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Supply Chains Progress Report

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Disclaimer

Authors

Lead author

Tsisilile Barlock, Office of Manufacturing and Energy Supply Chains (MESC) [On Detail from the National Renewable Energy Laboratory]

Contributing authors

Charles Yang, MESC

Brett Anders, Office of Technology Transitions (OTT)

Diana Bauer, Advanced Materials and Manufacturing Technologies Office (AMMTO), Energy Efficiency and Renewable Energy Office (EERE)

Matherly Gainer, AMMTO, EERE

Melissa Klembara, Office of Clean Energy and Demonstration (OCED)

Adam Orcutt, MESC

Skye Richmond, MESC

Jake Higdon, MESC

Nyla Khan, Office of Electricity (OE)

Neha Rustagi, Hydrogen and Fuel Cell Technology Office (HFTO), EERE

Thomas Fanning, Office of Nuclear Energy (NE)

William Ostertag, Loan Programs Office (LPO)

Christy Veeder, Office of Policy (OP)

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Contributors

Giulia Siccardo, MESC

Chloe Parrish, MESC

Patrick Gilman, Wind Energy Technologies Office (WETO), EERE

Colin Cunliff, OP

Jun Shephard, OP

Nicole Ryan, OP

Betony Jones, OP

Jessica Papa, AMMTO, EERE

Paul Basore, Solar Energy Technologies Office (SETO), EERE

Yasmin Yacoby, Office of Economic Impact and Diversity (ED)

Billy Valderrama, NE

Sam Baldwin, EERE

Andre Pereira, OE

Jonah Wagner, LPO

Amanda Mays, MESC

Jeremy Avins, MESC

Grant Bromhal, Office of Fossil Energy and Carbon Management (FECM)

Evan Granite, FECM

List of Acronyms

AMMTO	Advanced Materials and Manufacturing Technologies Office
ARPA-E	Advanced Research Projects Agency-Energy
BES	Basic Energy Science
BIL	Bipartisan Infrastructure Law
BTACs	Building Training Assessment Centers
CHIPS	Chips and Science Act
DOE	U.S. Department of Energy
DOD	Department of Defense
DOL	Department of Labor
DPA	Defense Production Act
ED	Office of Economic Impact and Diversity
EERE	Office of Energy, Efficiency, and Renewable Energy
EJ	Office of Energy Jobs
EV	Electric Vehicles
FECM	Office of Fossil Energy and Carbon Management
FOA	Funding Opportunity Announcement
GDP	Gross Domestic Product
GOES	Grain-Oriented Electric Steel
HALEU	High-Assay Low-Enriched Uranium
HFTO	Hydrogen Fuel Technology Office
HVDC	High Voltage Direct Current
IACs	Industrial Assessment Centers
IE	Office of Indian Energy
IEDO	Industrial Efficiency and Decarbonization Office
IRA	Inflation Reduction Act
LPO	Loan Programs Office

LPTs	Large Power Transformers
MEA	Monoethanolamide
MESC	Office of Manufacturing Energy and Supply Chains
NE	Office of Nuclear Energy
NOI	Notice of Intent
OCED	Office of Clean Energy Demonstrations
OTT	Office of Technology Transitions
PGMs	Platinum Group Metals
PV	Photovoltaics
R&D	Research and Development
RD&D	Research Development and Demonstration
REEs	Rare Earth Elements
RFI	Request for Information
SCEP	Office of State and Community Energy Programs
TEG	Triethylene glycol
USGS	United States Geological Survey
USTR	United States Trade Representative
VTO	Vehicle Technologies Office
WETO	Wind Energy Technologies Office

Executive Summary

This report summarizes the progress made by the Department of Energy (DOE) in building and securing supply chains to support the American energy sector industrial base. The energy sector industrial base is all the labor, capital, and public and private entities required to produce energy products. An energy product is any system, component, or consumable commodity used to generate, store, transport, transform, or conserve energy. The report covers progress made since the release of "America's Strategy to Secure the Supply Chain for a Robust Clean Energy Transition" in February 24, 2022. Equipped with broad policy tools such as the Bipartisan Infrastructure Law (BIL), the Inflation Reduction Act (IRA), Chips and Science Act (CHIPS), and the invocation of the Defense Production Act (DPA) — and complementary investments in RD&D through regular appropriations — DOE is positioned to tackle supply chain challenges and seize the clean energy transition opportunities.

In February 2022, DOE realigned to support the needs of the 21st century energy sector and to utilize policy tools to accelerate the deployment of clean energy. As part of this realignment, DOE created the Office of the Under Secretary for Infrastructure to focus on deploying clean energy infrastructure in pursuit of national goals. These goals include providing affordable and reliable energy, creating high-quality jobs, enhancing U.S. manufacturing, and addressing the climate crisis. The Office of Under Secretary for Science and Innovation continues the more traditional DOE role on basic research and applied Research Development and Demonstration (RD&D) to maintain the U.S. leadership in innovation. These offices collaborate to build out and strengthen domestic supply chains by engaging with private industry, communities, non-profits, and other key stakeholders in several strategic opportunities, including:

- ***Securing critical materials:*** Opportunities include investing in domestic material accessibility; identifying alternative materials and technologies; and improving material efficiency, reuse, and recycling capabilities. DOE works with other federal agencies to diversify foreign sources for materials with limited domestically viable deposits.
- ***Expanding energy sector manufacturing:*** Investments from BIL, IRA, and CHIPS are driving domestic manufacturing investments in battery manufacturing, semiconductors, and renewable power, including onshoring and nearshoring or "friendshoring". The United States continues to strengthen manufacturing and accelerate commercialization and scaling of both emerging and mature technologies.
- ***Growing the domestic clean energy workforce:*** Expanding the U.S. manufacturing and energy supply chains requires a growing clean energy workforce and well paying jobs. DOE requires BIL, IRA, and CHIPS applicants to submit a plan detailing how they will attract, train, and retain the local workforce.
- ***Building out supply chain capabilities:*** DOE is investing in analytical tools to assess, understand, and target DOE investments in strengthening and increasing resiliency of America's supply chains. These tools leverage existing capabilities and resources from DOE national labs and external partners to provide comprehensive supply chain insights that can inform government and industry investment decisions.

Leveraging funding provisions from BIL, IRA, CHIPS, and DPA authorities, DOE is committed to building a resilient supply chain to ensure America meets its economic and climate goals equitably.

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1. Introduction

This document presents an overview of the advances made by the Department of Energy (DOE) to in establishing and safeguarding supply chains that support the American clean energy industries, which is essential for achieving the country's economic and net-zero goals. The report is a follow up to "America's Strategy to Secure the Supply Chain for a Robust Clean Energy Transition" released in February 24, 2022, which detailed how the U.S. Government can utilize several policy instruments to capitalize on opportunities presented by the clean energy transition.

Section 1 summarizes recent legislation affecting American manufacturing and supply chains and discusses a new organizational structure at DOE designed to implement the various provisions of that legislation effectively and efficiently, as well as the complementarity and alignment of mission and scope across DOE program offices. Section 2 comprises targeted discussion of programs and progress in topics at the heart of this report, including securing critical materials, expanding U.S. clean energy manufacturing, growing the American workforce for clean energy, and building supply chain analytical capabilities. Section 3 offers concluding remarks.

1.1 Supply Chains: A Year in Action

Addressing supply chains of clean energy technologies

Clean energy technologies are supported by a complex and interconnected network of supply chains. Recent trends have exposed and exacerbated vulnerabilities in parts of this network. For example, the COVID pandemic had a significant impact on the global market for goods and services across various sectors, including the energy sector, and these changes have been amplified by instabilities from climate crises, geopolitics, and domestic resource constraints. The opportunity to accelerate the transition to affordable, dependable, secure, and clean energy sources is pivotal to national security. Over the past two years, the U.S. Government has taken bold actions to build strong and diverse energy supply chains.

The Executive Order 14017, "America's Supply Chains," issued by President Biden on February 24, 2021, aims to secure and strengthen the resilience of America's supply chains and preceded several actions from the executive branch and Congress including the following:[1]

[1]https://www.whitehouse.gov/briefing-room/presidential-actions/2021/02/24/executive-order-on-americas-supply-chains/

- ***American Supply Chain Strategy:*** In February 2022, the Department of Energy (DOE) released America's Strategy to Secure the Supply Chain for a Robust Clean Energy Transition. This comprehensive whole-of-government strategy builds on the 100-day report on high-capacity batteries and aims to strengthen the energy sector industrial base, including both direct and indirect stakeholders in the energy sector and its associated supply chain. This strategy presents a roadmap for the United States to strengthen clean energy supply chains and ensure secure and reliable energy for American families and businesses.[2]

- ***Defense Production Act Determinations:*** In June 2022, President Biden issued the presidential determinations that provided DOE with the authority to utilize the Defense Production Act (DPA) to accelerate domestic production in five key energy technology areas: 1) solar photovoltaics; 2) transformers and electric grid components; 3) heat pumps; 4) insulation; and 5) electrolyzers, fuel cells, and platinum group metals.[3]

- ***Legislative Actions:*** Building on the momentum and historic investments enacted by the Bipartisan Infrastructure Law (BIL) in 2021,[4] the U.S. Congress and the Biden Administration enacted two additional major laws in 2022. These laws strengthen the American innovation ecosystem and provide the U.S. Government with policy tools and funding to transform American innovations into market products at the scale and speed needed to meet U.S. net zero climate and economic goals, which will include strengthening domestic energy supply chains.

    - ***Inflation Reduction Act (IRA):*** Enacted in August 2022, this historic investment in clean energy included nearly $370 billion in energy security and climate change programs over the next ten years and the tools to revitalize American manufacturing. [5] Examples of funded programs administered by DOE include 48C (short for 26 U.S.C. § 48C)[6] – Advanced Energy Project Credit (up to $10 billion) and IRA Sec. 50143 – Domestic Manufacturing Conversion Grants ($2 billion).

