# REIMAGINING PROGRAM DESIGN AT DOE TO ACCELERATE TRANSFORMATIVE INDUSTRIAL TECHNOLOGY DEPLOYMENT AT SCALE

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**White Paper**

ACEEE

Smart Energy. Clean Planet. Better Lives.

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# About ACEEE

The **American Council for an Energy-Efficient Economy** (ACEEE), a nonprofit research organization, develops policies to reduce energy waste and combat climate change. Its independent analysis advances investments, programs, and behaviors that use energy more effectively and help build an equitable clean energy future.

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# Executive Summary

The industrial sector accounts for over 25% of U.S. energy use and greenhouse gas (GHG) emissions, making industrial GHG reductions vital to meeting climate stabilization goals. To reach net-zero GHGs, industry faces a multitude of daunting and parallel challenges in transforming how it sources and uses energy and raw materials, converts them into a dizzying array of products, and interacts with complex supply chains to meet consumer demands.

Numerous entities have called upon the Department of Energy (DOE) and its Advanced Manufacturing Office (AMO) to enable industrial decarbonization. The DOE and AMO have responded by developing a roadmap for industrial decarbonization, expanding USA Manufacturing Institutes, and building up support for Industrial Assessment Centers (IACs).

Growing societal demand for lower-carbon production, shifts in how energy is provided, and the limited time remaining to avert the worst climate impacts require changes in how both DOE and AMO partner with industry and other stakeholders to meet these challenges. In parallel, multiple stakeholders must work together to improve industrial competitiveness, prepare a diverse future workforce, and strengthen resilience.

This white paper explores how DOE and AMO can more effectively respond to these unprecedented challenges and accelerate the scaling of transformative technologies. AMO can build on the foundation of earlier industrial collaborations, incorporate external viewpoints on how to lower interaction barriers, consider new ways to finance major projects, and use agile programmatic approaches. ACEEE believes the focus must be on technology deployment, scale, and dispersion across the broad range of industrial activities and applications.

Our research shows that DOE and AMO can accelerate transformative technology deployment by pursuing the changes outlined below. We suggest that they pursue a phased approach with a mixture of quick wins, bigger stretch items, and parallel investments selected to prompt early progress, provide support for early transformative projects, and build experience.

- **Program management**. We suggest changes to move more efficiently and rapidly, including
    - Investing in staff members who are already experienced in working with industrial technology scale-up.
    - Tailoring approaches for large companies and consortia, small and medium-sized manufacturers (SMMs), light industry, international collaborations, and mega projects.
    - Adopting an agile, nimble, rapid learning and communication approach.
- **Procurement and contracting**. It is important for DOE and AMO staff to identify *how* to undertake procurement faster and with greater flexibility, while maintaining consistency with congressional direction. Changes to consider include the following:

  - Leverage the flexible financing, procurement, and multiparty collaborations that other agencies—such as the Department of Defense (DOD), the National Aeronautics and Space Administration (NASA), and Health and Human Services (HHS)—have found to be successful, including broader use of other transaction agreements (OTAs).
  - Leverage third-party state and regional administrating entities to accelerate procurement.
  - Support technologies through deployment, helping them to overcome implementation and scaling hurdles.
  - Providing tailored, low-burden procurement support for SMMs, such as guides on how to interface with AMO and leverage the DOD's approach to small businesses.
- **Financing/funding mechanisms**. Blended finance options should be considered because transformative technologies can cost $1–1.5 billion/project. Changes to consider include
  - Expanding coordination with the Loan Programs Office (LPO), Small Business Innovation Research program (SBIR), and Small Business Administration (SBA).
  - Packaging projects to better attract financing, including de-risking (where AMO can provide in-kind services with partners and national labs, thus lowering technical hurdles).
  - Leveraging commercial financing, philanthropy, green bonds, grants with regional/state GHG funds (e.g., the Regional Greenhouse Gas Initiative), or economic and community development funds, especially on diversity, equity, and inclusion (DEI).

Culture change will be a fundamental underpinning of this transformation. It will be vital to shift the emphasis to deployment, scale, and dispersion, to favor a proactive rather than reactive response, to establish an ecosystem of support, and to catalyze greater cross-pollination of ideas and experience to accelerate progress on reducing energy consumption and GHG emissions. To engage a broader portion of the broad distribution of industrial companies, a tailored, lower-overhead approach will be needed for SMM, light industry, and entrepreneurs.

AMO can upscale its vision, capabilities, and responsiveness to enable the dramatic changes needed in industry to effect energy and GHG reductions. It can tap its portfolio of technologies, practices, and industrial partnerships to spur adoption of transformative low-carbon technologies. A reimagined AMO can more extensively partner with industrial players, finance, and other agencies to catalyze change with speed and scale while developing a diverse workforce, improving competitiveness, and upgrading resilience.

# Introduction

The industrial sector accounts for more than 25% of U.S. GHG emissions (2,240 million metric tons [MT] $CO_2e$/year) (EPA 2021) and 32% of its primary energy use (19.4 quadrillion Btus, including feedstocks) (EIA 2021), making industrial GHG reductions vital to meeting the nation's climate stabilization goals. To reach net-zero GHGs, industry faces the daunting and parallel challenges of transforming how it sources and uses energy and raw materials, converts then into a dizzying array of products, interacts with complex supply chains to deliver the products, and meets diverse consumer demands—which will increasingly favor low-carbon products.

To avoid the worst impacts of climate change, there is an immediate need to rapidly reduce energy use and GHG emissions, accelerate reductions even more in the midterm, and mitigate hard-to-abate emissions in the longer term. Timing is critical given the projected climate impacts, which will continue to build.

Several entities (Nguyen and Hart 2021; House Select Committee 2021) have called upon the Department of Energy (DOE) and, specifically, its Advanced Manufacturing Office (AMO) to pivot to enable industrial transformation. DOE and AMO have been responding, developing a roadmap (Cresko 2020) for industrial decarbonization[1] as requested by Congress, expanding USA Manufacturing Institutes, and growing support for Industrial Assessment Centers (IACs).

To drive the transformation to a net-zero GHG industry, consumer preference for low-carbon products needs to be developed and supply chain adjustments need to be supported. Because transformations in how products are made will be needed to make low-carbon products, process technology research development and deployment (RD&D) will also be crucial.

While AMO has been at the forefront of supporting technology advances, the new drivers call for radical changes in how energy is provisioned and used, across all industries, at unprecedented scale, and within a compressed timeline. This will require new paradigms for how AMO interacts and partners with industry and other stakeholders.

In this work, we explore how DOE and AMO can respond to these unprecedented challenges in supporting the deployment and scaling of transformative technologies. Specifically, we examine the foundation of earlier industrial collaborations, provide external viewpoints on how interaction barriers can be lowered, consider new ways to finance major projects, and examine agile programmatic approaches.

[1] For this report, *decarbonization* refers to reducing atmospheric GHG emissions (in terms of $CO_2$ equivalents or $CO_2e$ attributable to industrial emissions).

# Foundation of DOE and AMO Industry Partnerships

## CURRENT PROGRAMS

As the key office in the U.S. government dedicated to improving industry's efficiency, productivity, and competitiveness, AMO is well placed to enable this transformation with all due speed, scale, agility, resourcefulness, and efficiency. AMO responded quickly to dramatic industrial needs during the natural gas supply crisis in 2005, helping industry save 98 TBtus, 9 million MT $CO_2e$, and $1.1 billion/year in the Save Energy Now program (Wright et al. 2010). Following the 2008 economic collapse, a portfolio of AMO investments spurred innovative industrial companies and entrepreneurs to create new products and jobs in renewable power, battery technology, and microelectronics. The DOE and AMO have a decades-long history of enabling the development and scaling of carbon capture utilization and storage (CCUS) technologies and pursuing utilization (KGS 2019; Solidia 2022). They have also engaged in regional initiatives to accelerate large-scale CCUS deployment (NETL 2019, 2021).

