SMI INSIGHT
FROM CONCEPT TO CAPABILITY

U.S. NEEDS "NATIONAL SCIENCE-AT-SCALE COLLABORATIVE" TO RESEARCH AND SCALE PROCESS INNOVATIONS FOR CHEMICALS AND CRITICAL MATERIALS

By David Howell, Vice President

KEY POINTS

- The United States excels at scientific discovery but struggles to scale laboratory breakthroughs into domestic industrial capacity, creating a critical "missing middle."
- Maintaining U.S. leadership in chemical processing and critical materials will require faster adoption and commercialization of process innovations.
- A National Science-at-Scale Collaborative would unite DoE, Argonne National Laboratory, academia, and industry to accelerate technology scale-up and deployment.
- Pilot-scale infrastructure, demonstration facilities, and techno-economic analysis are essential to de-risk emerging technologies and attract private investment.
- Domestic critical mineral supply chains depend not only on resource development, but also on innovations in processing, refining, recycling, and advanced materials manufacturing.
- Strong public-private partnerships can transform fragmented research and industrial capabilities into a continuous pipeline from scientific discovery to commercial impact.

The United States does not lack innovation in chemical processing – it lacks the national determination to scale it. The U.S. faces a dilemma on two fronts: how to effectively fill significant gaps that exist in domestic chemical processing capacity in areas like critical materials and how to ensure the nation's established chemical processing industry remains competitive for decades to come.

Federal policy has elevated supply chain security as a national priority. Programs and policies have been implemented to establish domestic production to fill critical processing gaps. Nevertheless, it is also clear that processing-as-usual may not be the remedy to ensure U.S. manufacturers remain competitive in the long term. Research institutions continue to push the boundaries of materials science. However, the path from laboratory breakthrough to domestic industrial capacity remains fragmented. Bridging this gap – the "missing middle" between research discovery and commercial deployment – will be essential to building a resilient, secure supply chain. Doing so will require a deliberate partnership between the Department of Energy (DoE), national laboratories such as Argonne, and the nation's chemical industry.

The urgency of this challenge is clear. How long can the established chemical processing industry remain competitive with foreign competition using conventional processing methods? The pace of process innovation has accelerated, and economies across the world are rapidly scaling. The domestic industry cannot afford to move forward based on legacy timelines.

Demand for critical minerals – lithium, nickel, cobalt, graphite, and rare earth elements – is also accelerating rapidly, driven by electrification, grid storage, and advanced manufacturing. At the same time, global supply chains remain highly concentrated, particularly in processing and refining. While the U.S. has taken meaningful steps to diversify supply and reshore capabilities, domestic capacity across the full value chain – from extraction, through refined materials and precursors, to advanced material components – remains limited. This is not simply a question of resource availability; it is also a matter of coordination, translation, and scale – each necessary to de-risk process innovations, accelerate market entry, and enable large-scale commercial production.

Historically, the United States has excelled at early-stage research and at downstream innovation, but has struggled in the intermediate scale-up phase where technologies are proven, de-risked, and prepared for industrial deployment. In the context of critical minerals, this "missing middle" is especially acute. New separation technologies, recycling processes, and alternative chemistries emerge from laboratories each year, yet relatively few are translated into commercial-scale operations within U.S. borders. The result is a persistent gap between what is technically possible and what is industrially realized.

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This is precisely where a "National Science-at-Scale Collaborative" partnership between DoE, Argonne National Laboratory, and the chemical industry becomes indispensable.

DoE plays a critical role as the architect of national strategy and the provider of catalytic funding. Through programs focused on supply chain resilience, advanced manufacturing, and energy innovation, DoE has the ability to define priorities, align stakeholders, and reduce early-stage risk. However, policy direction alone cannot produce industrial outcomes. To move technologies beyond the lab, these initiatives must be tightly coupled with institutions capable of bridging research and commercialization.

Argonne National Laboratory is uniquely positioned to serve as this bridge. With deep expertise in materials science, process engineering, and techno-economic analysis, Argonne operates at the interface between fundamental discovery and applied innovation. Importantly, it brings capabilities that are often inaccessible to individual firms, including pilot-scale facilities, advanced modeling, artificial intelligence, machine learning, and lifecycle assessment tools. These assets enable the validation, optimization, and scaling of new technologies in a pre-commercial environment – precisely the functions required to close the missing middle.

Yet even this is not sufficient without the active participation of industry. The chemical sector, in particular, is central to critical mineral supply chains, from processing and refining to materials synthesis and recycling. Industry partners bring not only capital, but also operational expertise, market access, and the ability to integrate new processes into existing value chains. Without their involvement, technologies remain stranded in demonstration phases, unable to achieve the scale and cost competitiveness required for real-world impact.

The "National Science-at-Scale Collaborative" partnership's strength is in its complementarity. DoE can convene stakeholders, identify and assist impactful process innovations, and help scale them with industry to de-risk market entry; Argonne, national laboratories, and universities can innovate, validate, and scale technologies with industry partners; and industry can deploy and sustain the chemical processing innovation scale-up. Together, they can create a continuum from discovery to commercialization that is currently missing.

To operationalize this collaboration, several priorities should guide action.

First, there must be a deliberate focus on pilot and demonstration infrastructure. Too often, promising technologies fail because they lack access to intermediate-scale validation. Expanding shared facilities – where national labs and industry can jointly test processes under realistic conditions – will be critical.

Second, techno-economic analysis should be embedded early and continuously. Many technologies falter not because they are technically unfeasible, but because they are not cost-competitive at scale. Institutions like Argonne are well-positioned to assess these dynamics, helping to direct investment toward pathways with the highest likelihood of commercial success.

Third, partnerships must be structured around long-term alignment, not one-off projects. Building domestic supply chains requires sustained collaboration across multiple stages of development. Mechanisms that enable ongoing knowledge exchange, co-investment, and risk sharing will be far more effective than fragmented, short-term engagements.

The stakes are high. Securing the chemical production and critical mineral supply chains is not only a matter of supporting the energy transition, but also of safeguarding economic competitiveness and national security. The U.S. has the scientific talent, industrial base, and policy momentum needed to succeed – but these strengths must be brought into alignment.

Closing the missing middle is ultimately a systems challenge. No single actor – government, laboratory, or industry – can solve it alone. But through intentional partnership, it is possible to transform fragmented capabilities into an integrated pipeline from innovation to impact. In doing so, the United States can move beyond supply chain vulnerability and toward a more resilient and self-sufficient critical mineral economy.