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[2] https://www.energy.gov/policy/securing-americas-clean-energy-supply-chain.
[3]https://www.energy.gov/articles/president-biden-invokes-defense-production-act-accelerate-domestic-manufacturing-clean
[4]https://www.whitehouse.gov/briefing-room/statements-releases/2021/11/06/fact-sheet-the-bipartisan-infrastructure-deal/
[5]https://www.whitehouse.gov/briefing-room/statements-releases/2022/08/19/fact-sheet-the-inflation-reduction-act-supports-workers-and-families/
[6] DOE only administers the selection process of the 48C program on behalf of the U.S. Treasury.

- ***Chips and Science Act (CHIPS):*** Also enacted in August 2022, CHIPS invests in research and development (R&D), manufacturing, and supply chains. CHIPS authorized $67 billion in funding, including $50 billion for DOE's Office of Science to enable advanced scientific research into materials, computing, manufacturing, and more to enhance U.S. competitiveness.[7]

Realigning DOE to delivering manufacturing and supply chain investments

As the global economy shifts towards clean energy and technology continues to advance, securing access to essential materials, components, and clean energy technology equipment is increasingly important. DOE is investing in manufacturing across the research-to-deployment spectrum to secure the Nation's supply chains. To meet the needs and challenges of the 21st century U.S. energy sector, including implementing $62 billion from the BIL, DOE realigned to create the Office of the Under Secretary for Infrastructure. This office complements RD&D efforts from the Under Secretary for Science and Innovation with strategically correlated deployment efforts. The Under Secretary for Infrastructure focuses on national goals such as providing affordable and reliable energy, creating high quality jobs, revitalizing U.S. manufacturing, and addressing the climate crisis. This realignment transforms DOE to support domestic manufacturing and accelerate equitable deployment and scalability (see **Figure 1**). The realignment aims to transform American innovation into market products to meet growing demand.

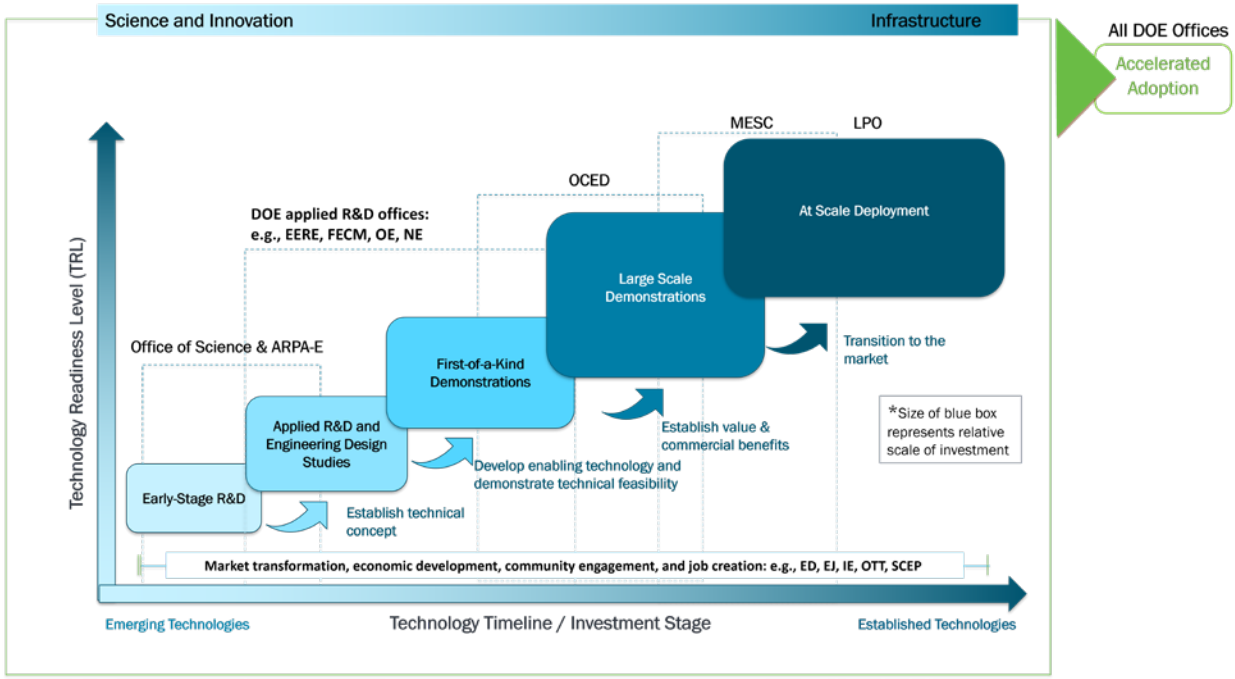


Figure 1. DOE Manufacturing Landscape

The current structure of DOE offices is designed to accelerate innovation at vital stages of a technology's evolution. This ensures that game-changing ideas can progress from their inception

[7] https://www.energy.gov/articles/statement-secretary-granholm-congressional-passage-chips-and-science-act

in the lab to being manufactured on America's factory floors. Each DOE office plays a unique role in helping novel technologies overcome complex barriers and move from fundamental science and research and development to demonstrations, deployment, and full-scale commercialization.

Within DOE, several crosscutting offices focus on advancing the Department's social and economic impact. These offices include the Office of Economic Impact and Diversity (ED), the Office of Indian Energy (IE), and the Office of State and Community Energy Programs (SCEP). These offices work with communities to create jobs, spur economic development, and ensure access to safe, affordable, and reliable energy. Additionally, the Office of Technology Transitions (OTT) works to expand the commercial impact of the research investments of the Department and to commercialize technologies that support the diverse missions of the Department. OTT advises on supply chain analysis methodology and supports ongoing supply chain evaluation, working closely with MESC and with experts across DOE offices and National Labs. Also, the Office of Energy Jobs (OEJ) works to ensure that the jobs created through DOE programs and initiatives are of sufficient quality to attract and retain a skilled workforce. All DOE offices collaborate to accelerate the adoption of clean energy technologies and help the United States meet its economic and climate goals.

Examples of DOE programs managed by the Under Secretary for Science and Innovation making investments in basic and applied research for manufacturing and supply chain includes:

- **Basic Energy Sciences (BES):** The BES office, located in the Office of Science, supports fundamental research in emerging energy fields, to ensure American competitiveness in next-generation technologies. Through public-private partnerships (like the recent public-private announcement for fusion energy), supporting the Energy Earthshots Initiative, and basic research in next-generation technologies like energy storage, BES funds and maintains the pipeline of next-generation technology competitiveness. Within BES, programs such as the Materials Science and Engineering division conduct research on advanced materials, chemistries, and processes that enhance U.S. manufacturing leadership which provide key advantages to nascent supply chain opportunities.

- **Office of Energy Efficiency and Renewable Energy (EERE):** EERE houses several important program offices focused on advancing RD&D of technologies and conducting significant technology-specific supply chain and manufacturing work, including technologies like advanced manufacturing, hydrogen, wind, and solar. Two offices that focus more broadly on critical materials, manufacturing, and industrial decarbonization in EERE are:

    - *Advanced Materials and Manufacturing Technologies Office (AMMTO):* AMMTO's mission is to inspire people and drive innovation to transform materials and manufacturing for America's energy future. AMMTO funds a range of RD&D in high performance materials, digital manufacturing, advanced processes, critical materials, circular economy, battery manufacturing, semiconductor manufacturing. AMMTO supports several consortiums that bring together national labs, universities, and manufacturers to identify bottlenecks, fund innovative solutions, and support education and workforce development, including the Critical Materials

Institute (CMI), which is a DOE Energy Innovation Hub[8], and six member institutes in Manufacturing USA's network. Additionally, the Manufacturing Demonstration Facility at Oak Ridge National Lab scales up novel clean energy manufacturing processes. AMMTO also collaborates across the agency on a range of topics.

  - *Industrial Efficiency and Decarbonization Office (IEDO):* IEDO accelerates the innovation and adoption of cost-effective technologies that eliminate industrial GHG emissions. This office supports RD&D for decarbonization of energy-intensive industries, as well as for cross-sector technologies such as decarbonization of process heat. IEDO also funds technical assistance and workforce development programs.

- **Office of Fossil Energy and Carbon Management (FECM):** FECM's mission is to ensure responsible use of fossil and mineral resources, minimizing the environmental impacts of fossil fuels and industrial processes, while working towards net-zero emissions across our economy. The Office's programs use research, development, demonstration, and deployment approaches to advance technologies to manufacture responsible carbon-based products and to reduce carbon emissions and other environmental impacts, including from manufacturing and industrial processes. The Office is also committed to improving the conditions of communities impacted by the legacy of fossil fuel use and to supporting a healthy economic transition that accelerates the growth of good-paying jobs.

- **Office of Nuclear Energy (NE):** The mission of NE is to advance nuclear energy science and technology to meet U.S. clean energy, environmental, and economic needs. This is achieved by investing in RD&D to keep existing nuclear reactors in operation, demonstrate and deploy new reactor technologies and their supporting supply chains, secure the nuclear fuel supply chain, and expand international cooperation. The Advanced Methods for Manufacturing program within NE invests in innovations that improve the manufacturing of nuclear reactors and their components.