AMO is an office of DOE, and AMO is the technology development office dedicated to improving the energy and material efficiency, productivity, and competitiveness of manufacturers across the industrial sector. Both DOE and AMO can benefit from the learnings and recommendations summarized in this white paper. DOE is undergoing reorganization (DOE 2022), and some of the activities in AMO may be spread across multiple DOE offices. Hence, in this paper references to historical and current practices will be referred to as AMO and future references as DOE.

## FUNDING LANDSCAPE

In line with the challenges of transitioning to low-carbon manufacturing, congressional appropriations for AMO are up 50%, from $257 million in 2017 to $396 million in 2021. In parallel, AMO is being tasked with driving adoption, deployment, and scaling of transformative technologies, in addition to its challenging RD&D objectives. The bipartisan Infrastructure Investment and Jobs Act of 2021 (IIJA) and Energy Act of 2020 together authorized $62 billion in clean energy investments—and there is more on the way, including provisions in the America Competes Act, which is currently in a congressional conference committee aimed at working out differences between the House- and Senate-passed versions. Following is a brief description of the funding provided by these federal acts.

- **Infrastructure Investment and Jobs Act (IIJA)**
    - $8 billion for hydrogen RD&D and four regional hubs to aid the demonstration of production, processing, delivery, storage, and end uses of clean hydrogen.
    - $500 million for multiyear grants to further the ability to reuse and recycle clean hydrogen, minimize environmental impacts, develop alternative materials, and devise alternative disassembly and resource recovery processes for clean hydrogen equipment, including fuel cells.

  - $1 billion for clean hydrogen electrolysis program grants to further the ability to reuse and recycle clean hydrogen, minimize environmental impacts, develop alternative materials, and devise alternative disassembly and resource recovery processes for clean hydrogen equipment, including fuel cells.
  - $3.7 billion for CCUS facilitation, demonstration, infrastructure, and storage.
  - $50 million for assistance to states to help implement smart manufacturing.
- **Energy Act of 2020**
  - $25 million for a manufacturing demonstration facility to support the research and development of additive manufacturing processes, low-cost carbon fiber, and other advanced manufacturing technologies.
  - $28 million for the Clean Energy Manufacturing Innovation (CEMI) Institutes.
- **America Competes Act of 2022**
  - $4 billion to provide financial assistance to projects for installing and implementing advanced industrial technologies at energy-intensive manufacturing facilities.
  - $250 million toward environmental product declaration assistance.

# Approach

We conducted a review of the literature and a series of expert interviews to identify key challenges in deployment and scale-up of technologies, as well as possible strategies for overcoming any hurdles and accelerating the process.

## LITERATURE REVIEW

The literature review included exploring past and current approaches for spurring and accelerating transformative decarbonization technology deployment, scale-up, and adoption in the United States. This encompassed the following:

- DOE offices (AMO, Loan Programs Office (LPO) Advanced Research Projects Agency-Energy (ARPA-E)), including its Industries of the Future Program from the 1990s, the DOE industrial decarbonization roadmap, and the current reorganization that is underway.
- Other U.S. federal agencies that are closely involved in promoting technology development and collaborating with industry and the private sector through consortia such as the Department of Defense (DOD) and the National Aeronautical and Space Administration (NASA), including their Offices of Advanced Manufacturing (DOD MTP 2022; NASA 2022), procurement/contracting mechanisms and infrastructure, and legal statutes and authorities.

- Other federal agencies involved in non-decarbonization-related technology development activities—including the Department of Health and Human Services (HHS), which recently supported accelerated COVID vaccine development, scaled-up production, and widespread adoption—for transferable lessons that may be learned from such ventures.

- Other U.S. federal agencies and institutions, including the Government Accountability Office (GAO) and the U.S. Congress, that have direct impacts on and review authority for AMO activities.

- State government agencies and organizations involved in guiding and supporting energy-related development, promoting entrepreneurial manufacturing and industrial activities, promoting clusters, and developing an advanced manufacturing workforce (e.g., New York, Delaware, and Mississippi).

- Private and quasi-private organizations (such as Pecan Street Research) involved in promoting entrepreneurial technology ventures.

Our review also explored international decarbonization and technology acceleration as well as scale-up policies, programs, funds, and nascent initiatives, including the following:

- **Canada.** We explored key federal and provincial government entities involved in technology demonstration work, such as the Industrial Technologies Office at Innovation, Science and Economic Development Canada, at the federal level, which administers the Net Zero Accelerator, the Strategic Innovation Fund, and the Technology Demonstration Project (ISED Canada 2022a, 2022b, 2022c, 2022d). We also looked at provincial efforts in Quebec (aluminum) and Alberta (cement).

- **European Union.** Initiatives we examined here included continent-wide approaches through the European Union, as well as individual country initiatives. European Union efforts include the European Green Deal (European Commission 2019), the European Innovation Fund (European Commission 2020a, 2021a), and the Sustainable Industry Low Carbon (European Commission 2020c) initiative. We also looked at a wide range of public–private partnerships, consortia, and collaborative ventures working on active large-scale decarbonization technology projects in the steel, pulp and paper, hydrogen, cement, chemicals/petrochemicals, and food and beverage industries. Finally, we explored large-scale European industrial decarbonization demonstration projects currently underway in steel, pulp and paper, hydrogen, and other areas.

- **Japan.** Through its Ministry of Economy, Trade and Industry (METI), Japan is in the process of creating economy-wide and industrial-sector-specific decarbonization plans (Japan METI 2020).

- **Other international efforts.** We explored transnational and transcontinental efforts related to technology decarbonization. These include recent and past efforts in countries such as China, which through its National Development and Reform Commission's Department of

Resource Conservation and Environmental Protection has been working on the Top 1000 Program to reduce energy intensity in industrial sectors (Price, Wang, and Yun 2008).

In addition to these efforts, we reviewed several non-governmental and commercial efforts that are relevant to industrial decarbonization, including the following:

- UN-driven partnerships, such as the 24/7 Carbon-free Energy Compact.
- World Business Council for Sustainable Development Decarbonization Projects.
- The International Energy Agency roadmaps for hard-to-abate sectors such as cement.
- The World Bank and International Finance Corporation technology funding mechanisms.
- Climate financing and technology funding strategies through private commercial banks and philanthropic investment organizations.

## EXPERT INTERVIEWS

To augment the literature review and gather practical perspectives from individuals involved (currently and historically) in technology development, we also conducted interviews with more than 20 experts across industry, manufacturing trade associations, environmental and energy law, finance, state and federal governments, non-governmental organizations (NGOs), and former DOE staff who identified key areas in which AMO would greatly benefit from pursuing change.

The interview pool included experts from the iron and steel, aluminum, and pulp and paper industries; financial institutions such as the World Bank and International Finance Corporation; philanthropic climate-financing NGOs, commercial banks, and investment groups; energy law and advisory firms; and federal agencies such as DOD and NASA. We also reviewed industrial programs, including past DOE programs such as Industries of the Future and DOE Manufacturing institutes, and state government energy office programs. Approximately 25% of the interview pool had international industrial energy, technology, decarbonization, or finance experience, and offered comparative perspectives for consideration.

