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Advancing Composites Materials and Manufacturing for America's Energy Future

Future Composites Symposium

November 13 - 14, 2024

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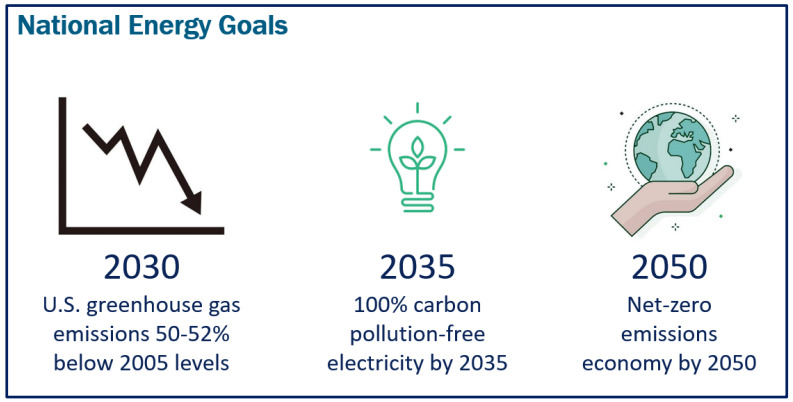
U.S. Department of Energy

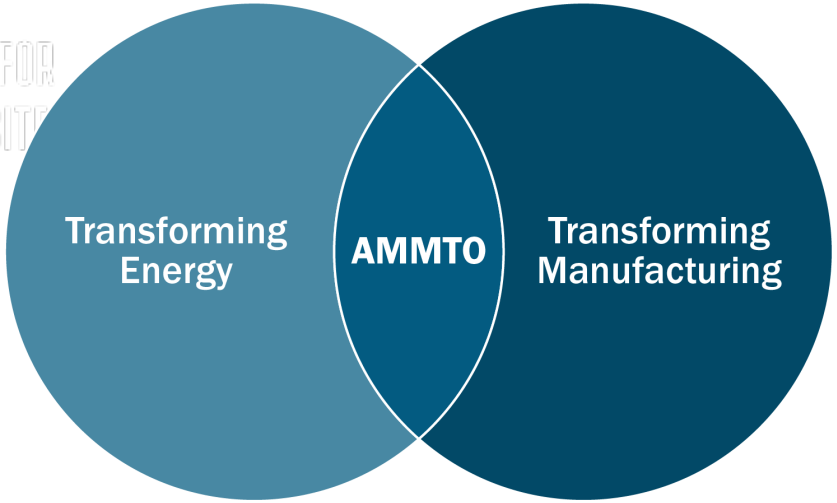
Co-Sponsors: AIM for composites; University of Delaware Center for Composite Materials, Celebrating 50 Years; SME

Advanced Materials and Manufacturing Technologies Office

- **Vision:** A globally competitive U.S. manufacturing sector that accelerates the adoption of innovative materials and manufacturing technologies in support of a clean, decarbonized economy.

- **Mission:** We inspire people and drive innovation to transform materials and manufacturing for America's energy future.





Innovation Ecosystems | Education and Workforce Development | Diversity, Equity, Inclusion, and Accessibility

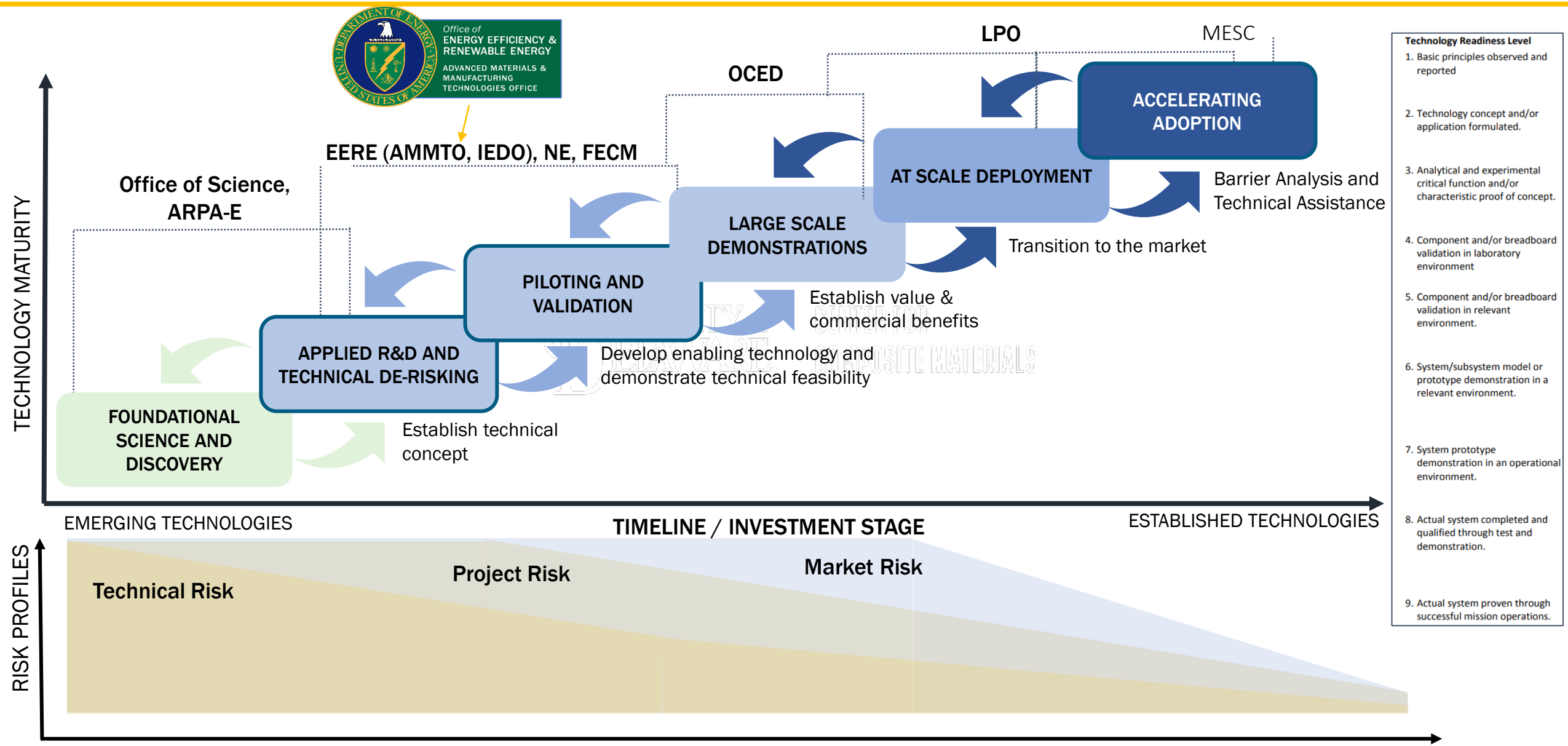
Supporting Clean Energy Manufacturing

Batteries and long duration storage
Wind turbines and wind blades
Hydropower components
Castings/forgings
Industrial motors
Hydrogen storage
High efficiency conductors
Power electronics
Microelectronics
…

Platform Manufacturing Technologies, Advanced Materials, Workforce

- Manufacturing Technologies: **smart manufacturing, AI/ML**, cybersecurity, high performance computing, roll-to-roll manufacturing, additive manufacturing, circularity
- Advanced Materials: **advanced composites**/metals/ceramics, critical materials, high conductivity metals, harsh service condition materials
- Workforce: training programs, curricula development, entrepreneurship

Bridging Innovation from Discovery to Deployment



Technology Readiness Level

1. Basic principles observed and reported
2. Technology concept and/or application formulated.
3. Analytical and experimental critical function and/or characteristic proof of concept.
4. Component and/or breadboard validation in laboratory environment
5. Component and/or breadboard validation in relevant environment.
6. System/subsystem model or prototype demonstration in a relevant environment.
7. System prototype demonstration in an operational environment.
8. Actual system completed and qualified through test and demonstration.
9. Actual system proven through successful mission operations.