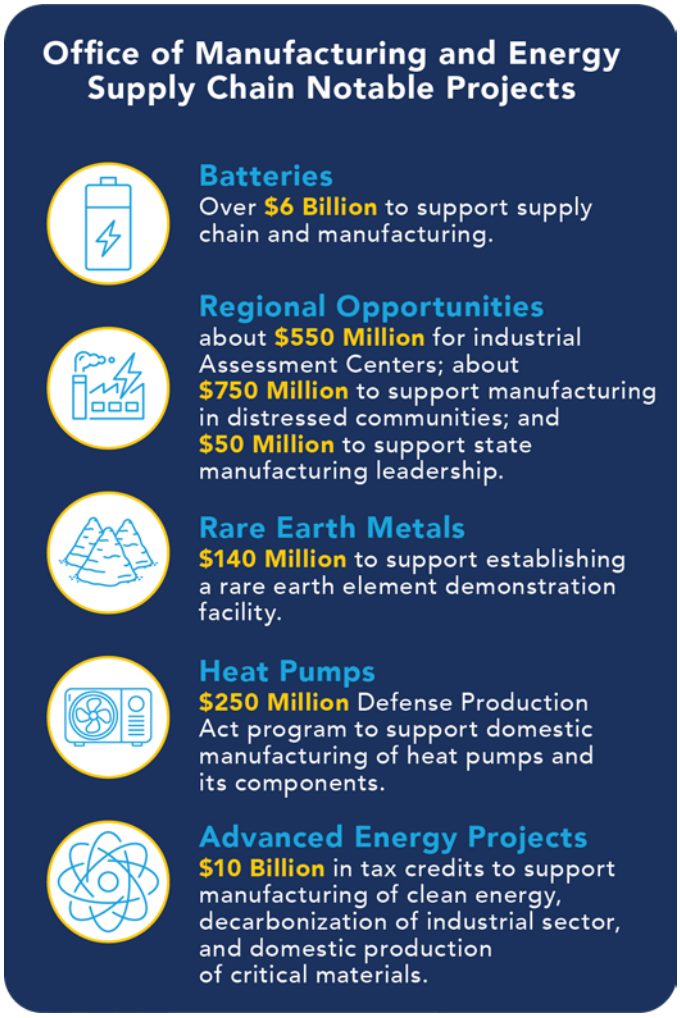
Examples of DOE programs managed by the Under Secretary for Infrastructure making investments in manufacturing and supply chain include:

- **Loan Programs Office (LPO):** LPO serves as a bridge to bankability for innovative and high-impact energy technologies, providing them with access to needed loans and loan guarantees when private lenders cannot or will not until a given technology has reached full market acceptance. Under its Title 17 Clean Energy Financing Program, LPO can finance projects in the U.S. that support clean energy deployment and energy infrastructure reinvestment to reduce greenhouse gas emissions and air pollution. Within the "Innovative Supply Chain" project category, LPO can provide financing for commercial-scale deployment of innovative manufacturing processes and technologies. In addition, under its Advanced Technology Vehicles Manufacturing Program, LPO provides direct loans to

[8] https://www.energy.gov/eere/ammto/critical-materials-institute-energy-innovation-hub

support the manufacture of eligible vehicles and qualifying components, funding advanced vehicle and qualified component manufacturing projects across the value chain that vehicle manufacturing projects across the value chain that increase transportation efficiency and reduce dependency on fossil fuels.

- **Office of Manufacturing and Energy Supply Chains (MESC):** The Office of Manufacturing and Energy Supply Chains (MESC) was established as part of the 2022 DOE realignment to secure and strengthen domestic supply chains. MESC expands upon existing DOE programs by focusing on manufacturing deployment and scale-up, with the goal of developing an energy sector industrial base through investments in domestic clean energy manufacturing and supply chains. MESC collaborates with private-sector companies, other federal agencies, as well as with key stakeholders within and outside of DOE to design programs, conduct analysis, and make investments on behalf of the DOE. With a budget of approximately $20 billion, MESC manages three major program offices: the Facility and Workforce Office, which supports infrastructure development, workforce training, and economic revitalization; the Battery and Critical Materials Office, which supports the scale-up of manufacturing capacity for grid and automotive batteries and the critical materials required to make them; and the Energy Sector Industrial Base Office, which supports the scale-up of energy and materials manufacturing, administers the Defense Production Act for energy, and drives energy sector supply chain investment strategy across the broader Department through thorough assessment of national and regional supply chain vulnerabilities and strategic opportunities.



2. Engaging and Investing in Strategic Opportunities

The Department of Energy's strategy to secure energy supply chains published in 2022 highlighted potential risks and vulnerabilities associated with the clean energy transition. The strategy also presented opportunities for the United States to build out the domestic supply chains of less mature technologies, such as fuel cells and electrolyzers, and strengthen supply chains of more mature technologies, such as nuclear fuel and solar photovoltaics (PV). These opportunities advance American innovation, revitalize American manufacturing, boost U.S. competitiveness, ensure energy security, create quality jobs to attract, invest in, and retain a highly skilled workforce, and advance energy equity and environmental justice. This section highlights key strategic opportunities in supply chains and progress made since DOE's initial publication of supply chain vulnerabilities in February 2022.

2.1 Securing Critical Materials

Securing materials critical to a variety of energy technologies (e.g., advanced nuclear technologies, energy storage, fuel cells and electrolyzers, solar photovoltaics, and wind) continues to be crucial. Through increased domestic production, recycling, development of alternatives, and friendshoring among U.S. allies and partners, there is a clear path to resilient supply chains for many of these materials and the technologies that currently rely on them (see examples in Table 1).

Table 1. Select Technologies with Robust Upstream Material Supply Chains

Illustrative Technology Categories	Relevant Materials with Relatively Robust Supply Chains
Carbon Capture and Utilization	**Raw materials:** Iron, Tin, Zirconium, Strontium, Magnesium, Nickel **Processed materials:** Steel, Aluminum, Cement, Triethylene glycol (TEG), Monoethanolamide (MEA) based solvent
Fuel cells and electrolyzers	**Raw materials:** Iron, Nickel, Zirconium **Processed materials:** Perfluorosulfonic acid – PFSA (Nafion) (electrolyte), carbon, Stainless Steel (end plate)
Nuclear	**Raw materials:** Nickel, Copper, Lead, Molybdenum, Silver, Tin, Titanium, Zirconium, Helium, Beryllium **Processed materials:** Ceramics, Steel, Concrete
c- Si Solar PV	**Raw materials:** Quartz, Silver, Bauxite **Processed materials:** Aluminum, Metallurgical- Grade Silicon, Solar Glass, Encapsulant

Embarking on the path to resilient critical material supply chains will require addressing known domestic and global risks. Vulnerabilities to U.S. energy supply chain resilience include low domestic production and high dependence on unreliable foreign sources (See examples in **Table 2**). The U.S. Government continues to collaborate with industry to take concrete actions that address key upstream critical material vulnerabilities through investments from BIL, IRA, and CHIPS (see examples in **Table 3**). Additionally, DOE recently released a Request for Information (RFI) for its critical material assessment, to gather input on the methodology and conclusions before a final assessment is published.[9]

Table 2. Examples of Priority Areas for Addressing Critical Material Supply Risk

Relevant Technologies	Materials	Vulnerabilities
EVs, Grid energy storage	Lithium-ion Battery Materials	Limited domestic manufacturing capacity due to inadequate access to global supplies of key cathode materials, such as cobalt, battery-grade nickel, and lithium. China dominates the upstream supply chains of these materials. For example, China is the primary refiner of lithium (61%), cobalt (72 %), manganese (95 %), and natural graphite (100 %). Also, 80% of lithium-ion battery recycling capacity is in China.[10]
Fuel cells and electrolyzers, Renewable/green fuels, Semiconductors, Nuclear	Platinum Group Metals	U.S. has limited availability and extraction capabilities, and underdeveloped refining capabilities. About 75% of U.S. production of PGMs come from recycling, but imports make up most of domestic consumption, with majority of imports sourced in Russia (34%) and South Africa (30%).[11]
Electric Vehicles and Wind Energy	Rare Earth Elements (REEs)	While some reserves for REEs exist, the U.S. does not have domestic capability to process them (e.g., neodymium, dysprosium)
c-Si Solar PV	Polysilicon	Establishing new U.S. manufacturing is not cost competitive, which drives reliance on imports; US plants have been significantly under-capacity for a decade, in large part due to Chinese tariffs on polysilicon imports
Nuclear	Enriched Uranium	U.S. reliance on imports of enriched uranium in nuclear fuel for the light water reactor fuel and no viable high-assay low enriched uranium for Gen IV reactors.

[9] https://www.energy.gov/sites/default/files/2023-05/2023-critical-materials-assessment.pdf
[10] https://rhomotion.com/battery-recycling-infographic-november-2022
[11] https://pubs.usgs.gov/periodicals/mcs2023/mcs2023-platinum-group.pdf

Table 3. Example of Investments Focusing on Upstream Priorities

Materials	Current Industry Investment	Current U.S. Government Investments
Battery Materials	• Electric vehicle manufacturers are signing offtake agreements with domestic mining companies to provide price stability to both buyers and sellers, as well as helping growth domestic supply of battery materials[12] • Private-sector startups are bringing to market novel chemistries, reducing reliance on critical minerals and scaling up new manufacturing processes. DOE is investing in many of these approaches (e.g., DOE's $100M investment in Sila Nanotechnologies silicon-based anode)[13]	• Substantial funding from BIL (e.g., $3 billion) and IRA (e.g., 45X which is uncapped) is directed towards funding battery material extraction, processing, and refining. • The DOE is continuing to fund RD&D in alternative battery chemistries for different applications that use more readily available materials e.g., $125 million in recent funding for next-generation rechargeable batteries[14] • IRA Clean Vehicle Credit (30D) has a critical material requirement which will help stimulate domestic production of critical materials and in other North America countries.[15]
Platinum Group Metals (PGMs)	BASF Corporation's increased investment in its PGM recycling facility and subsequent reorganization of business structure to emphasize recycling materials for automotive applications[16]	• Facilities that process, refine, and recycle PGMs categorized by DOE as critical materials or USGS as critical minerals are eligible for 48C from IRA ($10 billion). • DOE continues to fund research into PGM alternative and to increase material efficiency and resiliency of existing catalyst designs e.g., recently published research from Pacific Northwest National Lab supported in part by the Office of Science that reduces platinum usage and improves efficiency in catalyst[17]
Rare Earth Elements (REEs)	Private sector is beginning to invest in domestic rare-earth processing facilities, including USA Rare Earth in Oklahoma[18]	BIL funds a $140 million first-of-a-kind rare earth demonstration facility, to extract rare earth elements from unconventional waste streams such as coal.[19] Rare earth processing is also eligible for 45X and 48C.