We questioned interviewees on a range of topics, including

- Program management considerations
- Suggested improvements to DOE program approaches
- Program best practices
- Procurement and contracting approaches
- Financing and funding mechanisms

- Tools and partnerships
- Alternative models for large budget industrial projects
- Supply chain considerations
- Small- to medium-sized business considerations

All interviewees consented to having their remarks shared publicly and with AMO. For the purposes of this research, information from interviewees is presented without attribution and in aggregate.

# DOE Program Design

Why is change needed? With industry facing pressure for rapid change, it is vital to focus on deployment of all currently available commercial technologies that can yield step-changes in the carbon intensity of products, while in parallel advancing RD&D for technologies that are even more transformative. The pace of change must be exponential—not incremental—to meet climate stabilization targets and keep pace with marketplace changes. DOE is well positioned to accelerate technology implementation even in an environment in which carbon emissions are still "free."

A reimagined DOE needs an expanded vision, capabilities, and responsiveness to spark this change. It is already pivoting from energy efficiency to decarbonization, but it also needs to similarly shift from a primary focus on research to a more balanced focus on supporting implementation. DOE can tap its portfolio of past technology developments, practices, and industrial partnerships by pursuing multiple implementation options and supporting development of a diverse workforce.

From the view of those we interviewed and ACEEE, decarbonization requires changes in DOE operations to enable rapid low-carbon technology demonstration, adoption, and scale-up. Our interviewees also emphasized the need for DOE and AMO to pursue change in several major areas, as we now describe.

## PROGRAM MANAGEMENT

The need to move rapidly suggests a need for changes in approach to speed up the identification, deployment, and scaling of solutions. Suggested changes include

- Being agile, nimble, and flexible in interacting with the private sector, and staying aware of industry needs.
- Translating RD&D into actions that result in low-carbon technology adoption.
- Increasing the focus on deployment and scale-up, such as identifying industrial parks close to "green" electric power sources (e.g., the Four Corners site in New Mexico, which is a former coal plant, converted to use renewable energy and is located near transmission lines).

- Being aware of changing market dynamics that will spur collaboration, as well as of competitive forces that may hamper partnerships (e.g., consolidation and market shifts in the steel industry).
- Broadening the base of DOE engagement with target companies that have strong sustainability commitments and/or are close to end customers (i.e., consumer-facing companies).
- Rapidly communicating learnings so that industry can see opportunities for next steps.

*How to Pursue Change*

- Invest in experienced and coordinated development of "Tiger Teams" across DOE. Hire staff members with science and engineering backgrounds who understand technologies and industry, and who can translate between government, engineering, finance, and the corporate C-suite for durable support.
- Have project managers facilitate projects through integration, problem solving, and first implementation (e.g., do not stop at R&D; aid deployment, too).
- Bring in technology managers from industry who are experienced in driving and implementing large projects.
- Enhance two-way communication with companies so that DOE clearly understands industry's priorities.
- Provide longer-term funding for major initiatives, such as flagship projects (i.e., strategic/major investments with singular visibility and impact), to drive science/engineering of core and applied knowledge.
- Develop clear validation metrics to show usefulness of new technologies to industry.
- Build relationships with company energy managers who are responsible for identifying deployment projects Leverage relationships at national labs and industry to identify the right private-sector contacts at these companies.
- Leverage the Better Plants Program's account reps who are assigned to work with companies, and then be proactive (rather than reactive) listening for needs and proposing and pursuing opportunities with industrial partners and national labs.
- Tailor a portion of outreach activities to small and medium-sized manufacturers (SMMs).
- Build on the success of IACs to connect with smaller companies at the local and regional level while also addressing carbon emissions.

- Encourage larger companies to engage their SMM supply chain partners in transformative-technology projects.

- Address "corporate welfare" concerns by developing project portfolios that work with multiple companies on deployments in multiple sectors while involving SMMs and large manufacturers across supply chains.

- Increase DOE presence and visibility at the center of innovation communities by providing easier access to DOE resources (e.g., DOD Defense Innovation Units in Silicon Valley; Austin, Texas; and Boston, Massachusetts) (DIU 2021).

### *Adjust Program Management to Needs*

Program management is a key focus area, especially given the recent GAO report identifying it as a critical element to improve as DOE is standing up a new clean energy deployment office (GAO 2021; AIP 2022). The GAO identified a need for expedited negotiations of project proposals and cost controls while still allowing adequate time for negotiations prior to entering into cooperative agreements. It also suggests DOE should work to oversee projects more consistently with solid scopes, schedules, and budgets. Project risk factors may also be mitigated by ensuring that awardees of DOE funds pay their fair share throughout the project; by setting—and sticking to—performance milestones; and by competitively awarding these projects. Given this input, suggested options to consider at DOE include the following:

- **Invest in experienced and coordinated deployment "Tiger Teams."** To successfully complete deployment projects, it is critical to hire staff members with engineering backgrounds who understand technologies and staff members who can translate information between government, industry technical staff, and the industrial C-suite. It is important to create a two-way process, so the needs of both sides are being heard and met. DOE is currently engaged in setting up "Tiger Teams," and AMO should consider how best to leverage these teams. Empowering line managers to make decisions is also important. Further, it may be valuable to enhance the communication between other DOE offices such as renewable energy, transportation, and electricity to ensure a holistic approach to AMO project selection.

- **Tap experienced technology managers**. AMO may want to consider bringing in technology project managers from industry who have experience implementing large, industrial-scale technologies to facilitate DOE demonstration/deployment initiatives.

- **Select relevant projects.** It is vital to select commercially relevant projects to ensure industrial interest in deployments and demonstrations. Projects should use agile development, rapid learning, entrepreneurial approaches, and an end-user commercial deployment focus to ensure rapid and efficient progress. A focus on reducing technology uncertainty and risk should be included to lower hurdles for adoption dispersion and scaling.

- **Tailor program streams**. To simultaneously drive reductions with large and SMM companies, it may be useful to establish tailored programs.

- Large companies have the financial/other resources and the willingness to try experimental projects and are more likely to serve as the laboratories for DOE initiatives. They have the balance sheet to be able to support larger investments and projects with greater risk.

- SMM companies may lack those resources, but they still play an important role in innovation, market connection, and understanding and responding to customer needs, especially across the supply chain, and they should not be left out. SMMs find it challenging to work with DOE and AMO, so it would be useful to develop a better mechanism to engage them. IACs that provide outreach to SMMs is a model that could be expanded. Also, state energy offices have had success in reaching SMMs, which is another model that could be leveraged.

- An approach to involve both large and SMM companies would be to encourage larger companies to engage their SMM supply chain partners in transformative technology projects as part of clusters. DOE would benefit from considering as many aspects as possible of the industrial ecosystem in developing its projects.

- The box (right) shows an example of a tailored approach from an EU–Japan Industrial Collaboration (EU-JCIC 2022b), where a focused help desk provides assistance for small and medium-sized enterprises (SMEs).

**EU-JAPAN Industrial Collaboration**

EU-Japan Centre for Industrial Cooperation
一般財団法人 日欧産業協力センター

Among new strategic priorities, a key one is reinforcing support for SMEs, with a particular focus on international aspects. SMEs represent the backbone of EU and Japanese economies. The share of SMEs in the economy is more than 99% for both EU and Japan, with a similar percentage of employment creation (70–80%). The Centre provides business services, tools, and information on procurement opportunities to SMEs through a focused help desk. For taxation purposes, in Japan, a company is considered an SME when its capital does not exceed ¥100 million (approximately $800.000) under the Corporation Tax Law.