AMMTO's Subprogram Structure

NEXT-GENERATION MATERIALS & PROCESSES

- Advanced Manufacturing Processes and Systems
- High Performance Materials
- Digital Manufacturing

SECURE & SUSTAINABLE MATERIALS

- Circular Economy Technologies and Systems
- Critical Materials

ENERGY TECHNOLOGY MANUFACTURING & WORKFORCE

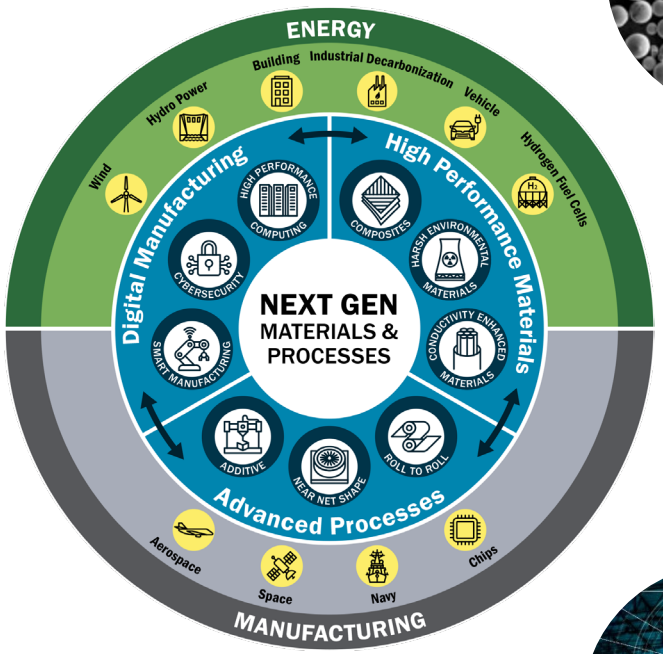
- Energy Conversion and Storage Manufacturing
- Semiconductors, Electronics, and Other Technologies Manufacturing
- Entrepreneurial Ecosystems and Advanced Mfg. Workforce

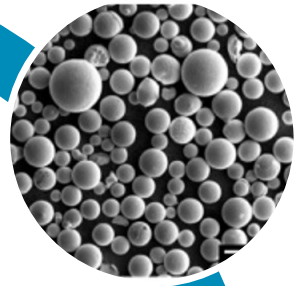
AMMTO Budget and Subprogram Breakdown

	FY22 Enacted ($Million)	FY23 Enacted ($Million)	FY24 Enacted ($Million)
	217	184	220
Next-Generation Materials and Processes	107	90	82
Secure and Sustainable Materials	66	40	76
Energy Technology Manufacturing and Workforce	44	54	62

Next Generation Materials and Processes (NGMP) Program

Objective: Support AMMTO mission through development of novel materials and manufacturing processes.





High Performance Materials

- Novel materials have improved properties that improve the functionality, extend product lifetime, increase lifecycle energy and materials efficiency
  - Advanced Composites
  - Harsh Environment Materials
  - Conductive-enhanced Materials
- RD&D Consortia: IACMI, CFTF
- AMMTO MT FOA ($27.6M), IEDO MT FOA ($4M)

Advanced Processes

- Additive Manufacturing
- Near Net Shape Manufacturing (NNS)
- Roll-to-Roll Manufacturing
- RD&D Consortia: MDF
- Wind FOA ($30M), NNS FOA ($30M)

Digital Manufacturing

- Smart Manufacturing (AI/ML, Digital Twin)
- High Performance Computing
- Cyber Security
- RD&D Consortia: CESMII, CYMANII
- HPC4MFG ($5M annually), SM FOA ($33M)

Enhance Material Properties and Energy Efficiency of Manufacturing, Improve the Resiliency of Domestic Supply Chains

AMMTO's Innovation Ecosystems

Energy Innovation Hubs

› Integrated, multidisciplinary research centers that combine basic and applied research with engineering to accelerate scientific discovery and address critical energy issues.

Manufacturing USA Institutes

› Network of manufacturing innovation institutes created to secure U.S. global leadership in advanced manufacturing through large-scale public-private collaboration on technology, supply chain, and education and workforce development.

Lab-led R&D Consortia

› Leverages unique facility capabilities and expertise in advanced manufacturing at national laboratories to work collaboratively on industrial-relevant, pre-competitive R&D.

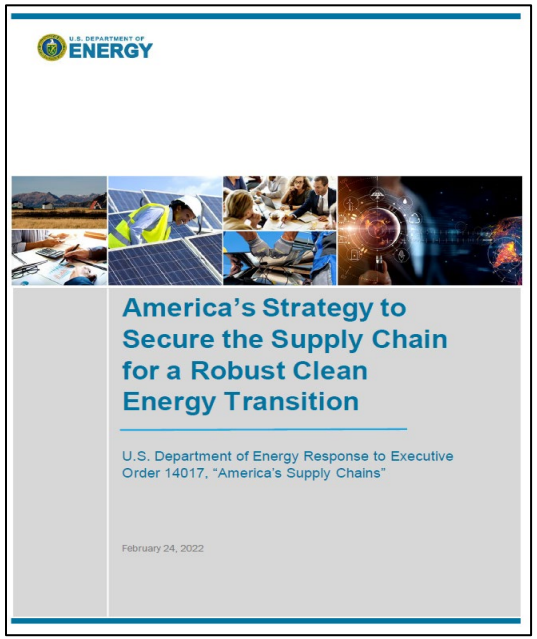
Lab-led R&D Manufacturing and Pilot-Scale Facilities

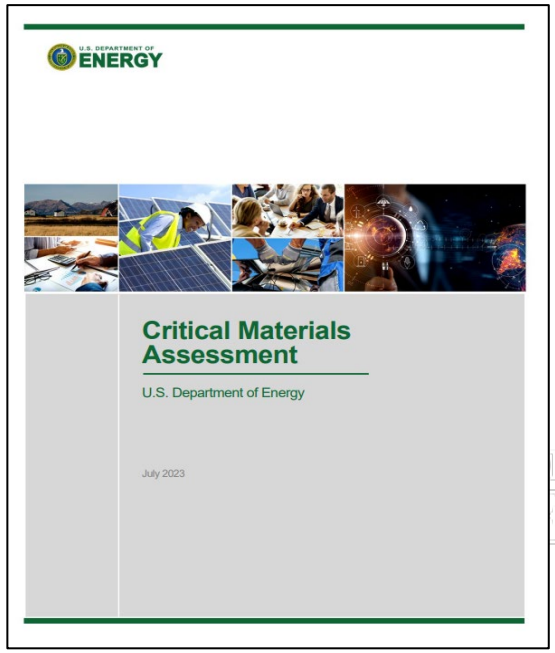
› Strategic investments in physical assets at labs to advance clean energy manufacturing.

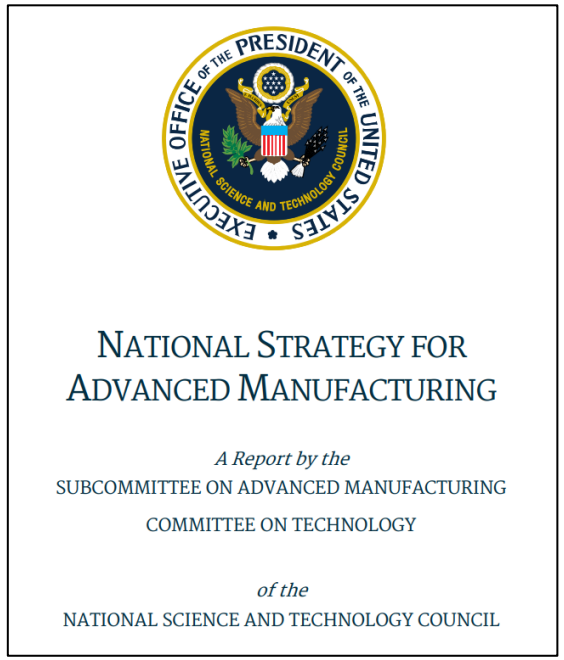
Lab-led Infrastructure for Manufacturing Industry

› Provides access and connectivity to lab programs, codes, facilities and experts in areas of entrepreneurial incubation and high-performance computing.

