



U.S. DEPARTMENT  
of **ENERGY**

Office of Critical Minerals  
and Energy Innovation

# **Advanced Materials and Manufacturing Innovation for Affordable Reliable Energy Systems and Secure Supply Chain**

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Advanced Materials and Manufacturing Technologies Office (AMMTO)

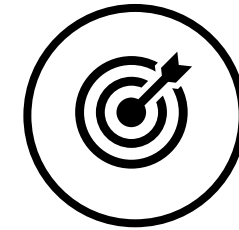
Feb 24, 2026

# Critical Minerals, Materials and Manufacturing (CM3)



## *Vision*

Global leadership in critical minerals value chains forged by competitive enterprise and unparalleled innovation, free of undue foreign influence.



## *Mission*

Drive innovation and commercialization across critical minerals supply chains, from extraction to manufactured products.

# CM3 Pillar Goals:



*Mission statement alignment across all goals:*

- *Innovation and commercialization*
- *From production through manufacturing of energy products*



***Extract***

- Expand the domestic critical mineral industrial base



***Produce***

- Fill domestic supply chain gaps by addressing midstream processing



***Manufacture***

- Catalyze the energy sector manufacturing base



***Recycle***

- Build a recycling ecosystem and develop alternatives to reduce material reliance



***Upskill***

- Reinvigorate America's workforce

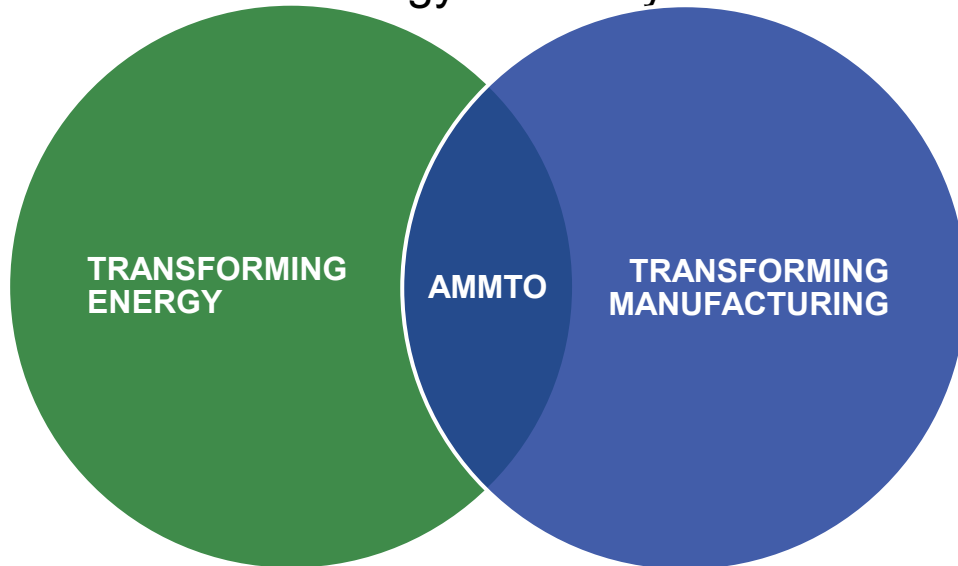


***Dominate***

- Drive globally competitive markets and leverage economic statecraft tools to advance energy security

# Enabling Secure, Innovative Domestic Manufacturing

The **Advanced Materials and Manufacturing Technologies Office (AMMTO)** drives and inspires innovation to transform materials, manufacturing, and supply chains to address critical material supply risk, catalyze a competitive manufacturing sector, and advance America's energy economy.