[12] https://www.sec.gov/Archives/edgar/data/1728205/000172820520000031/ex99_1.htm
[13] https://www.energy.gov/sites/default/files/2022-11/DOE%20BIL%20Battery%20FOA-2678%20Selectee%20Fact%20Sheets.pdf#page=19
[14] https://www.energy.gov/science/articles/department-energy-announces-125-million-research-enable-next-generation-batteries
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[19] https://www.energy.gov/mesc/rare-earth-elements-demonstration-facility

Materials	Current Industry Investment	Current U.S. Government Investments
Polysilicon	Capital investment in solar silicon manufacturing like Hanwha's stake in REC Silicon help drive manufacturing capacity increases[20]	Polysilicon is eligible for several federal funding sources including 45X which will encourage domestic production.
Enriched Uranium	Public-private partnerships are developing to bring back commercial HALEU production to the US private sector[21]	DOE has established the High-Assay Low-Enriched Uranium (HALEU) Consortium to support HALEU availability and help drive advanced nuclear deployment.[22] $700 million has also been made available through IRA funding.

Examples of investments listed in **Table 3** are a significant step towards reducing U.S. supply chain vulnerabilities. Overall, investments to secure upstream materials can be grouped into three main efforts highlighted below.

Increasing domestic materials accessibility

The United States can reduce import reliance by increasing domestic production of critical materials. To address the severe upstream vulnerabilities, several authorities from BIL focus on stimulating domestic production of raw materials. The U.S. Government has already taken several steps, including:

- **RD&D support:** DOE has granted funds across the national lab system to develop the technology to detect and quantify rare-earth elements and critical minerals in unconventional and secondary sources, including five operational small scale pilots to recover and upgrade to high purity mixed rare earth oxides.[23] In addition, $32 million will be awarded to support front-end engineering design to produce critical materials and rare-earth elements from conventional coal-based resources[24], while $140 million will go to funding a first-of-a-kind demonstration facility utilizing unconventional sources to extract, separate, and refine critical minerals.[25]

- **Regional efforts:** FECM's Carbon Ore, Rare Earths, and Critical Minerals (CORE-CM) Initiative involves 13 basin-centered coalitions involving industry, academia, state and local governments, Tribal organizations, non-governmental organizations, and others.

[20] https://www.hanwha.com/en/news_and_media/press_release/hanwha-solutions-becomes-the-largest-shareholder-of-clean-polysilicon-manufacturer-rec-silicon-to-build-a-green-solar-supply-chain.html
[21] https://www.energy.gov/articles/doe-announces-cost-shared-award-first-ever-domestic-production-haleu-advanced-nuclear
[22] https://www.energy.gov/ne/us-department-energy-haleu-consortium
[23] https://www.energy.gov/fecm/articles/doe-invests-over-5-million-help-secure-domestic-supply-chain-critical-minerals
[24] https://www.energy.gov/articles/doe-launches-32-million-program-advance-domestic-supply-chain-critical-minerals
[25] https://www.energy.gov/articles/biden-harris-administration-announces-156-million-americas-first-kind-critical-minerals

These coalitions are focused on identifying secondary and unconventional feedstocks within their region, as well as assessing regional resources (e.g., mineral, workforce, transportation, infrastructure) that are available to help stand up domestic supply chains for REE and other critical minerals. From this work will come the first national prospectus for recovery of critical minerals from unconventional and secondary sources.

- **Processing and refining:** In 2022, through IRA, Congress established the Advanced Manufacturing Production Credit (45X[26]) and expanded the Advanced Energy Project Credit (48C) to include facilities processing, refining, or recycling of several critical materials. The design of these programs is underway. For example, several materials such as polysilicon, REEs, and battery materials are eligible for these tax credits.

- **Alternative materials/technologies:** For over a decade, the Critical Materials Institutes led by DOE in partnership with industry, national labs, and universities has invested in finding alternative materials to critical materials as well as alternative technologies that do not use critical materials to strengthen the U.S. clean energy independence and security. With funding from BIL, DOE is well positioned to commercialize and scale alternative materials or technologies. For example, DOE has invested in scaling up manufacturing of alternatives to battery critical materials, including a $117 million grant to build a synthetic graphite production plant in Alabama and multiple investments in scaling up manufacturing of next-generation silicon-based battery anodes totaling $250 million.[27]

- **Domestic mining reform:** In February 2022, the Biden-Harris Administration released fundamental principles for domestic mining reform, which include consideration for expanding domestic production of critical materials key to the clean energy transition.[28] Consistent with these fundamental principles, the Department of Interior launched an Interagency Working Group on mining reform to review existing mining laws, regulations, and permitting processes.[29]

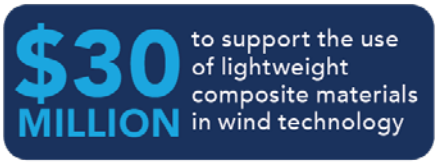
Improving material efficiency, reuse, and recycling capabilities

Reducing material intensity, extending life of equipment, promoting reuse of components and equipment, and increasing recycling of end-of-life energy equipment are strategic opportunities to reduce raw material use and build out supply chain resilience, while reducing end-of-life waste. Successful end-of-life strategies may also increase the domestic availability of critical materials for clean energy technology production and reduce the U.S. manufacturing sector's reliance on critical material imports. Recycling of clean energy technologies is still a niche area with several clean energy technologies currently approaching large-scale end of life installations. Scaling clean energy recycling will require strategic investment in RD&D to improve all stages of end-of-life

[26] Short for 26 U.S.C. § 45X
[27] https://www.energy.gov/sites/default/files/2022-11/DOE BIL Battery FOA-2678 Selectee Fact Sheets.pdf
[28] https://www.doi.gov/sites/doi.gov/files/biden-harris-administration-fundamental-principles-for-domestic-mining-reform.pdf.
[29] https://www.doi.gov/pressreleases/interior-department-launches-interagency-working-group-mining-reform

management. For example, establishing domestic lithium-ion battery recycling infrastructure requires investment in a variety of activities: safe and robust collection and transportation programs, battery state-of-health testing standards, sorting and disassembly activities, advancing recovery processes, improving material recovery rates, as well as investing in standing up recycling facilities. DOE, in collaboration with industry and other agencies, continues to strengthen the circular economy of clean energy technologies through the following:

- **RD&D:** Financial assistance grants and prize-based competitions can help spur innovation and bridge the gap between research and deployment of new technologies. There are several such efforts across DOE offices:
    - *Advanced Materials and Manufacturing Technology Office (AMMTO):* has supported innovation in scaling up wind turbines for greater efficiency. Early 2023, AMMTO released a Funding Opportunity Announcement (FOA) of $30 million to support use of lightweight composite materials in wind technology.[30]



    - *Hydrogen and Fuel Cell Technologies Office (HFTO):* in March 2023, DOE released a solicitation for $750 million of funding to reduce the cost of electrolyzers and fuel cells and advance recycling, recovery, and refurbishment technologies for their components (the first tranche of two BIL provisions authorizing $1 billion to reduce the cost of clean hydrogen and $500 million for improved manufacturing and recycling).[31]
    - *Vehicle Technologies Office (VTO):* finished Phase III of its prize-based Lithium-Ion Battery Recycling Competition in mid-2022 and awarded prizes to four private sector companies that developed novel recycling technologies over the course of the competition.[32]
    - *Wind Energy Technology Office (WETO)*: is also supporting the development of technology for the recycling and reuse of wind turbines, including $40 million allocated for this purpose under the Bipartisan Infrastructure Law.[33]

- **Recycling facilities:** Funding recycling facilities helps to promote a circular economy and to reduce dependence on imports.

[30] https://www.energy.gov/articles/us-department-energy-announces-30-million-materials-and-manufacturing-lower-costs-large
[31] https://www.energy.gov/articles/biden-harris-administration-announces-750-million-advance-clean-hydrogen-technologies
[32] https://www.energy.gov/eere/vehicles/articles/doe-announces-battery-recycling-prize-phase-iii-winners
[33] https://www.energy.gov/eere/wind/articles/carbon-rivers-makes-wind-turbine-blade-recycling-and-upcycling-reality-support

- *Office of Manufacturing and Energy Supply Chains (MESC):* issued a Funding Opportunity Announcement (FOA) on Advanced Energy Manufacturing and Recycling Grants in early 2023.[34] A portion of this funding will be awarded to manufacturers to re-equip, expand, or establish recycling facilities for critical energy technologies. MESC is supporting the implementation of the 48C tax credit through IRA, which has been expanded to establish domestic recycling facilities to recover critical materials, as well as recycle end of life clean energy technologies. The Internal Revenue Service has already released the initial guidance for 48C with instructions detailing the eligibility for recycling manufacturing facilities.