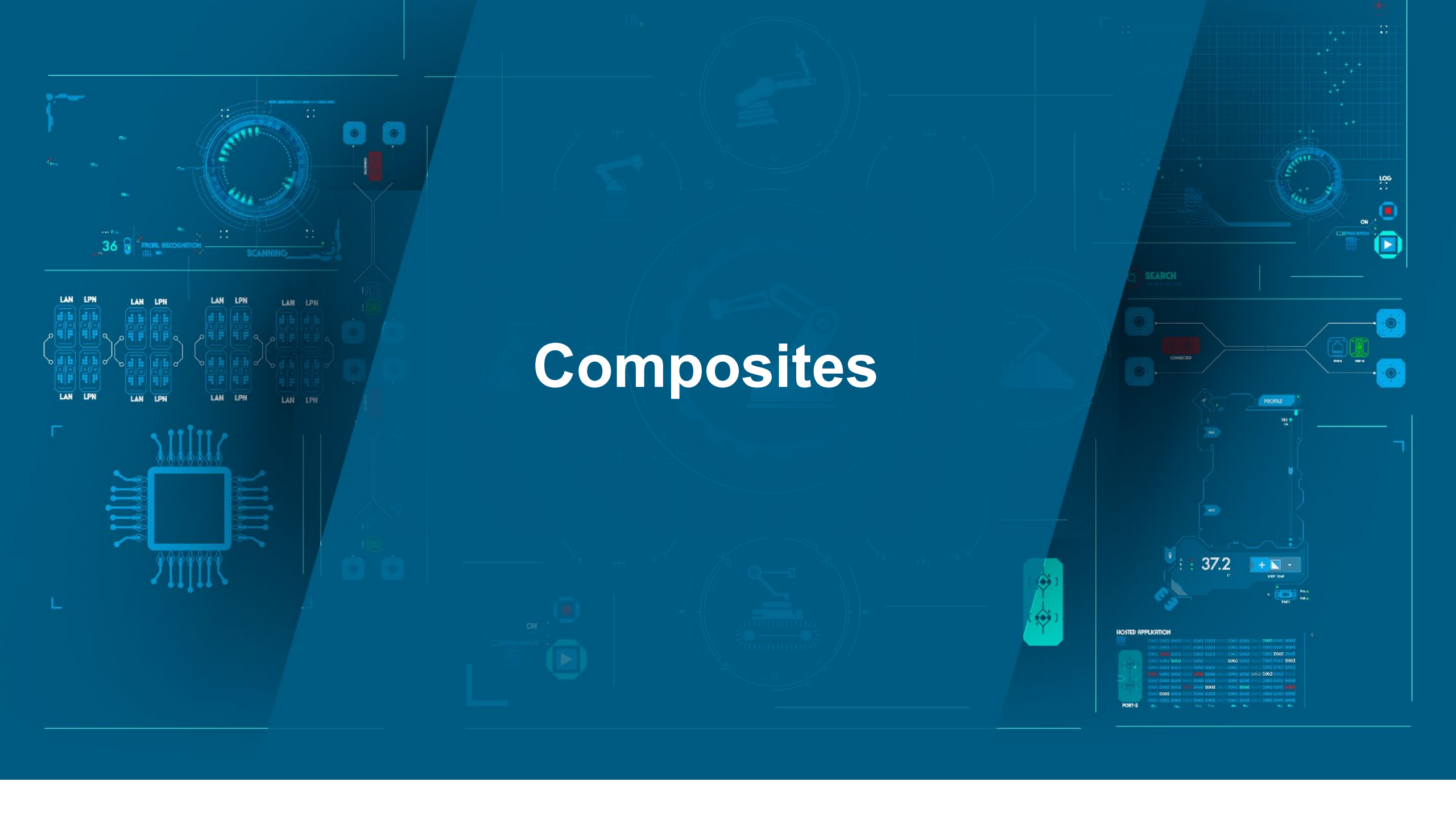
Manufacturing Technology Analysis and Strategy





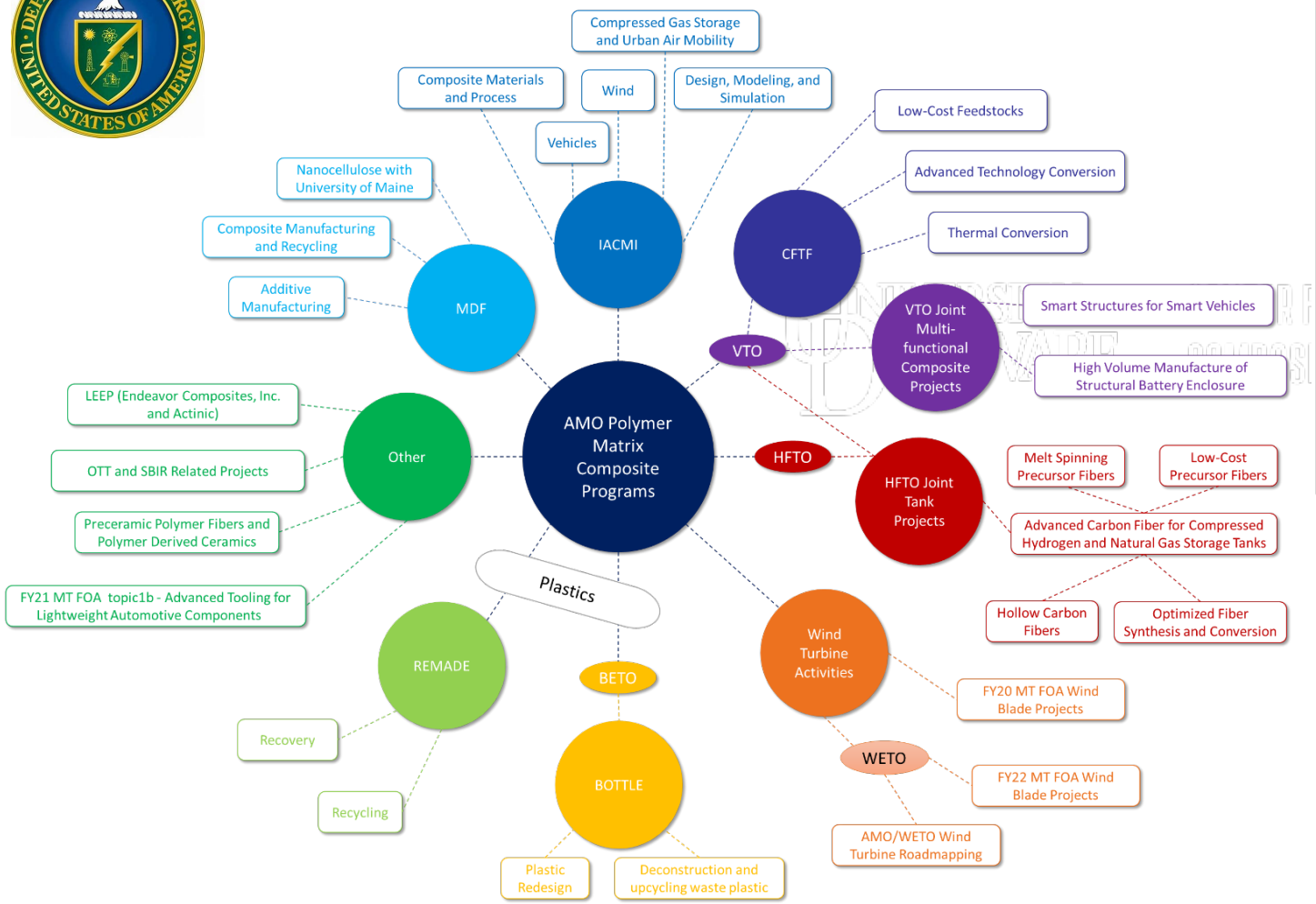


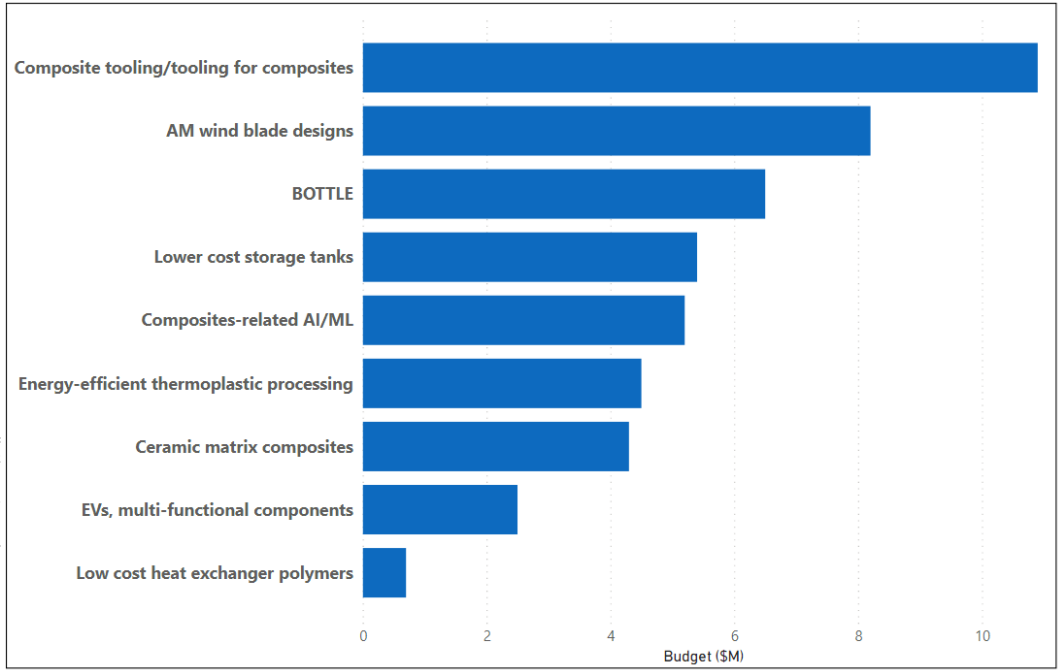
- Analysis guided research to drive impact of manufacturing innovation for supply chain resiliency and industrial decarbonization goals.
- Technology roadmapping for key manufacturing and materials technologies.
- Strategy development for manufacturing innovation in multiple areas including critical materials, smart manufacturing, circular economy, power electronics, microelectronics, harsh environment materials.


