings goals. The implementation was rolled out utilizing multiple EMIS, driving 10% reduction in energy intensity for each plant. This, in turn, reduced emissions by lowering the amount of energy input needed throughout each step.

Energy and utilities optimization

Beyond energy monitoring and reactive management, two factors largely enable proactive energy optimization to transform energy efficiency: the amount of energy and utilities data a plant can collect and the degree to which it can leverage predictive insights from that data for optimal operations recommendations. While data collection can be highly reliant on hardware and networks, optimization depends on software utilizing AI, machine learning, and advanced analytics platforms to achieve improved efficiencies. Typical key steps in this journey are to define the energy management strategy and road map for operations, develop improved processes and operating procedures to minimize energy usage and loss, and build a business case for advanced energy and utilities optimization solutions for dynamic energy supply/demand balancing.

Smart manufacturing capabilities present a significant opportunity to improve industry energy efficiency. By analyzing historical energy and utilities usage data against associated process data and events, AI models can learn operations patterns and provide insights. These models can determine the optimal operating conditions and process parameter settings to balance energy demand and supply, and to minimize energy usage and losses, leading to cost savings and reduced emissions. The optimization and balancing of planned energy consumption with energy supply from diverse sources, including renewables, can be performed while minimizing energy losses. End-to-end energy optimization starts with energy demand and supply planning. It then entails real-time monitoring and control to balance utilities and energy sources and sinks. Organizations can integrate these advanced energy optimization capabilities with existing EMIS.

4. Improved quality conformance and waste minimization

As the manufacturing sector advances, the focus on sustainability is diversifying. While monitoring emissions and optimizing energy use remain central, there's a growing emphasis on proactive quality management and waste reduction. This comprehensive approach to sustainability extends beyond just traditional quality management and overall asset efficiency. It encompasses every aspect of the manufacturing process, from design and sourcing to delivery and service. The move toward a more environmentally conscious future is closely linked with these diverse efforts, ensuring that each stage in the production process is eco-friendly.

The data on waste generation in the United States underscores the importance of quality control and waste minimization in manufacturing processes. In 2018, the United States generated approximately 292.4 million short tons of municipal solid waste.[15] Concurrently, research from MIT indicates that the generation rates of non-hazardous industrial waste (NHIW) were on the same order of magnitude, with estimates ranging from 246 million to 316 million US tons annually.[16] The Toxics Release Inventory (TRI) Program, which tracks specific chemicals due to potential health and environmental implications, reported that, in 2021, the United States managed 29.3 billion pounds of production-related TRI-listed chemical waste.[17] Of this, approximately 3.22 billion pounds were disposed of or released into the environment. These figures highlight the imperative for industries to adopt rigorous quality compliance and waste minimization approaches.

In the dynamic world of plant operations, Deloitte's Smart Manufacturing capabilities are pioneering the integration of predictive quality and smart statistical process control (SPC) to optimize production. Deloitte's approach to smart SPC standardizes data, visualizes performance trends, and dynamically adjusts control limits. In an implementation for a manufacturing company, Deloitte's Predictor & Solver solution used advanced analytics to optimize machine settings to enhance material flow and reduce waste. This intervention led to an impressive annual EBITDA improvement of $1.3 million, with primary value drivers being reduced waste, increased profitability, and heightened operational efficiency.

Predictive quality and process control to prevent quality deviations

A key challenge for the process industry is that performing quality test analyses of collected samples and receiving results takes a significant amount of time, during which deviations from product quality and wastage can occur. Predictive quality capability enables sustainable and safe production practices by proactively controlling production quality within specifications and minimizing waste. By leveraging AI/ML models, predictive quality can recommend adjustments of process variable parameters and equipment settings based on process data inputs. These predictive quality models can be developed using historical process and events data aligned with quality test results data from laboratory information management systems (LIMS). The models can be trained to predict key quality characteristics properties in real time based on process data and to provide the process control setpoint changes needed to keep the product quality within specifications.