- *Loan Programs Office (LPO):* can also support standing up recycling facilities through its debt financing programs. In early 2023, the LPO offered a conditional loan commitment of $2 billion to Redwood Materials to support the construction and expansion of a battery materials facility that will produce critical electric vehicle (EV) battery components from an increasing use of recycled materials.[35] The project would be the first domestic facility to support production of anode copper foil and cathode active materials in a fully closed-loop lithium-ion battery manufacturing process by recycling production and end-of-life battery scraps. In addition, LPO announced a conditional commitment to Li-Cycle for a $375 million loan to help finance the construction of a first-of-its-kind lithium-ion battery resource recovery facility in North America. If finalized, the loan will help Li-Cycle, already North America's largest lithium-ion sustainable pure-play battery recycler, further expand its operations. The facility, located in the Rochester, New York area, is expected to support the battery needs of approximately 203,000 EVs annually.[36]

Diversifying foreign sources

While there are several efforts to increase domestic production of many needed critical materials, there are some materials for which the U.S. does not have economically viable deposits, requiring sometimes sourcing from unreliable countries. Efforts to increase domestic production of critical materials are ongoing. However, not all materials can be economically extracted or processed in the United States. For example, the United States does not have significant deposits of natural graphite, some rare earth elements, and platinum group metals that are economically recoverable with current technologies. The U.S. Government continues to secure these critical materials through by engaging allied nations via international development activities and direct investment:

[34] https://www.energy.gov/mesc/advanced-energy-manufacturing-and-recycling-grants
[35] https://www.energy.gov/lpo/articles/lpo-offers-conditional-commitment-redwood-materials-produce-critical-electric-vehicle
[36] https://www.energy.gov/lpo/articles/lpo-announces-conditional-commitment-loan-li-cycles-us-battery-resource-recovery

- International Development Financial Corporation (DFC) invested $30 million to help support nickel and cobalt mining in Brazil[37] and the State Department has launched a Minerals Security Partnership (MSP) to collaborate with partner countries and MSP members are in the process of evaluating a dozen mines and projects to invest in globally.[38]
- The United States Trade Representative (USTR) has signed a critical minerals agreement with Japan to facilitate trade, promote fair competition, and enhance cooperation in securing critical mineral supply chains.[39]
- The Export-Import Bank (EXIM) has also worked to collaborate and host bilateral discussions with allied nations, including South Korea, Greenland, and Australia, around mining development and financing.[40]
- The U.S. Agency for International Development (USAID) is sponsoring a competition to spur innovation in rooting out corruption in mining development, identify human rights abuses, and promote sustainable mining practices across the supply chain.[41]
- The Department of Energy, International Affairs (IA) represents DOE's equities in various international for a and these activities mostly fall under technical facilitation and energy policy leadership. For 2023, multilateral work increased significantly for DOE owing to the increase in global focus on establishing diverse, resilient, and sustainable critical minerals supply chains. Notable accomplishments for 2023 include securing G7 Experts Group on Critical Minerals language in the Leaders Statement, securing expansion of DOE-led Conference on Critical Minerals and Materials (CCMM) to the G7 plus Australia. The CCMM remains one of the only multilateral engagements that convenes leading RD&D experts from each member country and serves to leverage each other's strengths and capabilities, to collectively monitor and priority issues, instead of acting in isolation.

[37] https://www.dfc.gov/investment-story/sourcing-critical-minerals-support-global-clean-energy-transition
[38] https://www.voanews.com/a/italy-joins-us-led-mineral-security-partnership-for-ethical-mining/6950081.html
[39] https://ustr.gov/about-us/policy-offices/press-office/press-releases/2023/march/united-states-and-japan-sign-critical-minerals-agreement
[40] https://www.exim.gov/news/export-import-bank-united-states-signs-co-financing-agreement-korea-trade-insurance
https://www.exim.gov/news/readout-export-import-bank-united-states-chair-reta-jo-lewis-welcomes-greenland-prime-minister
https://www.exim.gov/news/readout-export-import-bank-united-states-meets-australian-delegation-led-minister-for-trade
[41] https://www.usaid.gov/news-information/press-releases/nov-15-2022-usaid-calls-for-innovators-to-counter-corruption-in-the-green-minerals-industry

2.2 Expanding U.S. Clean Energy Manufacturing

Manufacturing plays a significant and re-emerging role in the U.S economy as demonstrated by its contribution to Gross Domestic Product (GDP) and employment. In 2021, manufacturing contributed about $2.3 trillion to the U.S. GDP, which is about 12% of the total U.S. GDP.[42] While the United States remains a strong manufacturing country, over the decades, it has been experiencing a declining trend[43], with several manufacturing activities offshored abroad.

Global supply chain disruptions due to COVID-19, followed by the Russian war in Ukraine brought to the forefront several underlining U.S. supply chain vulnerabilities associated with foreign dependence of key materials and components. Clean energy supply chains were not spared from these vulnerabilities as several key critical components and equipment for clean energy continue to heavily depend on foreign sources (See example of vulnerabilities in **Table 4** and investments meant to target those vulnerabilities in **Table 5**).

There is now an opportunity to invest in America and domestic manufacturing to rebuild middle class American jobs, upskill the American workforce, increase technology investment in the U.S. industrial base, unite the American manufacturing ecosystem, and strengthen U.S. supply chains.

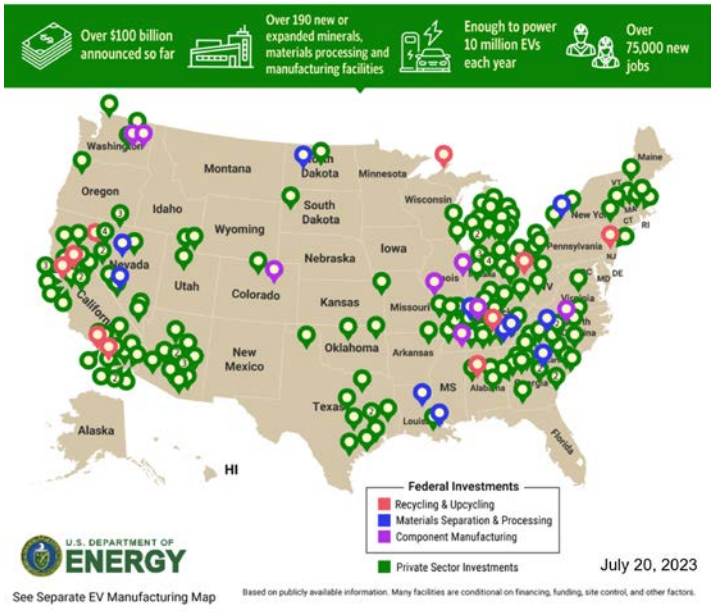
Table 4. Priority Opportunities in Manufacturing of Clean Energy Technologies

Component/Equipment	Relevant Technologies	Vulnerabilities
Large Castings and Forgings	Onshore wind, offshore wind, hydropower, and nuclear	U.S. does not have large-scale domestic castings and forgings capabilities to meet demand; certain technologies, such as nuclear, require higher grade equipment than others.
Rare Earth Magnets	EVs, onshore wind, and offshore wind	U.S. does not have manufacturing capability for Neodymium magnets with China dominating more than 92% of the capacity
Battery Components	EVs and grid energy storage	China maintains a stronghold in mid and downstream battery supply chain. China manufactures most cathodes (89 %), anodes (93 %), separators (89 %), electrolytes (94 %), and cells (75%)
Semiconductor	EVs, heat pumps, solar PVs, onshore wind, offshore wind	U.S. does not have domestic manufacturing capability to meet demand for semiconductors and lacks key capital equipment (e.g., lithography machines)
Ingots and Wafers	Solar PV	Manufacturing highly concentrated in China. U.S. has no supply of specialized manufacturing equipment to produce ingots and wafers (e.g., diamond wire saws, ingot pullers)
Grain-oriented electrical steel (GOES)	Distribution and large power transformers	U.S. has limited cost competitiveness with high foreign dependence particularly in Asia. With Russia production no longer accessible, competition for Asian market is expected to

[42] https://www.nist.gov/el/applied-economics-office/manufacturing/total-us-manufacturing
[43] https://nvlpubs.nist.gov/nistpubs/ams/NIST.AMS.100-49.pdf

Component/Equipment	Relevant Technologies	Vulnerabilities
		increase. Also, the growth of EVs may exacerbate the supply shortage of GOES as more non-oriented electrical steels is needed for EVs.
Transformers	Electric grid	U.S. manufacturing is constrained by the limited number of players and transportation infrastructure
Offshore wind component	Offshore wind turbines	U.S. manufacturing for most components is starting to scale but faces challenges across value chain due to significant cost increases for both offshore wind manufacturing and projects.
Specialized Components for Nuclear	Nuclear	The existing fleet of U.S. nuclear reactors depend, in part, on low-enriched uranium produced in Russia. The U.S. does not currently have sufficient domestic manufacturing capacity to meet total demand. Furthermore, the capacity to manufacture some specialized components that contain unique alloys or materials also needs to be developed for advanced nuclear reactors.

The experience of the past three years has also revealed opportunities for the United States to strengthen its supply chains to reduce reliance on unreliable foreign suppliers for critical components and equipment needed for clean energy transition. There are notable trends emerging as American businesses and the U.S. Government ramp up supply chain investments in critical sectors.



Source: https://www.energy.gov/investments-American-made-energy

Figure 2. American-Made Batteries (July 2023)

Onshoring Manufacturing back to the U.S.

Global supply chains allow countries to focus on producing goods and services that they have a comparative advantage in and trading goods and services that are not economical to produce domestically. However, global supply chains are prone to several vulnerabilities such as natural disasters, global pandemics, and unstable geopolitics, with external actors having limited or no control over operations that are located abroad. Post COVID-19, American businesses have strengthened efforts to onshore their supply chains.[44,45] For that reason, the U.S.

[44] https://business.bofa.com/content/dam/flagship/bank-of-america-institute/transformation/back-to-the-usa-rising-tide-of-reshoring-september-2022.pdf

[45] https://www.bloomberg.com/news/newsletters/2022-07-06/supply-chain-latest-ceos-start-to-turn-reshoring-talk-into-action

Government through BIL, IRA, and CHIPS, continues to support onshoring of several key manufacturing activities critical to energy transition, such as critical material processing and refining, battery manufacturing, uranium enrichment, and other clean energy technology manufacturing. Evidence of onshoring is seen in clean energy manufacturing investments and build out in the United States over the past two years (see example in **Figure 2**).[46] Further evidence can be inferred by looking at the increase in domestic manufacturing job listings. For example, there was an increase of 278% in domestic manufacturing jobs listed in the second quarter of 2022 compared to 2019, with most of these jobs listed in Texas, Tennessee, Michigan, and Arizona.[47]

Friendshoring and Nearshoring Manufacturing

In the near-term, it may not be feasible or economical to onshore all segments of energy supply chains, particularly on the timeframe necessary to meet clean energy and climate. In this case, diversifying U.S. import sources by friendshoring to U.S. allies with a comparative advantage to manufacture the needed critical components or nearshoring to countries near the United States is seen as another option to strengthen supply chain resilience by both industry and government.[48, 49]

Expanding Manufacturing RD&D and Accelerating Technology Commercialization

Expanding RD&D and accelerating commercialization of American innovation is seen as another solution to not only ensure future supply chains are resilient, but also help meet U.S. climate goals. There are several emerging clean energy technologies such as advanced nuclear and clean hydrogen with strong potential for growth and ability to transform the industrial sector, where the U.S. can establish global competitiveness. But there are also some areas in mature technologies where the United States is still lacking manufacturing capabilities or is not competitive compared to other countries. In this case, deploying cutting-edge and innovative technologies and processes that reduce costs could be an answer to increasing U.S. competitiveness.