Composites

AMMTO Composite Portfolio

Approx. 100 projects & $180M over last 9 years



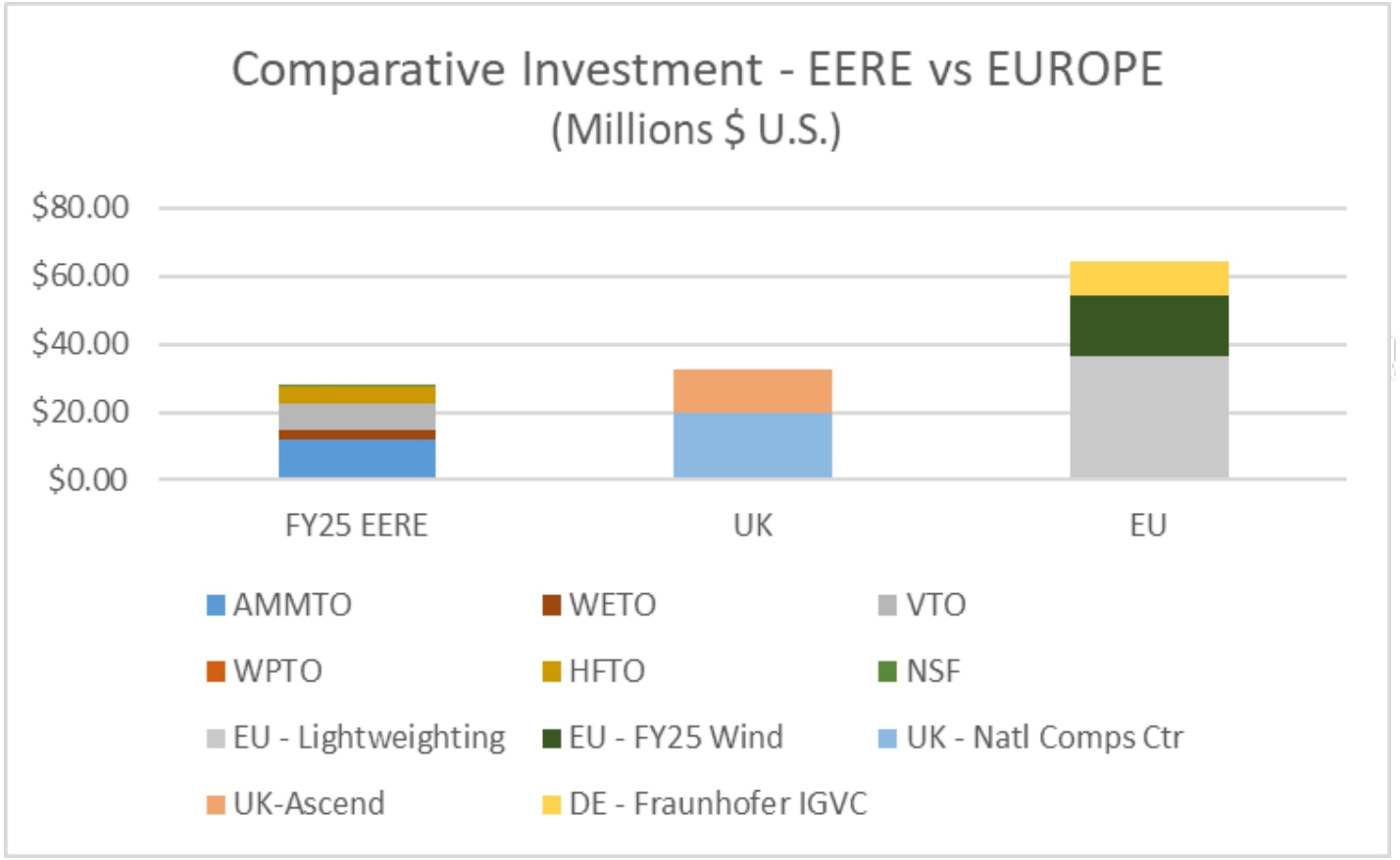


Priorities & Focus

- High-Rate Production
- Low-cost Carbon Fiber (LCCF)
- Advanced and smart manufacturing
- Process Optimization
- Materials Circularity

Composites Strategic Analysis – Manufacturing R&D Global Competition

- FY25 Composites-related Activities – AMMTO & Applications Offices – **overstates $** estimates (based on past FYs)
- UK and EU – compiled by J Winkel – not all inclusive & thus **understates $** estimates (average annual)



European Commission

Active Floating OSW – RD&D

€ 15 995 130 - NEXTFLOAT

€ 15 455 944 – INFINITE

€ 16 663 950 – WHEEL

$ 49 695 940 - EU contribution

Big Idea = targeted multi-Office, multi-material, multi-process (e.g. composites/AM) R&D efforts needed for US to compete

High impact:

- key Clean Energy material
- U.S. at risk of losing lead: industry =~ 3,000 cos. 500,000 employees in all 50 states, ~$70B annual revenues,

Large Wind Turbine Materials and Manufacturing

AMMTO Goal: Advance innovative design, materials and manufacturing methods to support a sustainable and resilient domestic supply chain of large-scale wind blade and turbine components for clean energy systems.

The goals of these projects align with DOE's Offshore Wind Strategy, the Offshore Wind Supply Chain Road Map, the interagency Floating Offshore Wind Shot, and the priorities identified in DOE's 2022 Wind Energy Supply Chain Deep Dive Assessment.

Key Technology Enablers: Additive Manufacturing, Modular, Smart Manufacturing, Digital Twin, Sustainability

Wind FOA: $30M, 13 projects awarded, 11 projects related to Composites

Large Wind Blade Additive Manufacturing

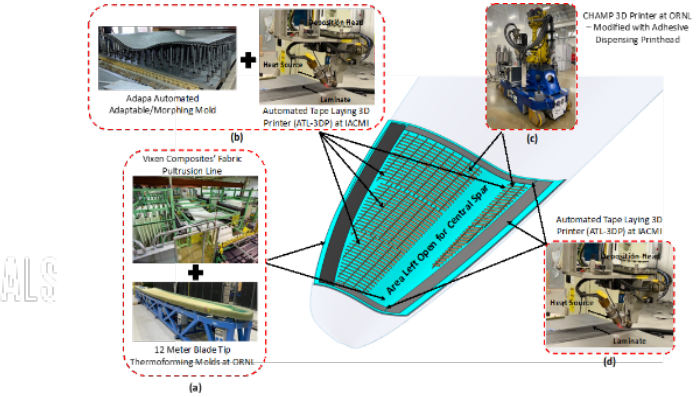
- Low-Cost, Fast Delivery of Adjustable Wind Blade Molds for Modular Blade Components (Oak Ridge National Laboratory)
- Additive Manufacturing of Modular Tools with Integrated Heating for Large-Scale Wind Blade Manufacturing (Purdue University)
- Fabrication of Fully Recyclable Wind Turbine Blades via Multi-Axis Additive Manufacturing (Virginia Tech)
- Additive Manufacturing Enabled Modular Shells for Large Wind Blades (Collaborative Composite Solutions/IACMI)