## National Impact



Energy  
Dominance



National and  
Energy Security



Economic  
Opportunity



Resilient  
Supply Chains



Domestic  
Startups



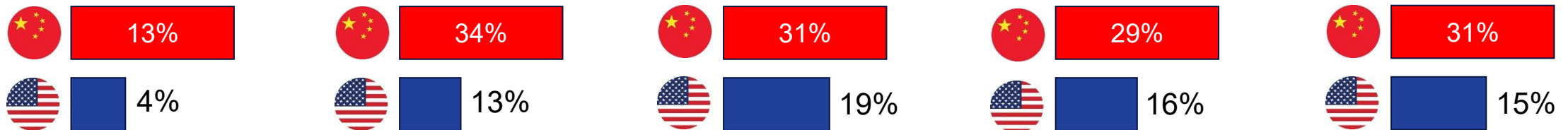
Domestic  
Workforce

# U.S. Energy-Manufacturing Industrial Base

*The energy-manufacturing industrial base contributes ~\$1.2T to U.S. GDP*



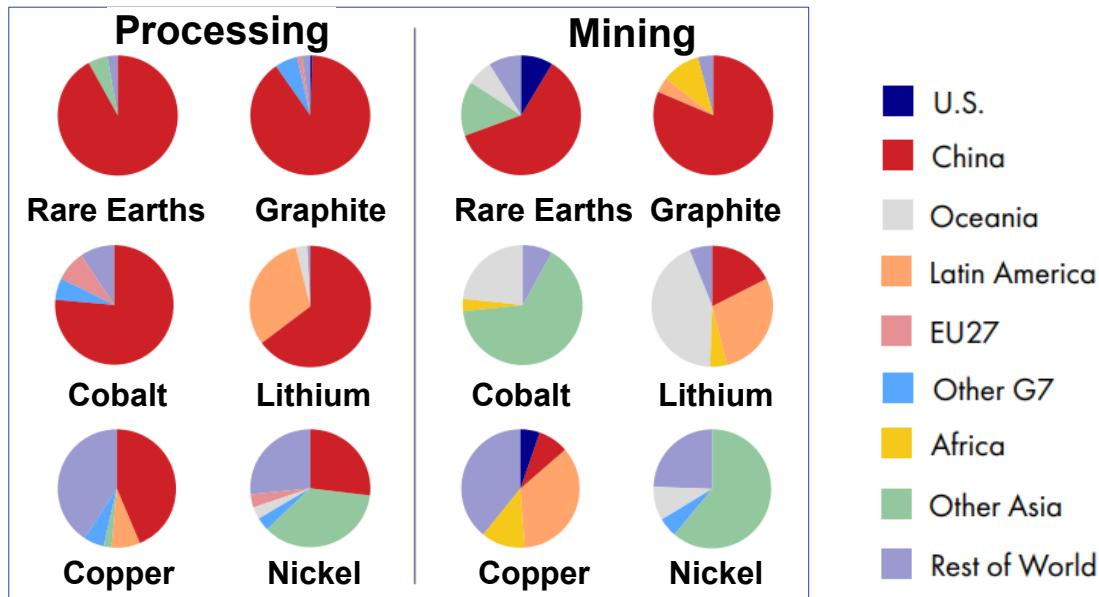
*The PRC dominates global production share across the energy-manufacturing supply chain*



# Supply Chain Vulnerabilities for US Energy Manufacturers

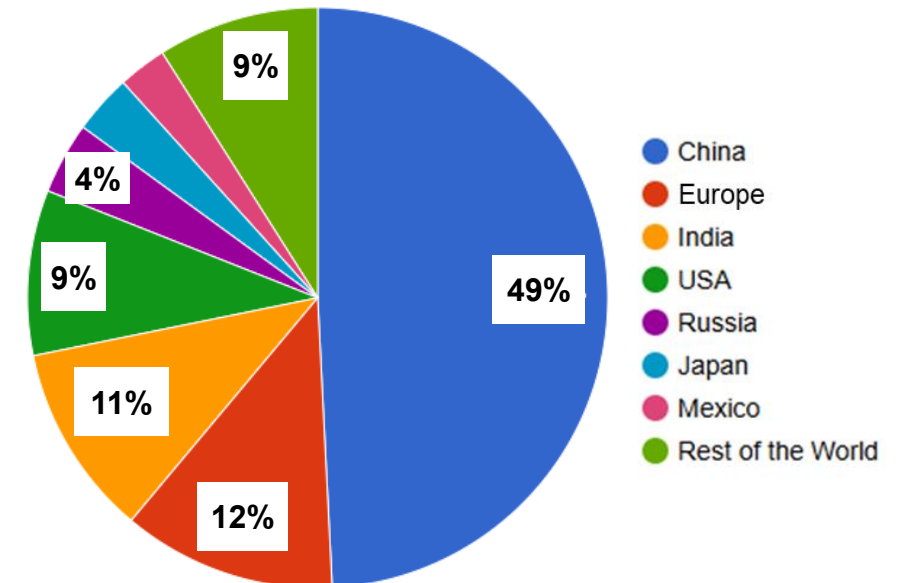
## Global raw materials production (2023)

- Greater concentration of midstream processing in PRC compared to mining for raw materials for energy



## Global castings production (2023)

- Long lead times for components critical for energy and industries: gas turbines, hydropower, nuclear



**Stages across the value chain must be addressed to secure the domestic supply chain for energy**

# AMMTO and Major Challenges for US Energy Manufacturing

## Major Challenges

- Production cost: High costs due to domestic labor, energy and other costs
- Performance: Manufacturing limited by quality, speed and other factors
- Agility: Slow manufacturing scale-up of disruptive innovation.
- Labor: Unavailability of skilled labor, limited workforce readiness.
- Supply chain: Foreign actions impacting availability of materials and equipment.