For a plastics products manufacturer, Deloitte developed a model predicting process anomalies well in advance, with troubleshooting and interventions leading to a potential value of $10 million across the plant network and an additional 40,000 pounds of production annually per line. The primary benefits were a significant reduction in waste and downtime, and a streamlined root-cause analysis and quality review process. The above-described innovative capabilities in Deloitte's Smart Manufacturing offerings signify a transformative shift in quality and waste management. They emphasize not just the integration of advanced technologies but a holistic approach to quality, efficiency, and sustainability, providing manufacturers a competitive edge in today's market.

5. How to get started on smart manufacturing-enabled decarbonization and sustainability

Similar to the safety and health transformation journeys of the previous decades, the transition to sustainable manufacturing is both an imperative and a challenge. Industries today face several complexities, from technological shifts to evolving regulatory landscapes. Traditional processes, reliant on fossil fuels for high temperatures, pose significant hurdles in the shift to sustainable alternatives. Yet, amid these challenges lies the opportunity to redefine manufacturing for a greener future. Recognizing these intricacies is the first step in crafting effective solutions.

The future of sustainable manufacturing starts with the seamless utilization and integration of advanced technologies to achieve both sustainability and efficiency. Global decarbonization challenges need to be addressed from the perspectives of people, process, and technology. The role of organizational culture and change management in embracing these sustainability priorities and enabling new technologies cannot be understated. To achieve the ambitious decarbonization targets set for the coming years, sustainability should be truly embedded into operations and business culture, driving behaviors from key performance indicators to incentives.

It is imperative that the industry transform to a "sustainability culture," in which employees are empowered to advocate and ensure sustainable operations as a priority, enabling the success of the decarbonization journey toward net-zero.

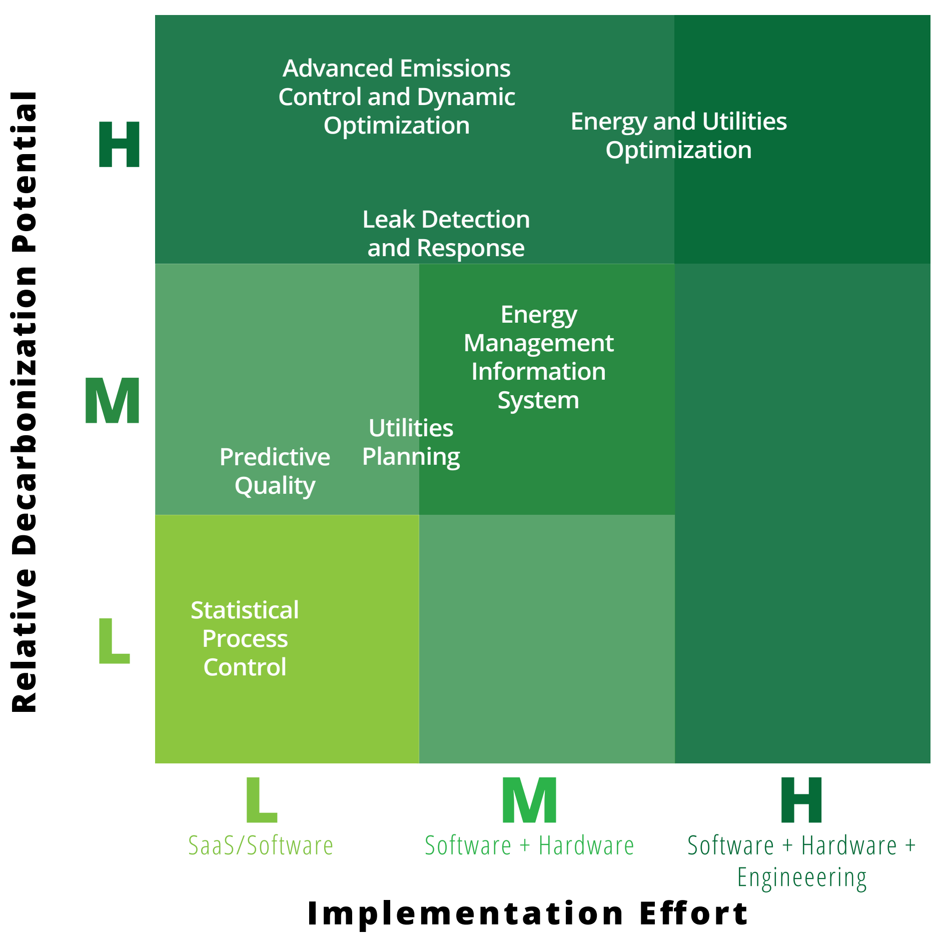
Companies also need to consider their unique operational challenges in achieving their sustainability goals. Beyond developing an overall corporate sustainability and decarbonization strategy, they should develop a multiyear plan and road map to achieve those targets along with the operating model and organizational change management to enable the transformation. Defining and prioritizing the initiatives for transforming existing brownfield plants and operations utilizing smart manufacturing technologies such as artificial intelligence, machine learning, IIoT, and advanced analytics should be a key part of these efforts.

