Turning Distributed Low-Value Wastes into Sustainable Products

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Processes that use organic wastes and byproducts as feedstocks are typically operated locally and utilize point sources of waste, which can make them difficult to scale up. Many of these reuse solutions have high capital and operating costs, and are not as practical as common alternatives, especially landfilling. Further, many waste streams are distributed and heterogenous — *e.g.,* variable biomass waste, contaminated recycled plastic streams, and mixed plastics in municipal solid waste (MSW) — which complicates recycling.

Commercially successful production processes usually rely on feedstocks that are easy to collect and transform at a high yield and low cost, such as natural gas and crude oil feedstocks used throughout the chemical process industries (CPI). Waste feedstocks are inherently low cost, but can be challenging to collect, prepare, and transform into high-value products. The U.S. government and private sector groups have worked to address reuse challenges; from these projects, we have learned that:

- solids handling is usually much more difficult than anticipated
- careful scaling of new unit operations is critical
- designing processes that are feedstock-agnostic is challenging.

Solids handling. Many process technologies to convert wastes to energy, chemicals, and fuels have been developed and demonstrated. Few, however, have been commercialized at scale and democratized across different industries and geographies — in part, due to the distributed nature and heterogeneity of the wastes. Wastes such as biomass, mixed plastics, and MSW are low density, bulky, and highly variable, which makes them difficult to transport and process.

Wastes are currently used as feedstocks in established processes where favorable market and regulatory conditions exist. Most of these processes use byproducts that would typically require environmental management, such as plants that convert waste to energy and production of renewable natural gas (RNG) from manure and landfilled waste.

Scaleup. Most new process technologies are developed at small scales and incrementally scaled up toward commercialization. However, financial and timeline pressures have, in some cases, forced large jumps in scale of these technologies, frequently resulting in problems, delays, and the eventual cancellation of development.

Determining the optimal scale for successful commercial use early in the development process is nearly impossible. Processes traditionally need to be large enough to take advantage of economies of scale, but also small enough to be an acceptable investment for first-of-kind, commercially unproven technologies. Most integrated process demonstrations (*e.g.,* integrated biorefineries) have been scaled too quickly and to too large of a scale, resulting in generally low yields and operational issues. Solid, heterogeneous feeds present an even greater scaling challenge because they are often poorly characterized and vary in availability and geographical location.

Feedstocks. Market and regulatory pressures are driving the need for sustainable solutions for waste reuse and upgrading, as well as for manufacturing products with less environmental impact. But producers and consumers typically favor sustainable solutions that are commercially and technically similar to current product offerings. The enthusiasm for sustainability decreases when solutions are more radical and/or more expensive. Unfortunately, simply substituting more-sustainable feedstocks, such as waste, into traditional processes is not feasible.

With these challenges in mind, the RAPID Manufacturing Institute virtually convened experts from industry, universities, and the national laboratory complex for the first DEPLOY workshop. Attendees worked together to better identify key problems and brainstorm potential solutions to address the three key steps of waste reuse:

- collection, sorting, and transforming waste into uniform feedstocks
- conversion of uniform feedstocks to an intermediate product
- upgrading intermediates to final value-added products.

Attendees suggested the development of refined and consistent technoeconomic models that properly value waste materials, account for environmental benefits, and consider the real cost of carbon. These models could also incorporate comprehensive lifecycle assessments and map their results to the United Nations Sustainable Development Goals (SDGs). In addition, the attendees identified the need for better technology roadmapping to allow technology developers and users to more easily identify process options for sustainably converting wastes to value-added products.

RAPID is committed to working with its member community to develop new tools and demonstrate process technologies that make sustainable, cost-effective waste reuse processes a reality. CEP