- **Build relationships**. AMO could benefit from identifying the right contacts at companies and building strong relationships. It could work with specific groups of company personnel, such as energy managers, that are impactful and relevant to the demonstration and deployment projects. It may want to leverage relationships developed by DOE National Labs to identify the right private sector contacts.

- **Use an agile, low-friction approach.** DOE may want to focus on being agile, nimble, and flexible in interacting with the private sector while reducing the burden and friction associated with projects. One suggestion is to expand on the Better Plants Program idea of dedicated "account representatives" who are assigned to work with companies and serve as the main DOE contact point to help answer or coordinate responses to questions. Another existing approach is to use programs like the EPA Energy Star's Energy Treasure Hunts, where the EPA supports using an easy-to-use "loan closet" without a lot of red tape.

- **Develop a portfolio of projects and strategies working with industry**. To address corporate welfare concerns, DOE may wish to develop a portfolio of projects that lets it work with several companies on deployments, engaging multiple companies in a single partnership or consortium using other transaction agreements (OTAs), advancing multiple deployments in multiple industrial sectors, and engaging a range of small, medium, and large manufacturers across the supply chain.

## PROCUREMENT AND CONTRACTING MECHANISMS

Consistent with the congressional direction, it is important for AMO staff to identify *how* to undertake procurement faster and with greater flexibility, leveraging other agencies' learnings and finding ways to lower hurdles. Changes might include the following:

- Offering a faster, flexible contracting approach.
- Being easier to work with and ensuring lower transaction "friction" (e.g., the paperwork and cycles needed to execute programs/agreements), especially for SMM partners.
- Providing support for deployment-at-scale, which is not an area of traditional AMO focus.
- Harnessing flexible financing, procurement, multiparty collaborations, and consortia, including those to engage the supply chain (e.g., DOD, NASA, HHS) (NSIC 2022; DOD OIP 2022; NASA 2014, 2022; MITRE 2022a).

*How to pursue change*

- Consider OTAs, and leverage precedents from DOD and NASA OTA use (NASA 2014; DAU 2022; MITRE 2022b).
- Leverage third-party administering entities, such as state and regional entities, to speed procurement.
- Streamline the current notice of funding opportunity announcement (NOFA) process building on precedents from other agencies (e.g., NSF Planning Rings).
- Support technologies through deployment, helping overcome implementation and scaling hurdles.
- Set targets for transaction timelines.
- Provide tailored, low-burden procurement support for SMMs, including guides on how to interface with and market to AMO; offer simple explanations of the rules/procedures through which AMO must work under congressional authority; and leverage lessons from the DOD small business approach (DOD OSBP 2022).

### *Transform Procurement Flexibility and Speed*

Increasing the flexibility and procurement speed at DOE will allow the agency to better meet its mission and amplify the impact of its RD&D efforts. To speed up contracting and procurement, DOE might consider taking advantage of the following useful tools and strategies:

- **Harness the power of OTAs.** To enable faster contracting, DOE can leverage instruments such as OTAs, which exist within its current arsenal of contracting authorities. DOE may consider exploring how agencies such as DOD and NASA have used OTAs to their advantage to speed up contracting and procurement and learn more about how OTAs can best be used. DOD and NASA have successfully used OTAs in deployment efforts and to promote the commercialization of nascent innovative technologies that are commercially valuable to industry. Engaging with government procurement personnel at the General Services Administration (GSA), in addition to DOD and NASA, and DOE legal counsel, would facilitate learnings on OTA use. Agencies such as DOD and NASA appear to have similar language in their congressional direction and appropriations, which DOE could use as a precedent for its own interpretations and actions.

- **Leverage third-party administering entities**. Using third-party entities to administer procurement for deployment projects, including entities at the state or regional level, is an avenue to identify projects and move them along the procurement pipeline without onerous federal procurement paperwork. The DOD employs one such entity, the Defense Innovation Unit, which has locations in multiple innovation hubs across the country including Silicon Valley and Austin, Texas. The unit speeds up procurement, with cycle times well under 60 days. Reaching out to such entities may offer useful ideas for DOE to establish its own third-party entities and speed up procurement.

- **Streamline the procurement process and the current NOFA process**. It would be valuable to identify the current choke points in the procurement, funding, and collaborative processes and to resolve them and reduce transaction friction for private companies. NSF Planning Rings are one proposed strategy to use when feasible in place of the current NOFA process.

- **Coordinate with LPO.** Improving coordination between AMO, LPO, and ARPA-E will ensure that the priorities for accelerating deployment and scaling up projects are aligned and supported across agency offices, sending a unified signal on decarbonization goals.

## FINANCIAL/FUNDING MECHANISMS, TOOLS, PARTNERS

Blended finance approaches are also options to consider. Transformative technology implementations can require investments of more than $1 billion per project. Although AMO funding is significant, at this level, relatively few projects can be funded, so it is important to leverage across multiple entities to maximize deployment in multiple industries and locations in the country, and with multiple technologies. Changes might include

- Facilitate coordination among other agencies to maximize impact on major projects.

- Proactively develop an array of funding partners interested in joining DOE in transformative funding.

*How to pursue change*

- Facilitate and assist in assessing how grantees can meet capital needs in collaboration with other agency, state, and regional initiatives.
- Expand coordination with LPO, the Small Business Innovation Research (SBIR) program, and the Small Business Administration (SBA).
- Package projects to better attract financing, including de-risking projects, where DOE can provide in-kind services and lower technical hurdles with partners (e.g., national laboratories and department experts).
- Coordinate with green bonds issuers (e.g., Delaware Sustainable Energy Utility) to maximize leverage, as well as with Community Development Financial Institutions (CDFIs) and state economic development agencies.
- Leverage large grants with regional and state GHG funds such as Regional Greenhouse Gas Initiative (RGGI).
- Tailor support to the level needed for entrepreneurial companies. Examples of this strategy include making it easier for them to submit ideas to AMO via an information portal and making technical assistance and financing explanations more readily accessible and clearer. For more examples, see the DOD SBIR/STTR Innovation Portal (GCN 2021), Pecan Street (2022), the Mississippi V-Quad (Mississippi Development Authority 2022b), and the New York State Empire Development Corporation (New York State 2022).
- Leverage and coordinate with economic and community development funds, especially on workforce engagement, development, and diversity, such as the Mississippi Advanced Manufacturing Workforce Development (Mississippi Development Authority 2022a).

### *Adopt New Financial Approaches*

- **Package projects to better attract financing.** Grouping projects into portfolios that appeal to finance institutions and investors can help in securing their financing. Focusing on this element may also align with DOE's interest in leveraging private financing to a greater degree in deployment projects. This may also be helpful in de-risking a group of technology projects that face common challenges.
- **Support finance that leverages multiparty funds.** Because DOE's contracting/financing flexibility may be restricted depending on the type of language used in legislation (grants versus cooperative agreements versus financial assistance), the DOE may wish to consider ways to leverage multiparty funding of deployment projects. OTAs offer one mechanism for this approach to bring in other funders to a project. DOE funding already includes cost-

sharing requirements and non-federal funds are allowable if no other federal funding sources (besides DOE) are included.

- **Leverage commercial financing, philanthropy, and community development financing institutions, and port authorities and other public financing entities**. Green Bonds have been successfully used in projects. For example, the Delaware Sustainable Energy Utility (DESEU) used the first scalable green bond in 2007 and created a platform to standardize, aggregate, and scale efficiency and renewable energy environmental investments. It represents a good example for scaling by accessing capital markets and aggregating to achieve scale. The entity had bonding authority and used standard contracting paperwork (DESEU 2022). DOE could partner with these organizations to provide leveraged financing for large projects.