## AMMTO Expertise Areas

- Advanced Processes: Develop, scale and integrate new processing and equipment for energy manufacturing
- Advanced Materials: Develop, optimize and qualify new material systems for energy applications
- AI for Manufacturing: Leverage AI/computing to improve production, processes and workforce
- Scaling Technologies: Accelerate new technologies to adoption by industry and new domestic manufacturers
- Supply Chain and Market Analysis: Map bottlenecks and barriers for manufacturing technologies

# Major Initiatives Support Administration Priorities

AMMTO's full portfolio, including initiatives in *critical materials*, *AI for manufacturing*, and *advanced materials* are highly aligned with Administration priorities

## DOE Secretarial Priorities

- **Energy Addition and Innovation:** Produce more American energy and prioritize affordable, reliable and secure energy technologies (i.e., fossil, nuclear, geothermal, hydropower)
- **Critical Materials Supply Chain:** Secure the domestic supply chain of critical minerals and materials needed to support American energy
- **Artificial Intelligence:** Prioritize high-performance computing, quantum computing, and AI to maintain global competitiveness

## Additional OMB R&D Priorities

- Advanced Manufacturing:** Agency R&D funds should advance innovation that fuels resurgence of domestic manufacturing
- Advanced next-generation manufacturing (e.g., additive manufacturing, robotics, automation)
  - Technologies that improve the efficiency and security of manufacturing (e.g., cybersecurity, digital twins, and AI)
  - Technologies that accelerate the discovery-to-insertion timeline for advanced materials, including AI and autonomous experimentation

# **Smart Manufacturing Portfolio and Strategy**

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# An Intelligent/Smart Manufacturing Infrastructure is the Backbone of American Energy Dominance

Manufacturing is where physical systems for energy dominance is born



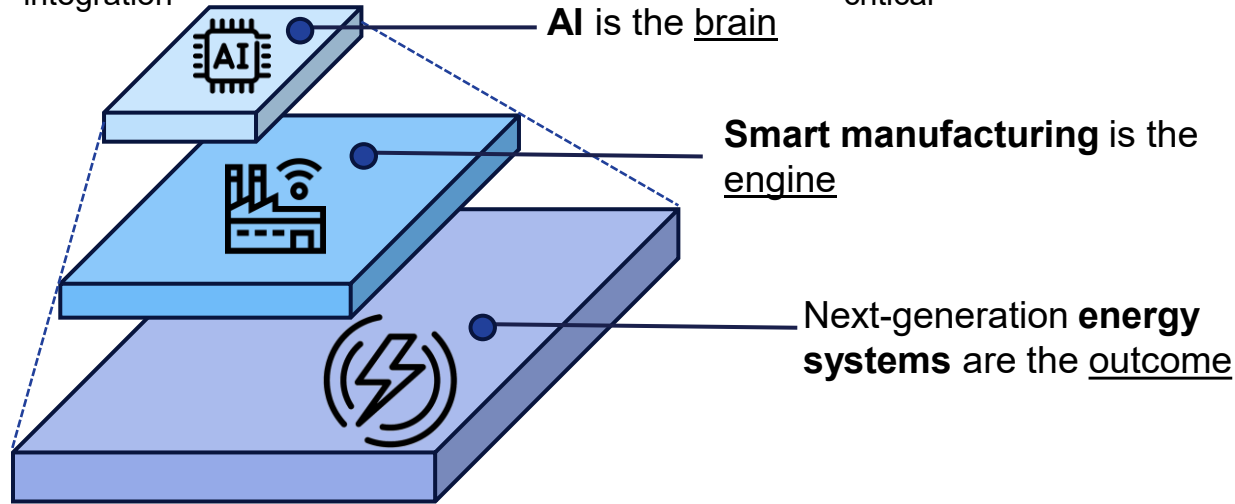
>70% of nuclear microreactor systems cost is driven by manufacturing, quality, and component integration<sup>1</sup>



Grid-scale power transformers cost millions of dollars and take >1 year to manufacture<sup>2</sup>



Manufacturing of gas turbines that account for >60% of utility-scale electricity generation is critical<sup>3</sup>



An AI-driven intelligent manufacturing infrastructure for energy delivers on every DOE pillar

- **Energy affordability:** Reduce production time and waste through AI-driven scheduling, manufacturing process optimization, and quality control making next-generation energy systems faster and cheaper to build.
- **Reliability and resilience:** Ensure the U.S. can build and maintain critical grid infrastructure through AI-enabled inspection and anomaly detection to improve uptime and fault tolerance.
- **Energy independence and security:** Achieve control over critical energy systems and reduce reliance on foreign manufacturing and supply chains through an autonomous, intelligent U.S. industrial infrastructure.

