Process Electrification to Drive Industrial Decarbonization

William Grieco ▪ **Ignasi Palou-Rivera** ▪ RAPID Manufacturing Institute®

Whether motivated by customer or shareholder demands, evolving global regulatory frameworks, or a drive for more efficient production, manufacturers are increasingly focused on decarbonizing to meet sustainability targets. Industrial decarbonization can be defined as reducing net carbon emissions per unit product output. Manufacturers look to achieve such reductions by developing more efficient processes that use less fossil energy per unit output, and/or by adding emissions control technologies that capture carbon emissions at the production site. Process electrification that exploits the increasing amount of renewable power is emerging as a viable tool for decarbonizing the chemical process industries (CPI).

Process electrification encompasses a broad category of technical options that use electricity as the driving force for process operations. Many of these technologies substitute electricity for traditional fossil-fuel-fired, thermal processes that are common in the CPI. Driving sustainability through electrification typically involves connecting production to renewable generation assets that are located near the site or that are a part of the existing electricity grid.

Process heating, electrochemical processing, and energy storage represent three opportunities for innovation in process electrification.

Process heating of process streams via electricity includes the use of electromagnetic (*e.g.,* induction, microwave, plasma) and heat pump technologies in place of traditional fossil-fuel-fired heating. Electromagnetic heating offers:

• more precise temperature control, including targeted heating of reaction surfaces (*e.g.,* catalytic materials) to decouple reaction surface temperatures from bulk temperatures and improve process yields

• faster response times for rapid startup and shutdown of processes

• broader turndown across a range of operating conditions.

While development of electromagnetic technologies is progressing, current implementations are largely limited to pilot operations. Deployment to commercial operation will require more efficient electromagnetic power sources and modular platforms.

Heat pumps also offer an alternative to traditional steam or oil heating of process equipment. With novel working fluids such as carbon dioxide that operate across broader temperature ranges than steam, heat pumps can be tuned to provide high- and low-temperature heat across flowrates typical to chemical manufacturing. High-temperature heat pumps are not yet ready for full commercialization, because their heat-exchange components are too costly and sensitive to support long-term operation.

Electrochemical processing is the use of electrochemistry in place of or alongside traditional thermochemical or biochemical production methods. Electrochemical processing is already commonly used to produce aluminum, adiponitrile, chlorine, and caustic soda. Electrolysis is also used to produce hydrogen as a more sustainable alternative to steam methane reforming.

Despite these commercial applications, electrochemical processing has not been applied broadly across the CPI due in part to slow development of electrodes, complex requirements for electrochemical cell fabrication and operation, and high capital and operating costs. However, spending on research and development in this area is increasing. Electrochemical reduction of carbon dioxide to C1 compounds (*e.g.,* carbon monoxide, formic acid, and methanol) has been demonstrated and is scalable, and the pace of applied research on cell development for the production of C2 and higher compounds (*e.g.,* ethylene, propylene, dimethyl ether, etc.) is accelerating. Development efforts must focus on demonstration of these process technologies at scale and over a range of operating conditions and feedstock qualities.

Energy storage in the CPI involves integration of electricity storage (*i.e.,* batteries) at manufacturing sites to manage renewable asset intermittency. For example, commercially available lithium-ion or redox flow batteries could be installed at or near production plants to manage intermittent photovoltaic- or wind-generated electricity.

Another application of energy storage includes the use of electrified chemical manufacturing as a grid-scale energy storage option. For example, renewable electricity can be used to convert water to hydrogen or natural gas to methanol in reversible reactions that store the energy in chemical bonds. When energy is needed, the reaction can be reversed to free it from the chemical bonds. This is a more complex integration of chemical manufacturing with electric utilities, but it offers a unique opportunity to time-shift renewable electricity production and store those electrons as high-value chemical products.

In both of these applications, implementation of energy storage will be site-specific, depending on the type and availability of renewable electricity assets, potential intermittency, and electricity demands of the operation.

Process electrification to date has mostly focused on the direct substitution of electrified options for conventional thermal technologies. Large-scale industrial decarbonization will require more thoughtful integration of process electrification technologies. Near-term solutions might include novel induction and microwave systems that offer more-efficient process heating to reduce carbon emissions and improve yield. Options for the future might include factory-produced, standardized modular platforms that enable cost-effective electrolysis. These platforms could become a mainstream method for distributed hydrogen production, a key feedstock for carbon dioxide upgrading to other hydrocarbons. Similarly, electrochemical processing modules with various cell configurations could enable distributed carbon dioxide upgrading to C1 and higher compounds. Each of these cases will require development and demonstration of more efficient electromagnetic power sources and more robust electrode and membrane materials.

To identify some of these development and demonstration needs, the RAPID Manufacturing Institute has chosen to focus the next DEPLOY workshop on the topic of process electrification, to be held at the 2022 AIChE Spring Meeting in San Antonio, TX. We look forward to working with attendees to identify novel process electrification options that are technically and economically attractive, meet market needs, and drive sustainability across different industries. CEP