- **Allow private companies to fund technology projects.** Letting companies fund technology demonstrations allows industry to be an active participant in the deployment process. This is important to get buy-in, as ultimately industry is the end user of such technologies.

- **Tailor support to the needs of companies and entrepreneurs**. Use a tailored approach to first understand where technologies and entrepreneurial companies are on the development timeline and scale, and to then support these technologies to help enable more successful deployments. This approach has been used by the DOD's Defense Innovation Unit, which uses a portion of its funds to choose the innovation projects that are closest to commercial success and help them get over the last hump toward deployment.

## ALTERNATIVE MODELS FOR MEGA PROJECTS

Scaling up mega projects may require alternative project approaches, including

- Negotiate to achieve clarity on what is to be accomplished, by whom, when, and with what resources (scope, timing, and financial and personnel resources).

- Regularly check in to evaluate progress but balance the overhead burden for grant recipients and partners.

*How to pursue change*

- Partner with other countries and consortia on decarbonization implementation (e.g., the EU–Japan collaboration on industrial decarbonization technologies) (EU-JCIC 2022b).

- Support special entities that allow companies to work together, while not triggering U.S. antitrust laws.

- Contract for RD&D using performance-based support and incentives (e.g., a clear, documented agreement on budget, scope, and performance goals).

### *Spur Use of Alternative Models for Mega Projects*

The scale-up needs of decarbonization projects may vary greatly, from mega projects to transnational partnerships. The European Union and Canada offer several examples of such mega projects. AMO is in the process of ramping up its international activities and rebuilding partnerships; following are some key implementation aspects that it might consider in that process:

- **Facilitating landmark project partnerships**. It is valuable to engage with large industrial companies on landmark projects, as these organizations often have the personnel and monetary resources and motivation to undertake large new technology projects. For example, Sweden's HYBRIT project (2021) brings several industrial companies together to advance fossil-free steel technology. To avoid antitrust concerns that may arise in such scenarios, special entities can be established and used to allow companies to work together and not trigger antitrust laws. The federal government has mechanisms in place to fund special entities. Also, allowing industry to drive the project ensures that technologies have commercial value, which motivates industrial partners to carry the deployment project to a successful endpoint. It may be useful to leverage these landmark or flagship projects to spur technology adoption, and then replicate the implementations across an entire industry.

**Sweden HYBRIT Project**


The HYBRIT project was launched in 2016 as a joint venture between utility Vattenfall, iron ore producer LKAB, and steelmaker SSAB, with political backing and de-risking of the early stage. The project has the potential to reduce Sweden's total carbon dioxide emissions by at least 10%, which is equivalent to one-third of the emissions from the industry.

**ELYSIS Zero Carbon Aluminum Initiative**


ELYSIS is a technology company created through a groundbreaking partnership between two global industry leaders—Alcoa and Rio Tinto—to revolutionize the way aluminum is produced across the globe. The process eliminates all direct greenhouse gases from aluminum smelting and produces oxygen. Alcoa, Rio Tinto, the Government of Canada, and the Government of Quebec provided a combined investment of $228 million (CAD) to create ELYSIS and to see this technology reach commercial maturity.

- **Partner with other countries, consortia, developers.** OTAs offer models that may be used to build consortia of organizations to work on projects collectively for better outcomes. As international relationships are rebuilt, engaging with other countries on mega technology projects would potentially allow the DOE to leverage its funds for more substantial deployments of greater scale and speed.

- **Pool resources.** Projects can look to models of pooling resources across the federal government, state governments, industry, and other private companies. An example here is

Canada's ELYSIS zero-carbon aluminum initiative, which leverages funding from Apple, Rio Tinto, and Canadian federal and provincial governments (ELYSIS 2022). With vested interests in the commercialization of the technology and finance institutions helping to implement the project, ELYSIS funders are pooling financial and intellectual resources in a borderline commercial project. Pooling resources in this way offers a team approach and a combined consortium with industry.

## TIMING AND SEQUENCING OF CHANGES

It would be difficult to implement all the changes noted above at once, yet to fully support the needs of transformative technology deployment and scaling—and rapidly pursue impact—it is important that the path to step-changes be pursued promptly. As figure 1 shows, a phased change approach is one potential route to pursue. This approach offers a mixture of quick wins, elements that would be a bigger stretch, and parallel investments that could be selected to prompt early progress, provide support for early transformative projects, build experience, and spur learning with an agile approach.

Table A1 in Appendix A shows a more expansive collection of options that DOE could pursue to support the needs of transformative projects, drive leveraged financing, and expand the engagement of partners—including tapping a broader distribution of industrial players.

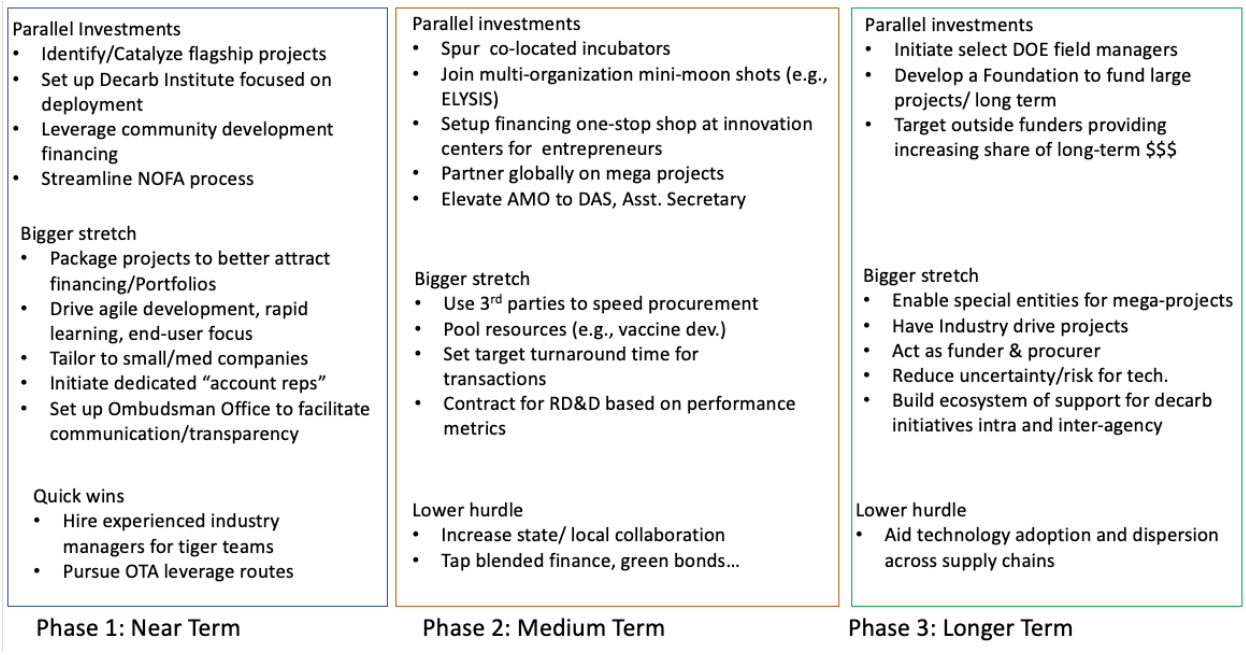


**Figure 1. Illustration of a phased implementation approach to change**

**Phase 1** – Achieve near-term changes that greatly improve impact and industrial interactions versus status quo
**Phase 2** – Implement best practice approaches, stretch further to accelerate progress, and solidify initial gains.
**Phase 3** – Implement additional leading practices and approaches.