In 2022, DOE released the *Industrial Decarbonization Roadmap* which identifies RD&D opportunities for industry and government to consider that will deliver the technologies needed to dramatically improve industrial processes and reduce emissions.[50] Retaining and supporting existing U.S. industry and industrial facilities, even those in adjacent industries, will be necessary to continue to expand domestic clean energy supply chains. The Commercialization and Competitiveness report released as part of the 1-year supply chain reports in February 2022 outlined a strategy and conceptual framework for building an economically competitive supply chain.[51] Building off this work, in early 2023, DOE released *Pathways to Commercial Liftoff* which focuses on four clean energy technologies – advanced nuclear, carbon management, clean hydrogen, and long duration energy storage. These pathways provide insights on how and when

[46] https://www.energy.gov/investments-american-made-energy
[47] https://business.bofa.com/content/dam/flagship/bank-of-america-institute/transformation/back-to-the-usa-rising-tide-of-reshoring-september-2022.pdf
[48] https://www.maersk.com/insights/resilience/friendshoring-for-supply-chain-resiliency
[49] https://www.cnbc.com/2022/07/19/us-treasury-secretary-on-supply-chain-resilience-use-friend-shoring.html
[50] https://www.energy.gov/eere/doe-industrial-decarbonization-roadmap
[51] https://www.energy.gov/sites/default/files/2022-02/Commercialization%20%26%20Competitiveness%20Supply%20Chain%20Report%20-%20Final.pdf

these technologies could reach full-scale commercial adoption, which is critical in informing investment decisions for both the private sector and government.[52]

In addition, BIL, IRA, and CHIPS invest heavily in RD&D and accelerating commercialization of key technologies to support both mature and emerging technologies. For example, as authorized under the Energy Policy Act of 2020 and funded through BIL, IRA, and base-level appropriations, DOE created the Office of Clean Energy Demonstrations (OCED), which focuses on investing in large scale, first of a kind, commercial demonstrations. OCED released several FOAs and a request for information to explore demand-side market mechanisms related to BIL and IRA provisions. OCED also now leads the management of two existing advanced nuclear reactor demonstration projects.[53] The Office of Nuclear Energy continues to manage other advanced reactor demonstrations, including the first commercial deployment of NuScale's VOYGR-6 small modular reactor through the Carbon Free Power Project[54] and five cost-shared projects with industry for a broad set of advanced nuclear designs.[55] To further amplify a focus on manufacturing RD&D, DOE has also reorganized the Advanced Manufacturing Office into the Advanced Materials and Manufacturing Technologies Office (AMMTO) and Industrial Efficiency and Decarbonization Office (IEDO) within the Energy Efficiency and Renewable Energy Office.[56]

Overall, the U.S. Government in collaboration with industry continues its efforts to revitalize domestic manufacturing capabilities through a range of authorized policy tools provided by BIL, IRA, and CHIPS. **Table 5** highlights examples of investments from industry and the U.S. Government to address component manufacturing vulnerabilities presented in **Table 4** (a detailed list of potential federal funding is in **Table 6** in the Appendix). These investments are a significant step in reducing some U.S. manufacturing vulnerabilities in the near and long term.

Table 5. Examples of Investment Focusing on Priorities in Manufacturing

Components	Current and Potential Industry Investment	Current and Potential U.S. Government Investments
Large Castings and Forgings	Manufacturers continue to invest in RD&D to enhance U.S. capability and competitiveness of large castings. [57]	• The Office of Nuclear Energy has stimulated more than $90 million in supply chain investments for large castings and forgings through ongoing awards and development activities for alternative large scale manufacturing capabilities. • AMMTO released approximately $30 million in funding to support manufacturing of large metallic near-net shape components[58]
Rare Earth Magnets	Mining firms in the U.S. are focusing on expanding domestic production due to higher renewed focus on supply chain security and clearer long-term demand e.g., MP America's Rare	• BIL invest more than $1 billion in continued RD&D funding across government agencies to identify and scale substitutes for rare-earth minerals. • BIL invest $140 million for rare-earth demonstration facility.[59]

[52] https://liftoff.energy.gov/about-the-liftoff-reports/
[57] https://www.ge.com/news/reports/catching-more-wind-2-ge-research-projects-seeking-to-grow-offshore-wind

Components	Current and Potential Industry Investment	Current and Potential U.S. Government Investments
	Earth Processing Facility that began construction in 2022.	
Battery Components	Offtake commitments between automakers and battery manufacturers are providing clear market signals to scale up domestic manufacturing e.g., General Motors investment in Lithium America's Thacker Pass Mine.[60]	• IRA tax incentives are expected to spur onshoring and nearshoring of battery component manufacturing. For example, the 30D tax credit includes battery component requirements.[15] • $3.3 billion in funding from BIL to scale up recycling solutions for battery components and minerals to ensure continued energy independence.
Semiconductor	Private-sector investments in new fabs for leading-edge or mature nodes (e.g., Texas Instrument $11 billion fab investment in Utah[61])	• CHIPS provides a 25% advanced manufacturing tax credit to grow America's semiconductor industrial base, as part of the overall $52.7B investment in semiconductor manufacturing from CHIPS.
Ingots and wafers	Private-sector investments in solar manufacturing are also increasing, following the passage of IRA (e.g., Hanwha $2.5 billion investment in Georgia[62]).	• IRA tax incentives, such as 45X, encourage onshoring of solar manufacturing, while the $11.7 billion in additional funding from the LPO may be used to support solar ingot and wafer manufacturing capabilities. • The DOE Solar Office funds RD&D for next-generation perovskite solar, which if successful would reduce reliance on silicon-based wafers.[63]
Grain-oriented electrical steel (GOES)	There is potential for steel manufacturers to revamp GOES manufacturing in North America, while engaging with DOE and relevant federal agencies on how to the government can provide appropriate support.	• GOES manufacturing will be eligible for several DOE funding opportunities, including 48C. • GOES is also one of the components eligible for DOE's Presidential determination to use Defense Production Act authority to expand domestic production.
Transformers	Hitachi Energy announced a $37 million modernization and expansion to their power	• BIL provisions rebates for energy-efficient power transformers, providing clear demand signal to manufacturers.[65]

[54] https://www.energy.gov/ne/articles/doe-approves-award-carbon-free-power-project
[55] https://www.energy.gov/ne/articles/5-advanced-reactor-designs-watch-2030
[56] https://www.energy.gov/eere/amo/about-amo-restructure
[57]https://www.ge.com/news/reports/catching-more-wind-2-ge-research-projects-seeking-to-grow-offshore-wind
[58]https://www.energy.gov/eere/ammto/funding-opportunity-announcement-domestic-near-net-shape-manufacturing-enable-clean-and
[59] https://www.energy.gov/mesc/rare-earth-elements-demonstration-facility
[60]https://www.globenewswire.com/news-release/2023/01/31/2598482/0/en/Lithium-Americas-Provides-General-Motors-Transaction-Details-and-Update-on-Construction-Plan-for-Thacker-Pass.html
[61] https://news.ti.com/texas-instruments-selects-lehi-utah-for-its-next-300-millimeter-semiconductor-wafer-fab
[62]https://www.reuters.com/business/energy/south-koreas-hanwha-q-cells-to-invest-231-bln-us-solar-manufacturing-2023-01-11/
[63]https://www.energy.gov/eere/solar/solar-energy-research-database
[65] https://www.energy.gov/mesc/energy-efficient-transformer-rebates

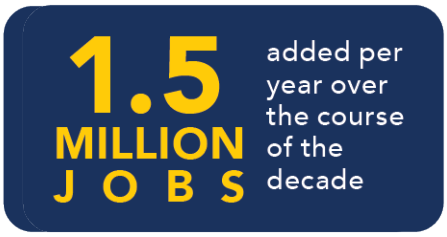
Components	Current and Potential Industry Investment	Current and Potential U.S. Government Investments
	transformer factory in Virginia to address growing demand.[64]	• Large Power Transformer (LPT) manufacturing facilities are also eligible for 48C. • LPTs are one of the components eligible for DOE's Presidential determination to use Defense Production Act authority to expand domestic production.
Offshore wind component	Private-sector led development of offshore-wind has spurred investment in bringing manufacturing closer to offshore wind development sites (e.g., Siemens new wind turbine facility in New York[66]).	• Section 48 Investment Tax Credit (ITC) credits with stackable Energy Communities and Domestic Content Bonus Credits, Section 45X Advanced Manufacturing Production Credit, and 48C from IRA help spur investments, encourage onshoring of manufacturing and stimulate demand. • Funding from BIL continues to allow the Wind Energy Technology Office's to fund advanced RD&D in offshore wind energy.[67]
Specialized components for nuclear	TerraPower and X-Energy continue to invest heavily in the development and advancement of the Natrium and Xe-100 advanced nuclear demonstration projects, respectively. NuScale continues to invest in the VOYGR small modular reactor and its supply chain. Industry investments are also being made by Kairos Power, Westinghouse, BWXT, Holtec International, Southern Company Services, GE-Hitachi, and other advanced reactor vendors.	• BIL appropriated $2.477 billion to extend the private-public partnership for the development and demonstration of the Natrium and XE-100 projects. • DOE-NE continues to support a multi-year cost share award with the Carbon Free Power Project to help demonstrate and deploy a six-module NuScale power plant located at the Idaho National Laboratory. • Starting from 2020, NE expects to invest approximately $600 million over seven years with advanced reactor industry partners providing at least 20% in matching funds. • Nuclear energy supply chain projects are also eligible for 48C funding opportunities.