Large Wind Blades – Advanced Manufacturing, Materials, and Sustainability

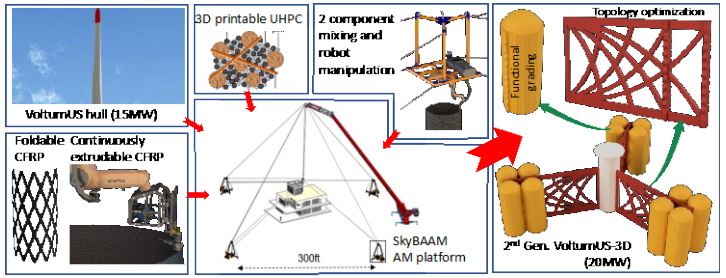
- Modular Blade Demonstration: joining of root and Chassis segments (BladeCAM) (GE Research)
- Sustainable Material and Process Development for Large Off-Shore Wind Blade Spar Caps (University of Delaware)
- Advanced Manufacturing, Materials, and Sustainability of Modular Wind Blades (University of Massachusetts Lowell)
- Smart Holistic Zero Waste Utilization Paradigm (SH0WUP) for reusing thermosets and effectively recovering fibers via mechanical, thermal, biological, and chemical pathways (University of North Dakota)
- Rapid Optimization of Curing Cycle in Large-Scale Composite Blade Manufacturing Enabled by A Smart Digital Twin (The University of Texas at Dallas)
- Rapid X-ray for Blade Manufacturing Quality Control and In-Service Maintenance (WEI7 LLC)

Additive Manufacturing of Wind Turbine Components

- Portside 3D Printed Lightweight Concrete Foundations for Offshore Wind Turbines (Orbital Composites Inc)
- A Versatile Additive Manufacturing Platform for Fabricating Low-Cost, Concrete Offshore Wind Support Structures in American Ports (RCAM Technologies Inc.)
- Design, Fabrication, and Repair of Multi-Material Gears for Improved Performance and Reliability of Wind Turbine Systems (GE Research)



Proposal: Additive Manufacturing Enabled Modular Shells for Large Wind Blades



Proposal: Portside 3D Printed Lightweight Concrete Foundation for Offshore Wind Turbines

Source: Funding Selections: AMMTO Large Wind Turbine Materials and Manufacturing Funding Opportunity Announcement | Department of Energy

IACMI – The Composites Institute

Project Overview

IACMI-The Composites Institute
The Institute for Advanced Composites Manufacturing Innovation
Knoxville, Tennessee

- Established in 2015 DOE Advanced Manufacturing Office
- One of 16 Manufacturing USA Institutes
- **IACMI Mission**: Convene, connect and catalyze the composites community to accelerate advanced composites design, manufacturing, technical and workforce solutions to enable a cleaner and more sustainable, more secure and more competitive U.S. economy
- Founding partners: **University of Tennessee, Oak Ridge National Laboratory**
- Additional core partners: **Purdue (IN), National Renewable Energy Laboratory (CO), Michigan State University (MI), University of Dayton Research Institute (OH)**
- Extensive ecosystem of core partners, state economic development agencies, trade associations, professional societies, workforce partners and multiple industry participants

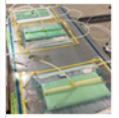
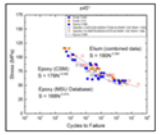
U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy
ADVANCED MANUFACTURING OFFICE
Manufacturing USA

Budget:

DOE Funded	$70M
Project Cost Share	$130M
Total	$200M

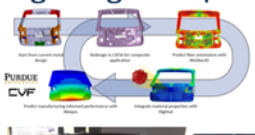
Results and Achievements - Examples

Recyclable Thermoplastic Wind Blade

- Novel polymerizing thermoplastic technology
- Small infusion studies, then scaling to 13m blade
- Static and fatigue testing coupon and at full scale
- Lower tooling and recurring costs demonstrated
- R&D 100 winner

Lightweight Composite Liftgate




- Optimized design using fiberglass composite
- Sub 3-minute cycle time
- 36% lighter than steel, 77% reduction in investment
- Recurring costs 9% lower vs. steel, 37% lower vs. Al
- Qualified for future production on US electric platforms

Results and Achievements

IACMI – The Composites Institute
2015-2022

$70M of DOE funding was matched by **$130M** of industry, university, and state cost share

TN, IN and MI ea invested $15M
CO, OH invested $5M ea

Technology
$150M portfolio
>60 R&D projects
25+ commercial products

Infrastructure
$400M Value

Pipeline
100 Internships
100% placement rate
15,000 Trainees
K-12, post-secondary & adult workers

Partnerships
120+ Members
Industry, Universities, National Labs, Gov't Agencies

Jobs
3,000 Manufacturing Job Commitments
by IACMI members partners

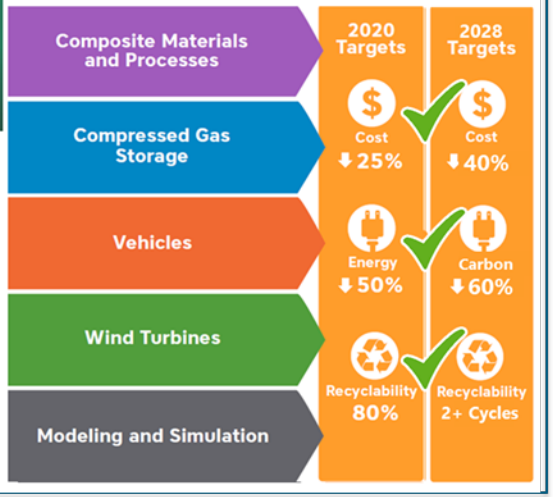
Future Work, Technology Transfer, & Impact

Advanced Materials & Manufacturing Technologies Office

DOE Furthers Commitment to Advancing Composites Manufacturing Through Innovation Institute Renewal

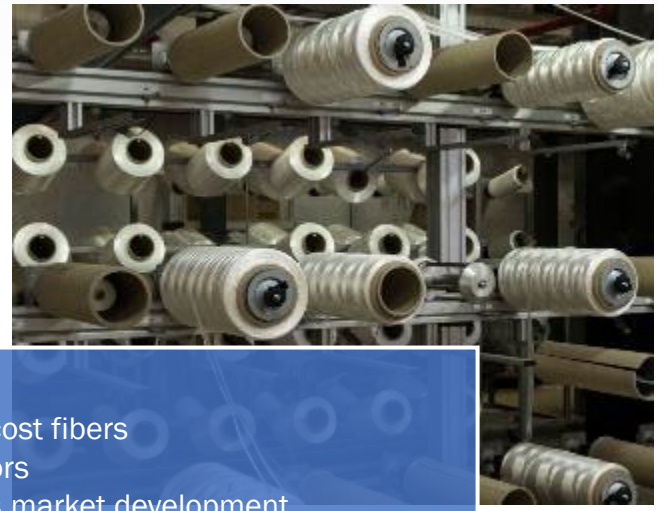
APRIL 11, 2023

IACMI Priorities 2023-2028	
Clean Energy Markets	Wind Energy, EVs, Hydrogen Storage
Cross-cutting Technologies	Circular Economy, Digitalization, Materials & Processes
Workforce of the Future	Education and Workforce Development, DEIA
Industry health	Small & Medium Enterprises; Robust, Resilient Supply Chains; Regional Partnerships/Clusters



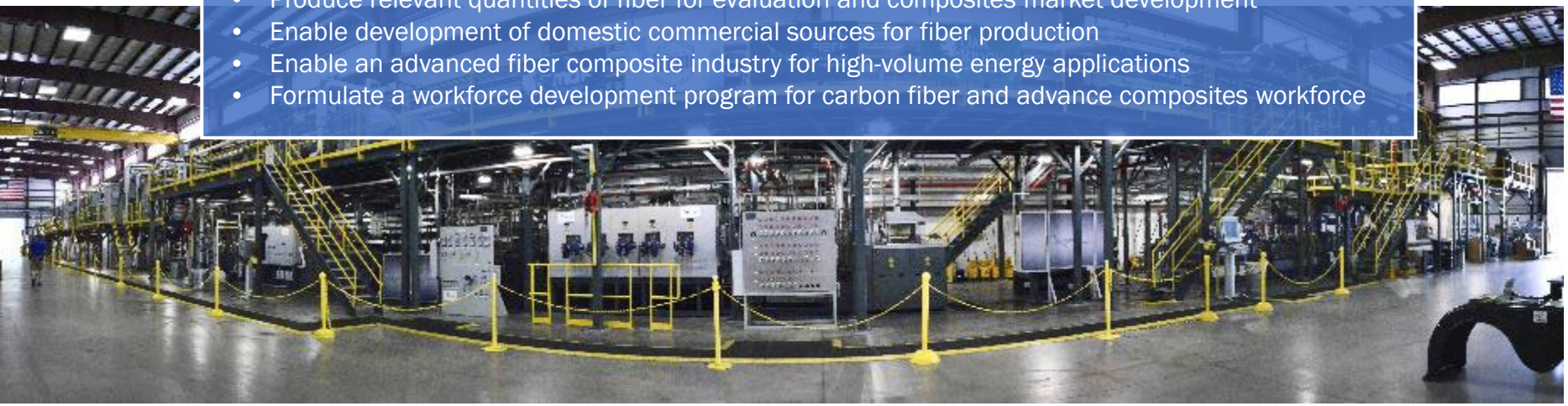
Carbon Fiber Technology Facility (CFTF)