*Our Smart manufacturing portfolio is not just about efficiency; It is about building the **capability**, **flexibility**, and **security** to produce critical hardware for American energy independence.*

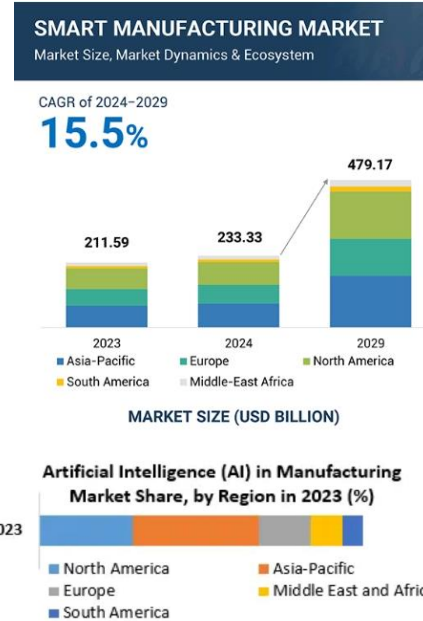
# Smart Manufacturing: Portfolio Summary

- Portfolio Goal: Build the **digital backbone** of the nation's energy system through an **intelligent manufacturing** infrastructure powered by AI. Our portfolio is about making American manufacturing **agile, energy-optimized, and resilient** to enable the production of next-generation energy systems and technologies that power our grid, secure our supply chains, and protect our national independence.
- Technical Goals:
  - Improve **energy productivity** across manufacturing sectors by 15-20% to reduce waste energy by up to 2% of total U.S. energy use<sup>1,2</sup>.
  - Decrease **manufacturing lead** time for critical grid components, such as large power transformers, by 50% to support grid modernization and resilience<sup>3</sup>.
  - Enhance **quality and reduce defects** in energy systems manufacturing by 20% through AI-driven quality control<sup>4</sup>.
  - Enhance **energy supply chain resilience** through using AI-driven intelligent manufacturing to reduce the time to recover from supply chain disruptions by 30%<sup>5</sup>.
  - Strengthen **cybersecurity** in energy manufacturing systems through decreasing mean time to detect cyber threats by 40% in manufacturing environments<sup>6,7</sup>.

# Smart Manufacturing: Market Landscape

## Global smart manufacturing market:

- The global smart manufacturing market is projected to reach **~\$479.17 billion** by 2029, with strong alignment to energy-intensive sectors such as chemicals, metals, advanced materials, and mining.<sup>1</sup>
- The Asia Pacific is leading in artificial intelligence (AI) in the manufacturing landscape, with **over 46% market share** in 2023. The widespread adoption of industry 4.0 technologies is helping the use of AI solutions.<sup>2</sup>



## Industry Adoption Status:

- **Challenges of AI adoption:** Only 5% of manufacturers in the U.S. (\$100-\$1 billion-sized) adopted advanced AI tools with most digital twin and AI applications still at TRL 4–6.<sup>3,4</sup>
- **Workforce readiness gap:** 69% of manufacturers report that their current workforce lacks the skills to work with AI and smart manufacturing technologies.<sup>3,4</sup>
- **Cybersecurity:** Cybersecurity readiness remains a critical barrier, with 87% of manufacturers lacking formal cyber protocols for smart systems.