In addition, the capabilities of the workforce of the future—including skills, talent, and training—should be defined for the roles, responsibilities, and requirements of key stakeholders. Then companies should develop business processes for how these personas interact and collaborate to resolve adverse events in a closed-loop fashion, utilizing these advanced technologies and solutions to their fullest potential.

Choosing fit-for-purpose technologies to achieve your goals

The synergy of technology and decarbonization is reshaping manufacturing. As industries embrace these state-of-the-art technologies, they not only reinforce their commitment to sustainability but also carve out a distinct market niche. Emissions reduction, energy efficiency, predictive quality, and waste reduction technologies are all beneficial goals for any company, but how do they contribute toward overall decarbonization goals? Subsequently, how can these technologies be layered into an existing operational excellence program? The technologies reviewed here have differing emissions reduction potentials, as well as differing software, hardware, and organizational needs. For instance, in emissions reduction, leak detection tackles a very discrete set of emissions, requires sensors, and needs software that is likely net new to the operational excellence program. On the other hand, an EMIS reduces a different source of emissions, but also requires hardware and software. In the case of the emissions control and dynamic optimization, some of the sensors, monitoring, and process models may already be in place, but software capabilities bring a more advanced approach and integrations to end-to-end emissions management. The matrix in figure 2 depicts the relative decarbonization potential (compared to the current status quo) versus the effort for implementation of these technologies (based on the solution type) for consideration.

Figure 2: Relative Decarbonization Potential and Implementation Effort for each smart manufacturing capability



6. Deloitte as the trusted partner in your journey to net-zero

Digital transformation underpins the factories of tomorrow. Deloitte's commitment to this vision is evident in our investments in innovation and development. At The Smart Factory @ Wichita, we've developed, deployed, and now operate use cases aligned with decarbonization and sustainability transformation. From energy efficiency to predictive quality, our initiatives help ensure manufacturing processes are optimized for reduced waste, emissions, and energy consumption. At our global smart factories and smart warehouses, we leverage intelligent automation technologies to create systems that are not only efficient but also adaptive and self-optimizing.[18]

By forging strategic collaborations with technology leaders and providers worldwide, we aim to pool collective experience, share insights, and co-develop tailored solutions for the factories of the future. Our research indicates that manufacturers that prioritize ecosystem collaboration are three times more likely to achieve advanced levels of smart factory maturity compared to those that don't.[19] This ecosystem-driven approach is pivotal, as 85% of manufacturers believe that ecosystems are the primary vehicle for improving the competitiveness of their business.[20]

As regulations evolve, so do the ESG risks for companies. Visibility and performance improvement become paramount. Deloitte's Sustainability 360™, powered by Salesforce, offers a comprehensive solution. This modular service provides a holistic view of sustainability performance, helping businesses detect risks, uncover operational improvements, and stay attuned to changing regulatory requirements. In addition, Deloitte's GreenSpace Tech service navigates the rapidly changing climate tech landscape and identifies opportunities for organizations to both decarbonize and create a sustainable competitive advantage. As a global orchestrator, Deloitte connects climate technologies to industry via an ecosystem spanning startups, research institutes, incubators, accelerators, and universities. We combine startup commercialization and climate knowledge to support industry in unlocking value through the integration of climate technologies.

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Endnotes

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