# ELEMENTS OF SUCCESSFUL PROGRAMS

## *Culture Change Across the Department*

Culture change is a fundamental and critical underpinning of transformation. Options to consider in effecting culture change within DOE include the following:

- **High visibility of decarbonization and deployment.** To show the importance of decarbonization, elevate decarbonization RD&D so that it is more visible, with support from senior leadership, instead of embedding it as just another DOE function.
- **Facilitate transparency and communication.** DOE would benefit from creating a senior-level ombudsman function, recruiting a person experienced in working through issues (including funding, project management, goal development, and implementation) with industry. SMMs would especially benefit and be motivated to interact with the DOE if they felt that their voices were heard. The ombudsman function/role would also help address other potential stakeholder communication challenges. The DOE has prior experience resolving such challenges from its Industries of the Future program in the 1990s.
- **Facilitate greater proactiveness.** It would greatly benefit the DOE to be proactive rather than reactive in developing projects and responding to industrial constituent or congressional concerns. Having an ombudsman at the beginning of the process can also help address these needs.
- **Building an ecosystem of support**. Decarbonization and deployment efforts would greatly benefit from having the buy-in and support of DOE leadership, Congress, the White House, and other complementary agencies, such as the Department of Commerce (DOC), to advocate for DOE. Such an ecosystem of support would transform RD&D from being just one program in a department at one agency with limited exposure to being a program with greater visibility and support. Additionally, given that other federal agencies (such as DOD and NASA) have Offices of Advanced Manufacturing, it may be valuable to consider how efforts could be pooled across the U.S. government to advance large-scale, collaborative, decarbonization technology projects. In particular, Title III considerations through the DOD offer one pathway to explore.
- **Cross-pollination of ideas**. Promoting intra- and interagency interactions and exchange of ideas and engaging forward thinkers from other DOE departments (e.g., LPO, OFE, and ARPA-E) or other federal agencies (e.g., DOC, DOD, NASA) will harness and amplify collective enthusiasm and spur change.

## *Engagement of a Broader Community Connected with Industry*

DOE and AMO are currently engaged with a limited set of companies that represent a small portion of the 300,000 manufacturing companies in the United States. What is needed is expansion to engage with a broader sampling of industry to involve more companies in

decarbonization, spur learning, and drive development of the workforce to accomplish the dramatic change required. Table B1 in Appendix B provides a high-level summary of the additional stakeholders to engage within DOE, other government agencies, industry associations, NGOs, global research initiatives, and finance partners; it also shows options to pursue and how to work with these entities. The following comments provide context.

- **Broaden reach to a diverse audience.** Expanding the office's reach to include new companies that may lie outside the existing range of established relationships will enlarge the office's audience and increase the scale of its decarbonization and deployment efforts. Using tailored approaches to engage and strategically partnering with SMM, entrepreneurial, and supply chain communities would be especially valuable in amplifying innovations, speed, and a wider base of the next-generation workforce.

- **Reach multiple stakeholders that are key to implementation.** Engineering companies, entrepreneurs, services firms, infrastructure companies, and many others hold key pieces of the puzzle to successfully demonstrate, deploy, and facilitate the dispersion of transformative technologies. Additional efforts are needed to engage these stakeholders and have them scale-up capabilities to support transformative technologies. Following are some of the ways to spur engagement:

    - Develop contacts, network, and conduct presentations at meetings and conferences around decarbonization challenges and the opportunities available through AMO.

    - Use the DOE Industries of the Future Program approach to increase engagement with trade associations and pursue collaborative projects that are aligned with current industry initiatives and future needs.

    - Engage with associations in the trades and service companies, building on the Industries of the Future model.

    - Engage with SMM stakeholders, supply chains, and leading companies in local and regional clusters where demonstrations/pilots are being pursued.

    - Engage with IACs and expand the Better Plants Program.

- **Establish common goals and coordination among stakeholder groups.** In working with a broad range of stakeholders, it is important to establish and work toward achieving common goals and objectives that are meaningful for all entities involved in the collaborative venture. Coordination is key to ensuring that stakeholders feel heard and that their contributions are valued.

### *Cross-Cutting Deployment Focus Strategies*

Lastly, to increase the focus on deployment of industrial decarbonization technologies, following are suggestions to build the DOE program:

- **Increase focus on deployment.** Generally, AMO is not focused on the last D (*deployment*) in RD&D. AMO should look for partners in each sector along with supply chain partners. AMO should target companies with robust sustainability programs and reporting procedures because those companies are most likely to be tracking detailed data to feed into their sustainability reports (a good place to look for/evaluate their depth of commitment could be corporate sustainability reports). It might also be beneficial to focus on consumer-facing brands, such as Proctor and Gamble, as they are directly sensing and responding to customer/market needs and changes.

- **Offer tangible incentives.** DOE should offer tangible incentives to the private sector, such as sharing insights that a company can then use and develop into a competitive advantage, partnerships that lead to cost-reducing improvements, or an advantage that can be advertised in a company's annual sustainability report, such as EPA Energy Star or the DOE Better Plants Programs. DOE could offer specific, graduated levels of incentives and support for first, second, and third deployments at an industrial facility.

- **Invest in "site banking."** *Site banking* refers to an approach in which potential industrial deployment sites that are close to electric power sources are scouted in advance. An example is the site of the former Four Corners power plant in New Mexico, which is a decommissioned coal plant near transmission lines that is now functioning as a renewable energy site. Site banking does not have to be on a brownfield—and can include more than just brownfields—but requires locations for which resource plans have already been developed.

- **Consider long-term threats to industrial development.** Market developments may create unanticipated challenges to industrial development. For example, crypto mining, which uses massive amounts of electricity (400 MW), may compete for power and thereby pose potential threats to the success of integrated advanced manufacturing industrial development.

## PERSPECTIVES FROM ABROAD

Other countries are pursing policies, programs, and funding initiatives that are working to achieve acceleration, scaling, leveraged financing, and lowered hurdles for industrial engagement. These efforts are more advanced and have access to greater resources than those available in the United States. Many of these ventures are built around ideas of shared funding with consortia to develop transformative tech (e.g., electric crackers); support through clusters; innovation centers through which academia, industry, and engineering companies can collaborate; and goal or target setting—along with the funding to reach the goals or targets.

While AMO is in the process of developing its decarbonization programs and policies, many of the following examples illustrate the dramatic scale and collaboration level between government and industry that foreign competitors are pursuing; they also offer strategies and lessons that can be adapted to the U.S. context.

- **Partnership coordination and funding programs.** The European Union (EU) has established several programs, including public–private partnerships for energy (European Commission 2020b), the EU Industrial Clusters Program (EIC 2018), the European Clusters Alliance (ECA 2021) and the European Observatory for Clusters and Industrial Change (European Commission 2022b), and the EU Innovation Fund for Demonstration of Low Carbon Technologies (European Commission 2020a).

- **Industrial clusters.** The United Kingdom has its own Industrial Clusters Competition and Industrial Decarbonization Challenge Programs (UKRI 2021a, 2021b). The Cracker of the Future Consortium, which consists of several private chemical and petrochemical companies committed to developing transformative technology (such as an electric cracker) is a direct result of the chemical industry's trilateral strategy and was drawn up by the Flemish and Dutch ministries of economic affairs and the government of North Rhine-Westphalia in Germany, along with industry associations (VCI in Germany, Essenscia in Belgium, and VNCI in the Netherlands), to boost the chemical sector's sustainability. The trilateral strategy is centered on three pillars: energy, infrastructure, and innovation. The trilateral region of the Netherlands, North Rhine-Westphalia, and Flanders is the world's largest chemical cluster, with annual revenue of €180 billion and 350,000 employees (Tullo 2021).