## To Power the Future, We Must Manufacture It—SMARTER

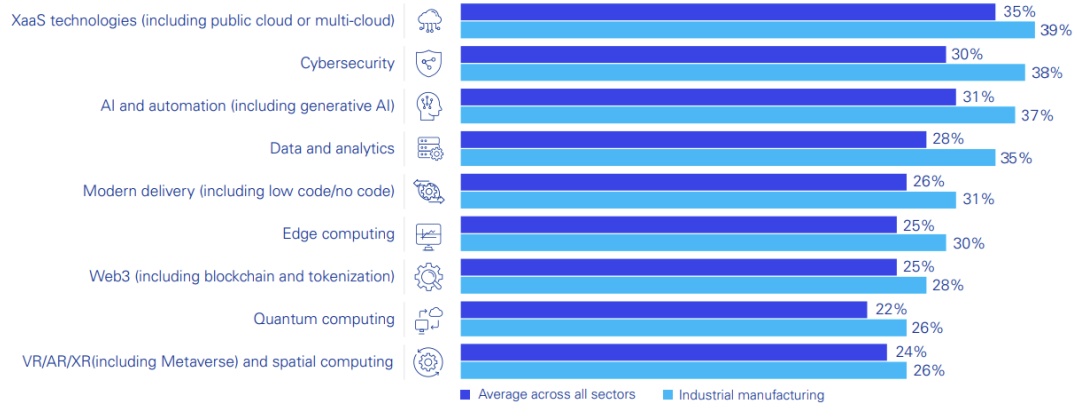
- **Modernize grid:**  
Meet 44% electricity load growth by 2028 due to data centers through AI-driven manufacturing<sup>5</sup>
- **Scale natural gas energy systems:**  
Meet power demands that expected to double by 2026 with AI for manufacturing solutions<sup>6,7</sup>.
- **Revolutionize safety and efficiency in nuclear energy operations:**  
Meet 6.19% annual growth needs with smarter, more efficient manufacturing operations<sup>8</sup>
- **Heat pumps market for geothermal:**  
AI integration in manufacturing is essential to meet expected \$6.48B billion market by 2029<sup>9</sup>
- **Refurbish federal hydropower fleet:**  
Meet substantial refurbishment demands that include up to \$20 billion in steel alloy components, only possible through smart manufacturing integration<sup>10</sup>



# Smart Manufacturing: Technology Landscape

## The Momentum is Real

- **Manufacturing is ahead of 8 other sectors** in the interest to adopt AI and other intelligent/smart technologies, with 43% reporting high value from its use<sup>1,2</sup>



- 2,360 executives in 32 countries rank the most important technologies driving success in manufacturing<sup>2</sup>



IBM Institute for Business Value

## But Adoption is Outpacing Architecture

- The full potential of AI-driven manufacturing is restricted by connectivity gaps between systems and data sets:
  - 36% of manufacturers operate with ten or more disparate systems<sup>4</sup>
  - Only 12% of manufacturers report having data of sufficient quality and accessibility<sup>5</sup>

## Innovation Gaps and Strategic R&D Needs



Innovation in AI **interoperability** to break down data silos across manufacturing systems<sup>1</sup>



<10% of manufacturers use scalable, **physics-aware AI modeling and simulation** tools for early-stage decision-making<sup>6</sup>



Innovations in robust **cybersecurity** protocols for AI-integrated manufacturing



**High Performance Computing (HPC)** is highly underutilized especially within SMEs<sup>7</sup>

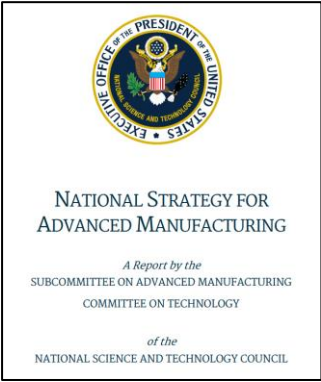
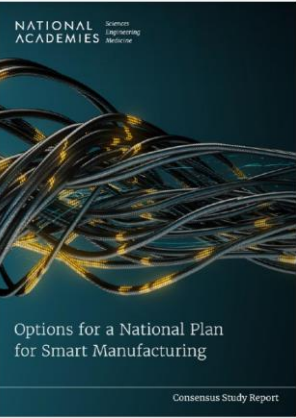






Most legacy systems lack sufficient **sensor or digital thread architecture** to support AI applications



61% of industry leaders cite lack of technical expertise as a top barrier to AI adoption in manufacturing<sup>8</sup>

# Smart Manufacturing: Portfolio Strategy



Areas	Challenges	Goals
 <b>Materials</b>	Slow discovery & design	Goal 1: Accelerate Materials Discovery and Integration
	Costly qualifications	
	Cyber risks in R&D	
 <b>Manufacturing Processes</b>	Slow process development	Goal 2: Modernize Manufacturing Process and Improve Quality
	High defects	
	Legacy Vulnerabilities	
 <b>Supply Chain</b>	Disruptions and dependencies	Goal 3: Strengthen Supply Chain Resilience
	Poor visibility & forecasting	
	Cyber risks to integrity	
 <b>Manufacturing Workforce</b>	Skills and training gaps	Goal 4: Cultivate a Smart Manufacturing Workforce