A DOE Designated User Facility



Mission

- Bridge R&D to demonstration, deployment, and validation of low-cost fibers
- Demonstrate advanced fiber production using lower cost precursors
- Produce relevant quantities of fiber for evaluation and composites market development
- Enable development of domestic commercial sources for fiber production
- Enable an advanced fiber composite industry for high-volume energy applications
- Formulate a workforce development program for carbon fiber and advance composites workforce



CFTF By the Numbers

- Only **open access** state-of-the-art facility in the U.S.
- **25 tons** annual capacity of carbon fiber
- **>14** university collaborations
- **91** industry partners
- **3,871** visitors from **823** orgs
- **4** licensed technologies
  105 patents/applications

Manufacturing Demonstration Facility (MDF)

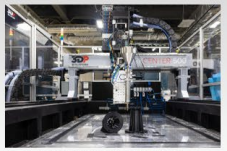
MDF By the Numbers

- **$1B+ impact** on U.S. manufacturing
  >20:1 ROI of DOE funding
- **>180** staff members; **250** total (interns, students & co-located industry partners)
- **280+** partnerships with **$170M+** in CRADAs (50% industry)
- **80–100** student interns per year
  >50 university collaborations
- **40,000+** visitors & **6,000+** company visitors representing entire supply chain
- **>50%** of MDF equipment is industry owned
- **~60** licensed technologies
  >200 patents/applications
- **6,000+** experts at ORNL with diverse backgrounds and experience
- **100+** Industry Fellows from industry and academia
- **>100** publications/year
  182 awards since 2012
- **110,000+** sq. ft. facility space
- **>230** pieces of equipment including over **100** AM systems; **$34M** in equipment, **>50%** placed through no-cost leasing

MDF Creating a Polymer and Composites Additive Supply Chain

OAK RIDGE National Laboratory

New AM Systems



Thermoplastic Printers

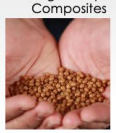
Thermoset Printer

Materials

Composites for Large Printing

High Temp Composites

Foams



Biocomposites

Interpenetrated Network Composites

End Applications

3D Printed Underwater Vehicles
https://roboticsandautomationnews.com/2021/09/01/ocean-engineers-optimize-design-and-performance-of-autonomous-underwater-vehicle/46058/

Concrete Molds, Domino Sugar Building
https://www.6sqft.com/amazing-photos-show-cooktops-domino-sugar-tower-getting-its-crystalline-facade/

Future Digital Systems

Configurable Holonomic Additive Manufacturing Platform (CHAMP)

Additive Manufacturing – Compression Molding (AM-CM)

Equipment OEM's

MVP, INGERSOLL Machine Tools, Strangpresse, Cosine, CINCINNATI

Feedstock Suppliers

Polynt, Dixie Chemical, Mitsubishi Chemical, PPG, TCPOLY, DowAksa, ARKEMA, TECHMER PM

End Users

AIRTECH, AEG, BOEING, tpi, Ford, emrgy, HODGDON, GATE

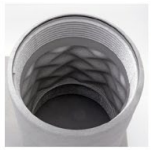
AMMTO & MDF Support DOE Program's to Enable Clean Energy

MDF research is accelerating advanced manufacturing to impact clean energy

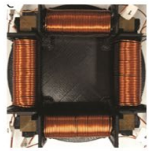
1) Securing a U.S. supply chain.
2) Addressing affordability of clean energy technologies.
3) Improving energy efficiency in fabrication and application.

DOE & EERE

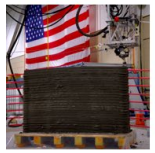
AMMTO — Stakeholder Engagement; Core Projects; Technical Collaborations



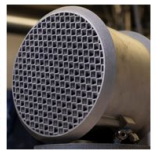
Complex geometries for Geothermal Prize: Geothermal



Printing of Transformers for Grid: Office of Electricity



Thermal Energy Storage for Buildings: EMPOWER Wall FEMP / Buildings



Enhanced CO2 Emission Capture: Fossil Energy and Carbon Management

Deposition of Tungsten for Plasma Facing Surfaces: Fusion Energy

New Materials for Efficient Transportation: Vehicles

Digital Certification of AM for Nuclear Components: Nuclear Energy

Wind Turbine Blade Manufacturing: AMMTO and Wind

Affordability for Low Head Hydro Power: Water Power and AMMTO

ORNL & U-Maine MDF Hub& Spoke

Sustainable Forest Products in Additive and Composite Manufacturing Processes

- Connects a $2+ Billion national laboratory to local ecosystems.
- U-Maine's Advanced Structure & Composites Center (ASCC) is the largest university-based research Center in Maine; 260 personnel.
- Combines MDF-ORNL expertise in advanced manufacturing with UMaine innovation in forest-derived biocomposites.
- Facilitates access to ORNL and UMaine assets and expertise to bring new, sustainable, and functional materials and processes to the market.

➢ **Optimize the production, implementation, and manufacturing of bio-based materials to reduce dependence on fossil fuel-derived polymers and composites.**

➢ **Integrate these materials and processes into mainstream manufacturing industries to achieve carbon neutrality and clean energy in US industries.**

Hub and Spoke R&D Results Drive Industry Adoption

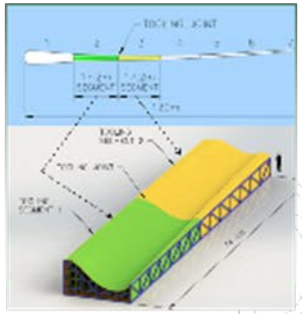
Packaging

Replacing single-use plastic with highly filled, cellulose-reinforced plastic. offset 250,000lb/yr. petroleum-based resin at 15% cost savings

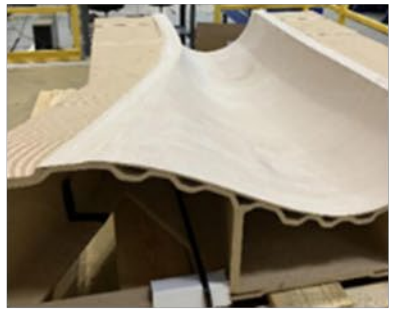
3D printed lightweight packaging. using low-carbon biofoams. CAMX 2021 Innovation in Green Composites Design Award

Wind

Bio-reinforced, recyclable thermoplastic 3D printed tooling for Wind Blade Root



3D printed integrated heating channels are more energy efficient and using biobased material decreases the embodied energy of the mold



Construction

3DP biobased floor assembly for productized construction. Offsite manufacturing and rapid assembly on-site for mid-rise residential buildings

1000 floor cassettes/building, 39 parts reduced to 1, >3000 hr. labor savings, 100% biobased cassette displaces concrete and gypsum

Building Materials

Replacement for foam insulation, net shape, 100% biobased to reduce embodied energy and replace with local supply chain materials

Cellulose nanofibers and mycelium foam, near net shape, density optimized for energy efficiency

Marine

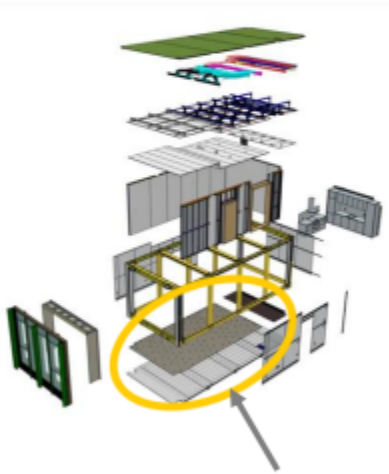
Bio-reinforced, semi-structural 3D printed transom door for marine craft

50% cost savings, lighter, bio-reinforced out of recyclable thermoplastic, integrated hinges and latch recess