- **Large-scale demonstration projects.** Europe is also in the process of advancing several high-profile industrial decarbonization projects, including the HyflexPower Project, the first demonstration of an integrated power-to-hydrogen-to-power project in which hydrogen produced by electrolysis replaces natural gas in the pulp and paper industry. The project is a collaborative consortium of entities from the EU, France, and Germany (ENGIE Solutions 2020). In Sweden, the HyBrit Fossil Free Steel project is a collaboration between a utility, raw material producer, and steel manufacturer that also leverages public–private partnerships (HyBrit 2021). The EU also has projects on hydrogen and DRI iron (Bellona 2021) and promotes large-scale demonstration projects through both policy and funding (European Commission 2021a, 2021c, 2022a).

- **Whole of economy efforts.** Japan has established industrial innovation cluster projects that are based on collaborations between industry, academia, and government (Japan METI 2009, 2022); a green innovation fund (Japan METI 2021b); and public–private partnerships to promote circular economy principles between the government and the Japanese Business Federation (Keidanren 2021).

- **Transnational and transcontinental efforts.** Examples of large-scale cooperative efforts to promote industrial decarbonization include the EU–Japan Center for Industrial Collaboration, which facilitates services and tools for small and medium-sized businesses (EU-Japan 2022a, 2022b); the HyGate Fund and Hydrogen Innovation Technology Incubator, which is a collaboration between Germany and Australia (ARENA 2022); the Just-Energy Transition Partnership, a groundbreaking international project between France, Germany, the United Kingdom, the United States, the EU, and South Africa to decarbonize the electricity sector in South Africa (European Commission 2021b); and the Asia carbon capture utilization and storage network, an international industry–academia–government platform aimed at

knowledge sharing and improvement of the business environment for CCUS applications (Japan METI 2021a).

- **Non-governmental efforts.** Non-governmental ventures are also advancing decarbonization transnationally and across the business community. These efforts include sector-based projects for chemicals, pulp and paper, the circular economy, and tire recycling through the World Business Council for Sustainable Development (WBCSD 2021a, 2021b, 2021c, 2021d); and the 24/7 Carbon-Free Energy Compact, which is a global group of companies, policymakers, investors, and organizations working together (UN 2021).

Several international-level planning documents for industrial decarbonization are worthy of note, including the UK's *Industrial Decarbonization Strategy* (UK BEIS 2021), the EU's *New Industrial Strategy* (European Commission 2021d), and Japan's national-level *Carbon Neutral Society Framework* (Japan METI 2020). Also, section 4.6 in the UK's *Industrial Decarbonization Strategy* outlines how to engage the cement industry to decarbonize sites at dispersed locations. International strategies of note include those geared toward crosscutting technologies, services, and infrastructure. The clusters approach connects these cross-cutting areas and is employed by both the EU and the United Kingdom. Although industrial clusters are typically specialized concentrations of companies producing the same goods, the technologies and strategies enabling their decarbonization can be used throughout industry. The UK plan, for example, includes up to £170 million, matched by £261 million from industry, to invest in developing technologies such as CCUS and hydrogen fuel switching and to deploy and scale-up these technologies within the United Kingdom's largest industrial clusters. The EU's European Industrial Cluster is intended to generate joint actions for collaboration on industrial modernization and industry 4.0 to foster sustainability and emissions reductions.

**UK East Coast Cluster**


The East Coast Cluster (ECC) is expected to remove 50% of the United Kingdom's industrial cluster $CO_2$ emissions, protect thousands of jobs, and establish the region as a globally competitive climate-friendly hub for industry and innovation. Nearly half of carbon emissions come from Britain's historic engine room: Teesside and the Humber. The ECC is bringing together communities, business, industry, and academia to deliver the CCS infrastructure needed to decarbonize this key industrial heartland of the United Kingdom. Selected as one of the first two carbon capture, usage, and storage clusters to be taken forward by the government, the ECC ensures UK leadership in the energy transition and the emerging global low-carbon and hydrogen markets. Individual decarbonization projects within the ECC have submitted bids into phase two of the government's cluster sequencing process. Shortlisted projects, to be announced in May 2022, will be eligible for government business model support and unlock further investment. (UK ECC 2022)

Revenues from the price on carbon are being reinvested in industry, as well as other sectors in Canada and the European Union. In Canada, the Strategic Innovation Fund targets reinvestment of some $5.2 billion to date in R&D (stream 1), technology demonstration involving multiple partners (stream 4), and large-scale national innovation ecosystems (stream 5) (ISED Canada

2022b). Projects include investments in hydrogen-ready steel production, direct reduced iron–fed electric arc furnace at scale, development and adoption of innovative technologies and processes to lower the oil and gas industry's environmental impacts, and acceleration of automation and digitization in the food and beverage sector (ISED Canada 2022b).

# Summary and Conclusions

AMO and DOE are well positioned to support industry in the dramatic transition needed to reach the future of net-zero industrial GHG emissions. Congress has recently appropriated resources through several bills that will allow AMO to greatly expand its industrial support and pivot to enable industrial decarbonization. To achieve the radical changes needed in a compressed time frame and to deploy, scale, and disperse transformative technologies across industry, AMO will need to change the way that it interacts with industry.

Program management will need to support the scaling of transformative technologies. Hiring staff members experienced in working with transformative industrial technologies and driving applications to scale is a way to start fast and efficiently. Tailored approaches will be needed to work with large companies and consortia that are driving transformative technology. A more interactive approach, with lower interaction hurdles, will be needed with SMMs and light industry. One route to spur engagement with SMMs is to have large companies participating in projects to bring their SMM supply chain partners into the project.

Procurement and contracting will be crucial mechanisms to supply resources to those driving transformative technology deployment. Where hurdles and bottlenecks are encountered, DOE needs to consider flexible solutions, such as successful routes proven by other agencies. This includes the use of OTAs, third-party administering entities, and flexible support of multiparty collaborations.

Financing mechanisms that tap blended financing will be important, as transformative technologies can be quite expensive ($1–1.5 billion per project) and thus exhibit risk high enough to bankrupt most industrial companies. DOE can help serve as a bridge to a range of entities that will make a big difference in project success, including LPO, commercial financing, philanthropy, green bonds issuers, grants with regional and state GHG funds (e.g., RGGI), and economic and community development funds (especially on DEI).

A reimagined AMO can more extensively partner with industrial players, finance, and other agencies to catalyze change with speed and scale, while developing a diverse workforce, improving competitiveness, and upgrading resilience.