[64] https://www.hitachienergy.com/us/en/news/press-releases/2022/10/hitachi-energy-invests-us-37-million-to-expand-transformer-manufacturing-facility-in-south-boston-virginia

[66] https://www.siemensgamesa.com/en-int/newsroom/2023/02/021323-siemens-gamesa-press-release-new-york-offshore-nacelles-facility

[67] https://www.energy.gov/eere/wind/wind-energy-funding-opportunities

2.3 Growing the Domestic Workforce for Clean Energy



DOE supply chain reports published in 2022 indicated a mismatch between demand and supply of skilled and unskilled workers in the energy sector.[68] This mismatch in the workforce continued throughout 2022. It is estimated that BIL and IRA will add an average of about 1.5 million jobs per year over the course of the decade.[69] Recent preliminary estimates suggest that, without any active efforts to better prepare the workforce, BIL alone could lead to a supply and demand workforce mismatch of supply and demand of workforce of about 350,000 jobs[70] which is likely to be exacerbated by other policy levers such as IRA and CHIPS by driving increased demand for labor. As discussed in DOE's 2022 report, *America's Strategy to Secure the Supply Chain for a Robust Clean Energy Transition*, this mismatch in labor demand and supply relates to a wide range of social, economic, technological, and demographic factors that include declining wages in the manufacturing sector, increasing precarity of jobs, a lack of investment in worker skill development, an aging workforce, and changes in workforce preferences.[71]

There are active efforts from both the private and public sector to address the mismatch, starting with renewed attention to the importance of job quality in attracting and retaining skilled workers. With over $97 billion from BIL and IRA to invest in energy programs,[72] DOE is requiring every applicant for BIL and IRA funding to include a community benefits plan as part of their application. The community benefits plan consists of four sections - Justice40; Diversity, Equity, Inclusion, and Access (DEIA); Good Jobs and Workforce Continuity; and Workforce and Community Agreements.[73] The Good Jobs and Workforce Continuity section asks applicants to explain how they will attract, train, and retain the local workforce needed to support the clean energy transition, including by investing in workforce education and training initiatives like registered apprenticeship, involving workers in health and safety plans, paying above average compensation, and providing affirmative support for worker organizing and collective bargaining. The DEIA section asks applicants to explain how they will increase and improve access to jobs for workers with barriers to employment, such as through apprenticeship-readiness programs and partnerships with community-based workforce organizations.

For the Inflation Reduction Act, applicants must meet certain labor standards to claim the full amount of several tax credits. For example, 48C applicants can pursue a 6% tax credit on their qualified investment, but if prevailing wage and apprenticeship requirements are met, applicants are eligible for an enhanced credit of 30%.

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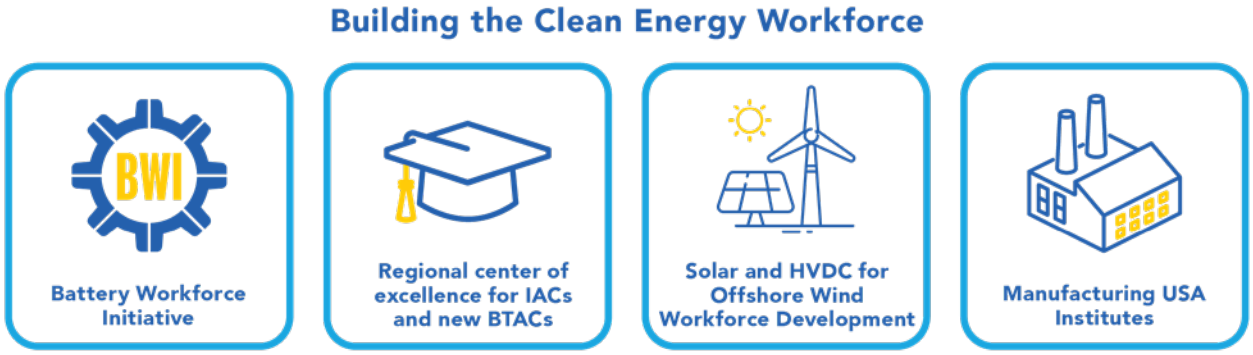
[68] https://www.energy.gov/policy/articles/americas-strategy-secure-supply-chain-robust-clean-energy-transition
[69] https://www.energy.gov/articles/doe-fact-sheet-bipartisan-infrastructure-deal-will-deliver-american-workers-families.
[70] https://www.mckinsey.com/industries/public-and-social-sector/our-insights/will-a-labor-crunch-derail-plans-to-upgrade-us-infrastructure
[71] https://www.energy.gov/policy/articles/americas-strategy-secure-supply-chain-robust-clean-energy-transition
[72] https://www.energy.gov/clean-energy-infrastructure/clean-energy-infrastructure-program-and-funding-announcements
[73] https://www.energy.gov/infrastructure/about-community-benefits-plans

The CHIPS Act, which allocates more than $50 billion to support the domestic semiconductor industry, requires applicants to secure commitments from regional educational and training entities and institutions of higher education to provide workforce training. The goal is to ensure all federally-funded projects invest in America's workforce by creating good jobs for workers and having clear actions in place to attract, train, and retain a skilled workforce.

In addition, program offices across DOE are stepping up to the challenge of building the clean energy workforce:



- *Battery Workforce Initiative*: The Office of Energy Jobs (OEJ) along with the Vehicle Technology Office (VTO), the Advanced Manufacturing Office (AMMTO), and EERE are leading a collaborative, industry-driven effort to develop national training guidelines and a system of training to support the rapid development of a globally competitive U.S. battery industry. After building employer consensus on training and skill requirements, DOE will work with the Department of Labor (DOL) to certify national training guidelines and develop a curriculum to develop the workforce to support rapid expansion and long-term success of the domestic battery supply chain. This effort is a pilot for developing "sectoral strategies" in other parts of the clean energy supply chain as well.[74]

- *Regional center of excellence for Industrial Assessment Centers (IACs) and new Building Training Assessment Centers (BTACs)*: IACs and BTACs provide free energy assessments to small- and medium-sized manufacturing facilities and commercial and industrial buildings, respectively. Through BIL, the Department of Energy disbursed $18.75M in funding for five new regional Centers of Excellence.[75] A new funding opportunity will also invest up to $54M in the creation of new IACs and BTACs at trade schools, community colleges, and union training programs.[76] This program is jointly managed by the State and Community Energy Program (SCEP) and the Office of Manufacturing and Energy Supply Chains (MESC).

[74] https://netl.doe.gov/bwi
[75] https://www.energy.gov/sites/default/files/2023-04/IAC%20-%20Ctr%20of%20Excellence%20-%20Project%20Factsheets%20-%20April%202023.pdf
[76] https://www.energy.gov/doe-stem/events/industrial-assessment-center-iac-program-and-building-training-and-assessment

- *Solar and HVDC (High Voltage Direct Current) for Offshore Wind Workforce Development*: Solar and Wind Energy Technologies Offices have both released funding in the past year to develop workforce partnerships and invest in training programs to ensure adequate labor supply for anticipated demand of solar and offshore wind projects, as well as create equitable job opportunities. For example, SETO released a $10M BIL funding opportunity for collaborative workforce programs that will facilitate the rapid deployment of solar energy.[77]

- *Manufacturing USA Institutes*: DOE-supported Manufacturing USA's network of Institutes provides technical workforce development, education resources, and career training. Each institute provides specialized training across the member ecosystem and creates regional talent pipelines connecting graduates and reskilled labor to manufacturing employers.

2.4 Building Supply Chain Analytical Capabilities

Supply chains are complex with many interdependencies and so are the risks associated with them. As the United States continues to build out its supply chain, understanding supply chains and untangling risks is becoming vital to informing where strategic interventions are needed, including prioritization and sequencing of investments. The Office of Manufacturing & Energy Supply Chains (MESC) has created the Supply Chain Modeling, Mapping, and Analysis program to strengthen DOE's supply chain analytical capabilities. These analytical capabilities are built upon existing capabilities, tools, models, and expertise from DOE National Laboratories and external sources in consultation with stakeholders.

MESC is collaborating with other DOE offices to identify areas of prioritization for strategic investment and to build out analytical tools for reviewers to evaluate the supply chain implications of several funding proposals from BIL and IRA. One of MESC's priorities is to improve the robustness and transparency of supply chain tools used to inform decision-making. As a first step, MESC, in collaboration with LPO, OTT, and the national labs synthesized an updated existing supply chain analysis. Through this process, MESC produced a heatmap to summarize in visual form the degree of public and private investment required to establish industry-leading US energy supply chains (see example in **Figure 3**). MESC aspires to convert this initial heatmap into a "live tool" that will be updated as needed through a combination of insights from modeling and consultation with industry, national labs, academia, and other relevant stakeholders. These heatmaps are an additional resource from which both private and public sectors with an interest in energy supply chains can draw insights as they develop their investment strategies. Fully addressing our energy manufacturing supply chain opportunities will take public and private sector investment. To catalyze US supply chains, DOE has already deployed over $3B in funding to key battery and offshore wind supply chain segments in the past year and is in process of deploying another $294B, focusing primarily on supply chain segments where significant investment is required.