Industry Demand for Housing Manufacturing Innovation

Customer Problem

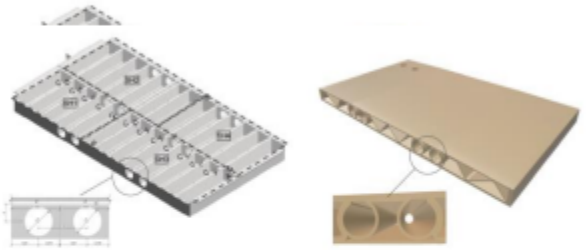
Marrying digital twin technology with modular building. **Combine high-quality, high-end aesthetics with green, affordable off-site construction**



GOAL: replace conventional floor assembly construction with a 3D printed multifunctional, low carbon product

Solution

3D Printed floor assembly using 100% biobased feedstock



3DP integrated ductwork and through-holes for MEP systems, and registration features for aiding assembly

Impact

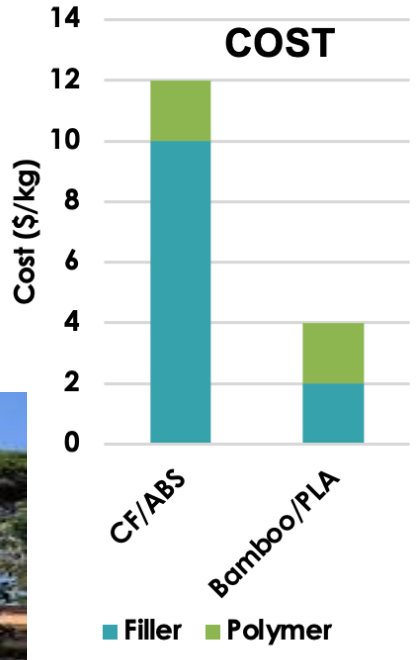
Reduced part count from 39 parts, 3 materials to 1 part with 1 material
Assembly time reduced by 56%
Labor Cost reduced by 25%

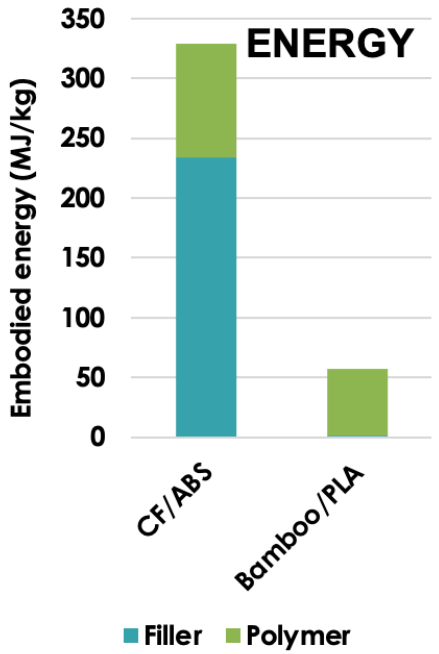
Removes 53 ft^3 of concrete per floor unit. Average mid-rise assembled building contains 1056 units.

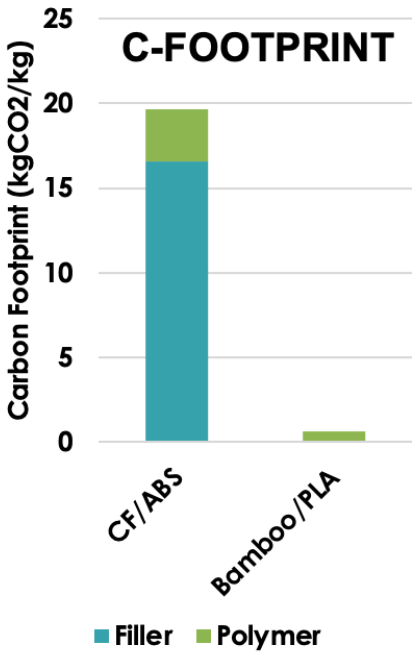
Sequestering 1.7 million lbs carbon per building with volume of wood residuals in printed floors.

ASSEMBLY OSM

Carbon-storing Biomaterials for Decarbonization in Housing







Design Miami | shop | Branch Technology | Oak Ridge National Laboratory | University of Nairobi | SM2ART

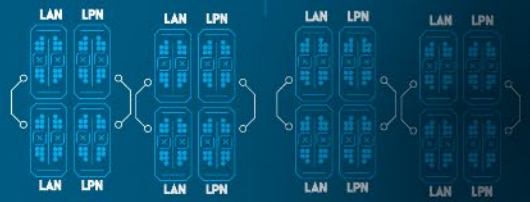
Green Engineering and Materials Factory of the Future Vision

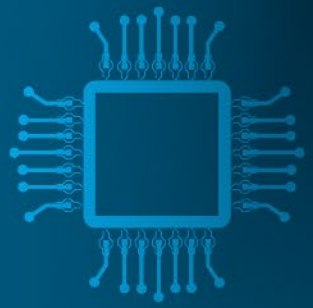
SM²ART

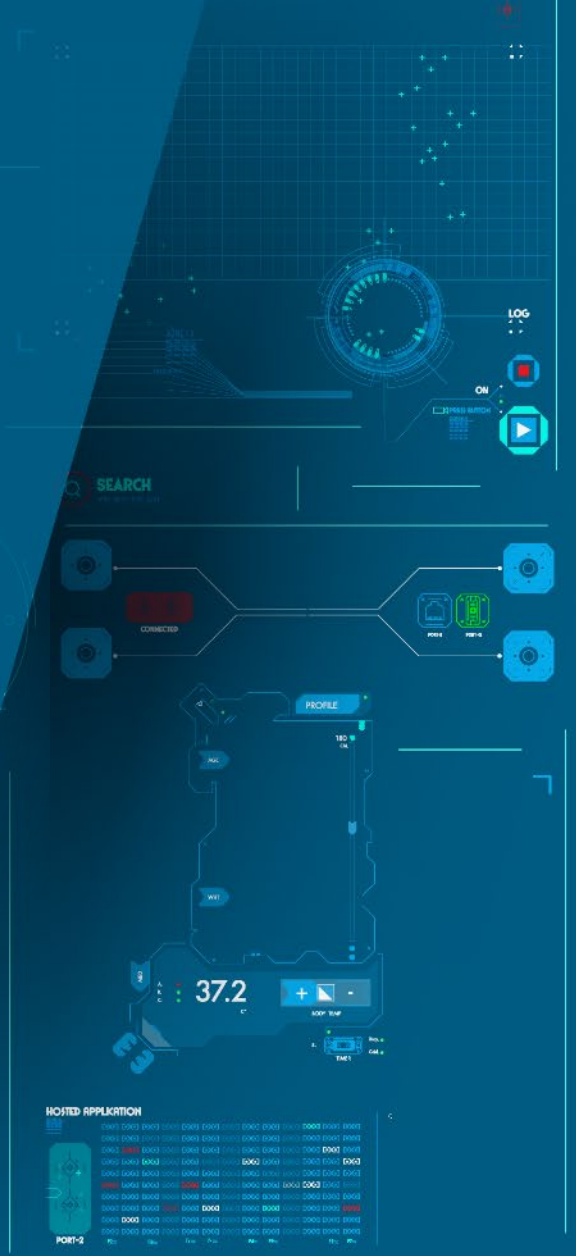
A truly transformative facility focused on manufacturing large-scale, high-performance modules, integrating advanced automation, smart manufacturing and sustainability principles, working together with nationwide core industry partners.

20

Manufacturing Digitalization







Digital Manufacturing

- Focus on Technology Innovation and Acceleration to drive manufacturing digitalization
- Address industry problems and opportunities in energy sectors
- Enhance and secure related U.S. supply chain

Synergistic with Consortia:

CESMII THE SMART MANUFACTURING INSTITUTE

CYMANII the cybersecurity manufacturing innovation institute

HPC 4 MANUFACTURING

MDF

SM2ART Sustainable Materials and Manufacturing Alliance for Renewable Technologies

OAK RIDGE National Laboratory | CARBON FIBER TECHNOLOGY FACILITY

	Smart Manufacturing Technology Program Pillars				
Smart Manufacturing Technology Areas	Enhance Product Quality	Support Process Innovation	Accelerate Materials Development	Enable Materials Circularity	Drive Asset Optimization
Operational Technologies	X	X	X	X	X
Data Connectivity	X	X	X	X	X
Data Interoperability	X	X	X	X	X
Digital Twin	X	X	X	X	X
Artificial Intelligence	X	X	X	X	X
Predictive Analytics	X	X	X	X	X
Materials Informatics			X		
Cloud/Edge Computing	X	X	X	X	X
High Performance Computing	X	X	X	X	X
Collaborative Automation		X	X	X	
Cybersecurity		X			X
	Crosscutting Program Pillar - Increase Workforce Readiness				

Advanced Materials & Manufacturing Technologies Office

$33 Million in Funding Available To Advance Smart Manufacturing Technologies To Help Accelerate a Clean Energy Economy

JULY 18, 2024

Topics:

- Circular Economy
- Tooling/Equipment
- High Performance Materials
- Critical Mining

High Performance Computing for Manufacturing

HPC4MFG program capabilities can help manufacturers lower their energy demands and decarbonize their processes, through building highly complex models and simulations to answer previously unanswerable questions or run experiments virtually that would be too long or costly otherwise.