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# Technical Appendices

## APPENDIX A

**Table A1. Options for pursuing transformative technologies to accelerate adoption and scale***

| Category | Ambition of change: Quick wins | Bigger stretch | Step-change |
|---|---|---|---|
| Culture change | Include advance manufacturing *and* basic manufacturing in project selection | Drive agile development, rapid learning, entrepreneurial approaches, end-user focus | Fund select commercial technologies past the final hump on deployment |
| | Increase collaboration with state and local organizations | Tailor outreach for small/medium companies | Catalyze flagship projects to spur technology adoption and replicate across industry |
| | Expand cross-agency collaboration (DPA Title III) focused on decarbonization | Prioritize highest impacting opportunities and engage supply chains (portfolio management) | Spur innovation centers (co-located industry, academia, incubators, etc.) |
| | Empower line managers | Act as funder and procurer | Pursue collaboration in partnership with consortia of industrial firms |
| | Support external innovation forums, with strong industry engagement | Prepare the workforce of the future while incorporating DEI | Address aversion to act per commercial concerns (market situational awareness) |
| | Elevate AMO leader to deputy assistant secretary (DAS) | | Engage at multiple levels for broader views |
| Procurement | Streamline NOFA process | Use third-party administrating entities to speed procurement | Set up financing shop at the center of an innovation community (easier access) |
| | Set targets for transaction timelines | Tailor vehicles for small/medium manufacturers | Set targets for transaction timelines |
| | Other transaction agreements (OTAs) | Better interactions and work with LPO | Use OTAs |
| Program management | Provide longer-term funding for major investments (flagship, institutes, etc.) | Bring in tech managers from industry to drive multiple large projects | Field DOE managers to help with integration, problem solving, response speed; learn as you go |
| | Have clear validation metrics to show usefulness of new tech to industry | Reduce uncertainty and risk for technology to drive adoption, integration, dispersion | Return to select DOE field offices for greatest prospects and needs with clusters |
| | Create clear, low-hurdle entry points for industry to approach DOE | Leave IP in the hands of industry | Establish DOE Institute on Industry Decarbonization, with focus on late TRL technology deployment and scale |
| Incentives and finance | Package projects for finance | Use green bonds | Outside entities provide most of funding |
| | | Blended finance | Use methane tax revenues |

| Category | Ambition of change: Quick wins | Bigger stretch | Step-change |
|---|---|---|---|
| | | fora for angel investors | Create funding repository, isolated to retain independence |
| | | | Leverage financing capacity organizations and community development financing |
| Alternative models | Shared drive toward goal | Let industry drive projects | Partner with other countries on mega projects/ revolutionary processes |
| | Aid technology pick-up across supply chains | Pool resources to drive action (as on vaccines) | Contract for RD&D progress on big projects |
| | | Enable special entities for mega projects | Collaborative projects (ELYSIS) |
| | | Spur mini-moon shots and rapid learning | |

*** Ambition of Change:**

- **Quick Wins:** adjustment of current processes, practices, and approaches
- **Bigger Stretch:** greater change in processes, practices, and approaches
- **Step Change:** significantly different mechanisms, tools, and approaches

**Categories:**

**Culture change:** changing the culture (see footnote 2)
**Procurement:** changing to more flexible, quicker mechanisms
**Program management:** changing for more empowerment, flexibility
**Procurement:** changing to quicker, more flexible mechanisms
**Funding mechanisms:** changing to a wider range of mechanisms, tools, and partners
**Alternative operating models:** changing to new models for programs, processes, and functions

# APPENDIX B

**Table B1. Potential partners in pursuing change**

| Category | Entity/Organization | How to work with them (examples) |
|---|---|---|
| Programs in energy efficiency technology area (EERE) | Building Technologies Office (BTO) | Collaborate on embodied carbon standards development projects by supporting development of innovative low embodied carbon materials by industry |
| | Federal Energy Management Program (FEMP) | Implement industrial new tech pilot demonstration projects at federal facilities |
| | Weatherization and Intergovernmental | Improved coordination with state energy offices, for example, support collaborative efforts of multiple states/regions for industrial decarb grant applications |
| Programs in EERE (renewable energy) | Solar, Wind, Geothermal | Joint project selection at the interface of scale and integration to improve industrial manufacturing and competitiveness of renewable technologies (e.g., implement NREL solar thermal research in industry (McMillan et al. 2021) |
| Programs in EERE (sustainable transport) | Hydrogen and Fuel Cells | Collaborate on cross-sector decarb projects viz. H2 for power and industrial sectors (e.g., low-carbon hydrogen with DRI iron (Bellona 2021) |
| Programs in EERE (operations) | Golden Field Office | Streamline procurement process to reduce transaction friction for DOE institutes and other contractors; promote training in and use of OTAs |
| Other DOE program offices | Fossil Energy and Carbon Management | Cross-sectoral (power/industrial) decarbonization projects; joint project selection |
| | Science | Work with field operations (DOE labs on early TRL projects); leverage clusters with universities, DOE labs and industry for AMO projects; reactivate DOE field offices |
| | ARPA-E | Improved coordination between AMO, LPO, and ARPA-E |
| | Electricity | Cross-sectoral decarbonization projects with Energy Resilience and Grid Operations Divisions (e.g., support ventures that integrate variable electricity power sources with advanced technologies such as crackers) (Tullo 2021) |
| | Loan Program Office (LPO) | Improved coordination between AMO, LPO, and ARPA-E |
| | Cybersecurity, Energy Security, Emergency Response (CESER) | Joint ventures on energy sector industrial control systems related to information sharing, technology development, and coordination among industry and government partners |
| | Technology Transitions (OTT) | Leverage public–private partnerships for technology commercialization |
| | International Affairs (OIA) | Work together on joint international mega projects and revolutionary processes |
| U.S. federal agencies | DOD Office of Industrial Policy | Defense Production Act (DPA) Title III Joint ventures (DOD OIP 2022) |

| Category | Entity/Organization | How to work with them (examples) |
|---|---|---|
| | NASA | Learn more about non-defense sector consortia and OTAs (MITRE 2022a, 2022b); work with NASA Office of Technology, Policy and Strategy, Industries of the Future, Advanced Manufacturing (NASA 2014, 2022) |
| Industry associations | American Chemistry Council (ACC) | Establish common government–industrial goals/objectives; leverage PPP; industry advisory councils; select projects of interest to industry |
| | American Forest and Paper Association (AF&PA) | Establish common government–industrial goals/objectives; leverage PPP; industry advisory councils; select projects of interest to industry |
| | Alliance for Pulp and Paper Technology Innovation (APPTI) | Identify future technologies of interest based on industry roadmaps and research |
| | American Concrete Institute (ACI) | Identify future technologies of interest based on industry roadmaps and research |
| | Portland Cement Association (PCA) | Establish common government–industrial goals/objectives; leverage PPP; industry advisory councils; select projects of interest to industry |
| | American Iron and Steel Institute (AISI) | Establish common government–industrial policy objectives; leverage PPP; industry advisory councils; select projects of interest to industry |
| Non-governmental organizations (NGOs) | NGOs in energy/industrial decarbonization space | Neutral third-party convener for government–industry convenings |
| | World Economic Forum (WEF) | Leverage initiatives and roundtables for international partnerships on topics such as circular economy (e.g., Japan) ((WEF 2021; Keidanren 2021) |
| Global research initiatives | 24/7 Carbon-Free Energy Compact initiated at COP26 (UN + Industry + NGOs) (UN 2021) | Leverage group action to scale technologies, energy policies, procurement practices, and solutions to transform the broader energy system U.S.-wide and worldwide. |
| | World Business Council for Sustainable Development (WBCSD 2021a, 2021b, 2021c, 2021d) | Work on joint research and collaboration opportunities with industry in chemical, forest solutions, and tire industry projects, and circular economy initiatives |
| | International Energy Agency (IEA) and Cement Sustainability Initiative at WBCSD (IEA 2018) | Leverage joint interests in cement sector decarbonization technology roadmaps and other sectoral ventures |
| Finance partners | Commercial banks | Leverage private financing and joint financing in large decarb projects |
| | Philanthropic groups (Bloomberg, Gates) | Leverage blended finance options in large decarb projects |
| | Industry | Leverage industry interest/funds for success of decarb projects based on future industry needs |
| | Investment firms (BlackRock) | Leverage private capital for public–private financing of decarb projects |