[77] https://www.energy.gov/eere/solar/articles/funding-notice-advancing-equity-through-workforce-partnerships
https://www.energy.gov/eere/wind/articles/funding-notice-offshore-wind-centers-excellence

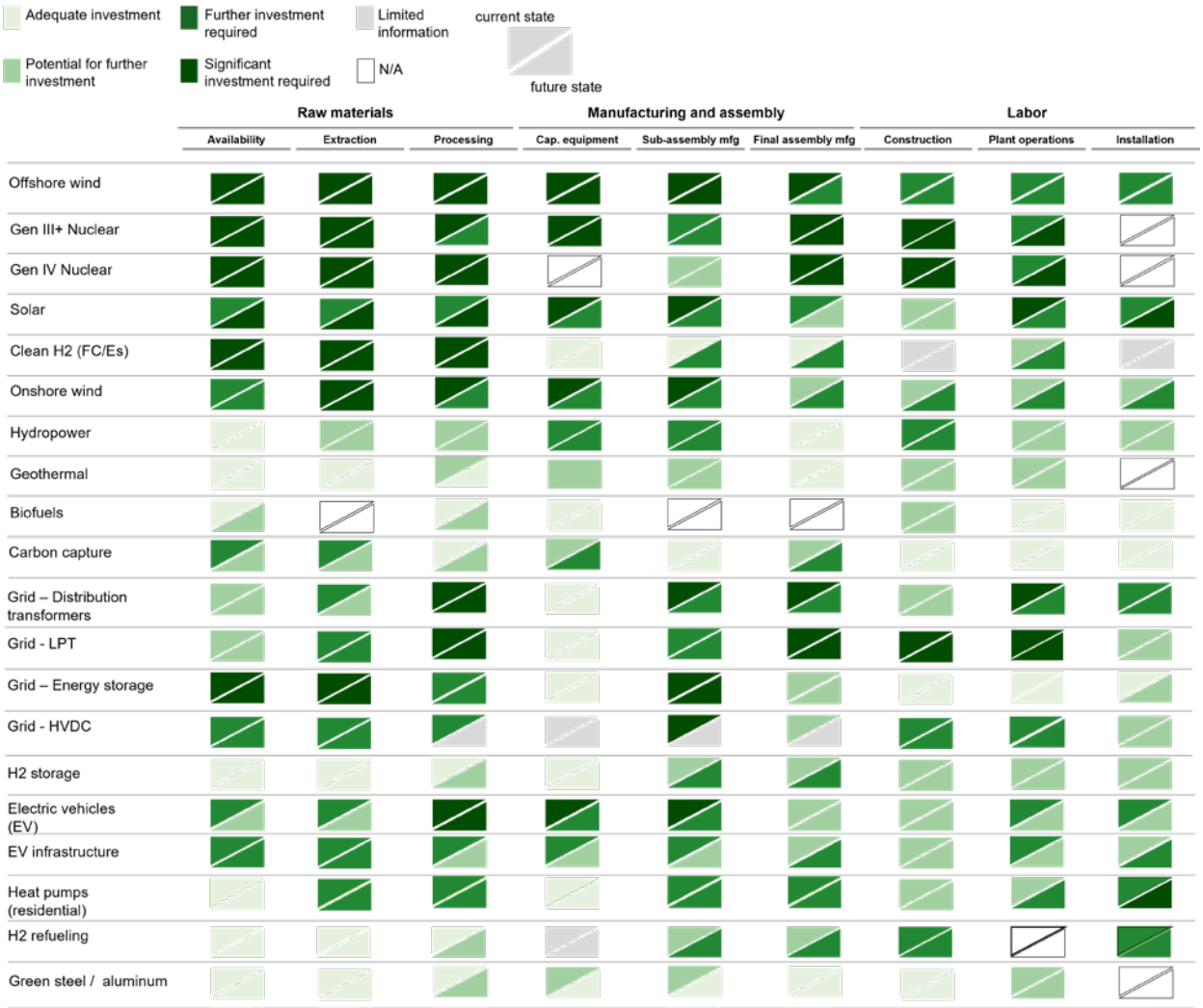


Figure 3. Visualization of Initial Cross-cutting Areas of Opportunities

Notes: The supply chain heat map is divided into nine supply chain components for a standardized evaluation framework. For each supply chain component, the current and future (5-10 years) vulnerabilities are assessed from a domestic perspective. The heatmap coloring is based on whether demand exceeds supply and or there are assessed vulnerabilities in the supply chain. The nine supply chain components are as follows:

1) Availability: Abundance of raw material required for fabrication
2) Extraction: Capacity to extract raw materials
3) Processing: Capacity to process raw materials
4) Manufacturing and Assembly: Availability of capital equipment
5) Sub-Assembly: Availability of sub-assembly manufacturing
6) Final Assembly: Availability of final assembly manufacturing
7) Construction: Availability of labor for construction
8) Plant Operations: Availability of labor for plant operations
9) Installation: Availability of labor for plant operations

3. Conclusion

The U.S. Government is committed to supporting American businesses in securing and strengthening domestic supply chains to spur economic prosperity, maintain national security, create jobs for American families, and meet climate goals. This commitment is reflected in the historic investments from BIL, IRA, and CHIPS, and DOE's emphasis on large-scale demonstration and deployment projects. The Department is well-positioned to meet the industrial challenges of the 21st century through leveraging existing program offices' inherent knowledge and new programs and emphasis on later stage development added by DOE's organizational restructuring.

DOE is investing in building up the energy sector industrial base through funding provided in BIL, IRA, CHIPS, and regular appropriations. Substantial progress has been made in addressing supply chain vulnerabilities and opportunities by securing critical materials, funding the expansion of US clean energy manufacturing, and growing the American workforce. DOE is also investing in developing new supply chain analytical capabilities to inform its investment decisions. In the coming year, DOE will continue to adapt its processes and investment strategy to respond to supply chain challenges and create new economic opportunities.

Appendix

Table 6. Detailed List of BIL/IRA/CHIPS Funding to Address Notable Priorities

Materials	Provision section	Potential Federal Funding	Amount	Program status
Upstream				
Battery Materials	IRA – 45X	Advanced Manufacturing Production Credit	10% of production cost	Available for tax year 2023
	CHIPS – 10359	Critical Minerals Mining Research and Development	Funding amount not available	Funding Opportunity Announcement (FOA) Open
	BIL – 40207(b)	Battery Material Processing Grants	$3 billion	Notice of Intent (NOI) released
	BIL – 40207(f)	Battery and Critical Mineral Recycling	$125 million	NOI released
	BIL – 40210	Critical Minerals Mining and Recycling Research	$100 million	Not open yet
Platinum Group Metals (PGMs)	IRA – 45X	Advanced Manufacturing Production Credit	10% of production cost	Available for tax year 2023
	CHIPS – 10359	Critical Minerals Mining Research and Development	Funding amount not available	FOA open
	BIL – 40314	Clean Hydrogen Electrolysis, Manufacturing, and Recycling	$750 million	FOA open
	BIL – 41003(b)	Rare Earth Mineral Security	$127 million	FOA closed
	BIL – 41003(c)	Critical Material Innovation, Efficiency, and Alternatives	$465 million	Request for Information (RFI) closed
	BIL – 41003(d)	Critical Material Supply Chain Research Facility	$75 million	RFI closed
	BIL – 40210	Critical Minerals Mining and Recycling Research	$100 million	Not open yet
	BIL – 40205	Rare Earth Elements Demonstration Facility	$140 million	FOA closed
Rare Earth Elements (REEs)	IRA – 45X	Advanced Manufacturing Production Credit	10% of production cost	Available for tax year 2023
	CHIPS – 10359	Critical Minerals Mining Research and Development	Funding amount not available	FOA Open

Materials	Provision section	Potential Federal Funding	Amount	Program status
	BIL – 41003(b)	Rare Earth Mineral Security	$127 million	FOA closed
	BIL – 41003(c)	Critical Material Innovation, Efficiency, and Alternatives	$465 million	RFI closed
	BIL – 41003(d)	Critical Material Supply Chain Research Facility	$75 million	RFI closed
	BIL – 40205	Rare Earth Elements Demonstration Facility	$140 million	FOA closed
	BIL – 40210	Critical Minerals Mining and Recycling Research	$100 million	Not open yet
Polysilicon	IRA – 45X	Advanced Manufacturing Production Credit	$3/kg	Available for tax year 2023
Enriched Uranium	IRA – 50173	Availability of High-Assay Low-Enriched Uranium	$700 million	Draft Request for Proposals (RFP) recently completed interagency review and is expected to be cleared for publication in the near future
	IRA – 48C	Availability of High-Assay Low-Enriched Uranium	30% ITC, total fund of $10 billion	Application opens late 2023
Midstream				
Large Castings and Forgings	N/A	N/A	N/A	
Rare Earth Magnets	IRA – 45X	Advanced Manufacturing Production Credit	10% production cost	Available for tax year 2023
Battery Components	BIL – 40207(c)	Battery Manufacturing and Recycling Grants	$3 billion	NOI released
	BIL – 40208	Electric drive vehicle battery recycling and second-life applications program	$200 million	FOA awardees announced
	BIL – 40209	Advanced Energy Manufacturing and Recycling Grant Program	$750 million	FOA open
	IRA – 45X	Advanced Manufacturing Production Credit	$35/kWh for battery cells	Available for tax year 2023
	IRA – 48C	Advanced Energy Project Tax Credit	30% ITC, total fund of $10 billion	Application opens late 2023

Materials	Provision section	Potential Federal Funding	Amount	Program status
Semiconductor	CHIPS – 107	Advanced Manufacturing Tax Credit	25% ITC	Notice of Proposed Rulemaking (NOPR) Open
Ingots and Wafers	IRA – 48C	Advanced Energy Project Tax Credit	30% ITC, total fund of $10 billion	Application opens late 2023
	IRA – 45X	Advanced Manufacturing Production Credit	$12/sq. m.	Available for tax year 2023
Grain-oriented electrical steel (GOES)	BIL – 40101; 40103; 40107	Grid Resilience and Innovation Partnerships	$10.5 billion	FOA Open
Large power transformer	BIL – 40101; 40103; 40107	Grid Resilience and Innovation Partnerships	$10.5 billion	FOA open
	IRA – 48C	Advanced Manufacturing Tax Credit	30% ITC, total fund of $10 billion	Application opens late 2023
Offshore wind component	IRA – 45X	Advanced Manufacturing Production Credit	$20-50K/MW	Available for tax year 2023
	IRA – 48C	Advanced Energy Project Tax Credit	30% ITC, total fund of $10 billion	Application opens late 2023
	BIL – 40209	Advanced Energy Manufacturing and Recycling Grant Program	$750 million	FOA open
Specialized Nuclear Components	IRA – 48C	Advanced Energy Project Tax Credit	30% ITC, total fund of $10 billion	Application opens late 2023

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