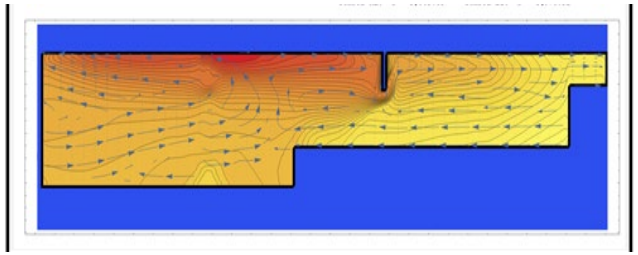
Challenge: Industry is lagging in HPC adoption

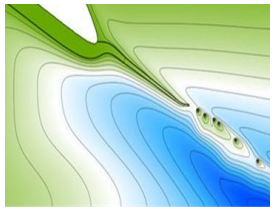
- Manufacturers are often unfamiliar with HPC and where it can solve an important problem or improve a complex process.
- Industry often does not have the expertise to develop modeling & simulation approaches that can use HPC.
- Industry has difficulty estimating the return on investment of computational capabilities and therefore is reluctant to invest in HPC computers

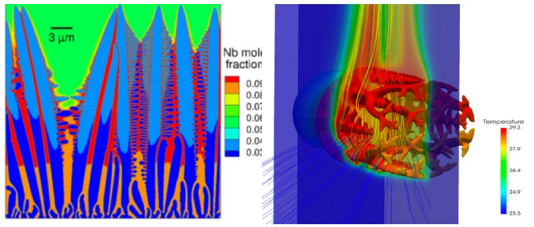
Solution: Use HPC capabilities at DOE National Laboratories to overcome key technical challenges needed to save energy through:

- Process optimization
- Advanced product design
- Complex materials discovery and design
- Predicting performance and failure rates

This program helps "buy down" risk of computational effort.







Over 150 projects have been funded with over 90 manufacturers in US

Clean Energy Smart Manufacturing Innovation Institute (CESMII)

CESMII THE SMART MANUFACTURING INSTITUTE

mission. strategy. role.

Driving the **next wave** of manufacturing productivity, energy productivity and competitiveness through smart manufacturing innovation.

U.S. DEPARTMENT OF ENERGY

2017
Founded by the D.O.E

$140M+
Private/public partnership

Improve energy productivity through sensing, control, modeling, analytics & platform technologies

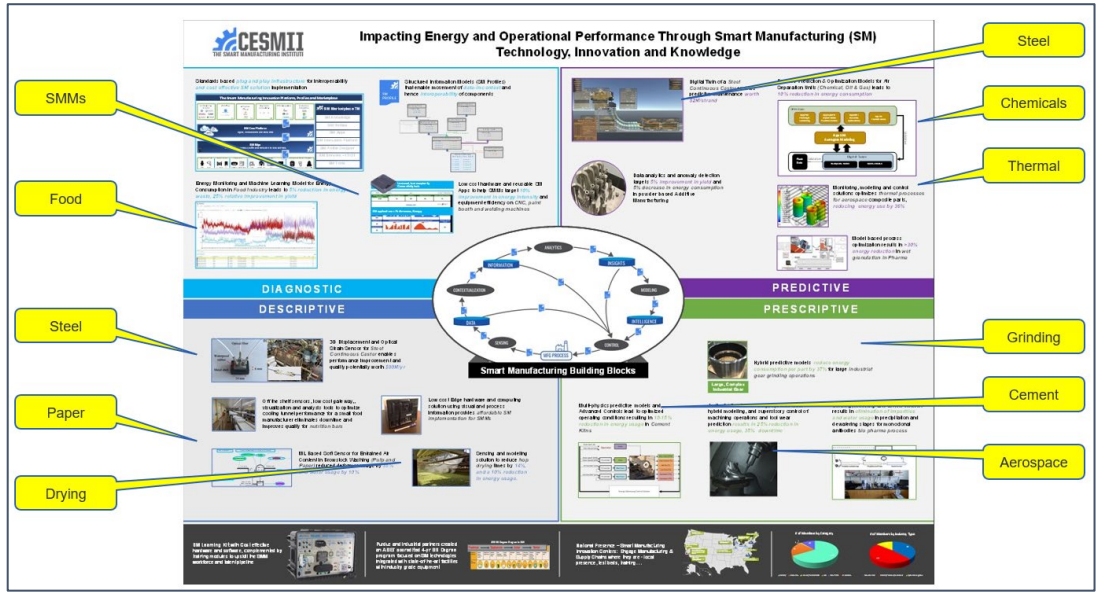
How. Fund the Innovation and R&D necessary to **dramatically** reduce the **cost** & **complexity** of using **real time operations data** to drive **revenue** & **cost improvements** and **generate cash.**

*CESMII represents the **voice of manufacturing;** engaging the smart manufacturing ecosystem through a membership model*

- **Manufacturers** Small, Medium & Large
- **System Integrators & Consultants**
- **Machine Builders**
- **Technology Providers**
- **Academia & Labs**

INDUSTRIES IMPACTED

- Steel
- Agriculture
- Cement
- Chemical
- Aerospace
- Pulp & Paper
- Additive Manufacturing
- Pharmaceutical
- Thermal Treatment
- Injection Molding
- Automotive
- Supply Chain & Warehousing
- Metal
- Food
- Machine tools



The Cybersecurity Manufacturing Innovation Institute (CyManII)

CyManII's Vision

is to secure U.S. manufacturers as they digitize by fortifying their physical systems with embedded cybersecurity and energy-efficient solutions.

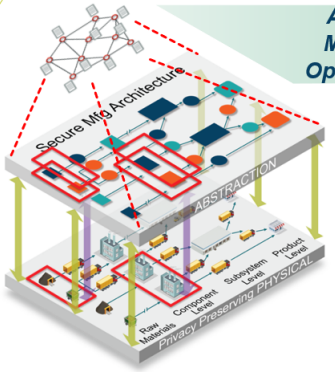
Core Pillars

ε-PURE

1	2	3
Secure the digital thread	Secure.*TOGETHER*	Create a cyber-informed workforce
• Build defensible architectures • Create identify-centric cyber-physical passports • Secure a decarbonized ecosystem	• Partner across industry's supply chain • Cooperate across Govt stakeholders • Focus on: Manufacturing Sectors Critical Energy Infrastructure Data and beyond…	• Focus on OT / ICS security • Leadership on CIE • Empower current workers • Expand emerging workforce (students)

CYMANII the cybersecurity manufacturing innovation institute

Secure Defensible Architecture (SDA)



Analysis
Modeling
Optimization

- Maximize E&E Efficiency
- Maximize Production
- Minimize Risk

Integrated Model of Automation & Supply Chain

- Perimeter defenses insufficient in modern **digital design lifecycle**
- We treat **Automation as nodes in Supply Chain** network

Framework for Security & Efficiency Across "Sectors"

- Digital **identity** = physical + cyber + energy (Cyber-Physical Passport)
- Automation **activities** validated across supply chain

Agile, Adequate, & Consequential Formalism to Validation

- **Targeted formal methods** and evidential basis for design & implementation
- Continuous Integration/Deployment (**CI/CD**) in manufacturing context

Unify security across the digital thread of design, build, deliver for industries of all sizes

SDA Project Update: Cyber-Physical Passport on CNC parts

Results to Date: A key concept in SDA is automatically deploying a **Cyber-Physical Passport (CPP)** to support system hardening, provenance tracking, process verification, and attack monitoring:

- Needed both locally at the manufacturing site and across companies along the product's supply chain.
- CyManII demonstrated the CPP on a CNC's aluminum parts productions and verification of the parts' **digital authenticity** against intended **design** (@ONRL MDF).

Future Work: Expand SDA framework and tools to support multiple innovations through **Industrial Use Case** pilots.

- Additive Manufacturing
- Smart Manufacturing enterprise (CESMII)
- Energy components supply chain

This presentation does not contain any proprietary, confidential, or otherwise restricted information

Thank You