U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

Manufacturing Innovation in the DOE

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manufacturing.energy.gov

What is Advanced Manufacturing?

A family of activities that:

- Depend on the use and coordination of information, automation, computation, software, sensing, and networking; and/or
- Make use of cutting edge materials and emerging capabilities.

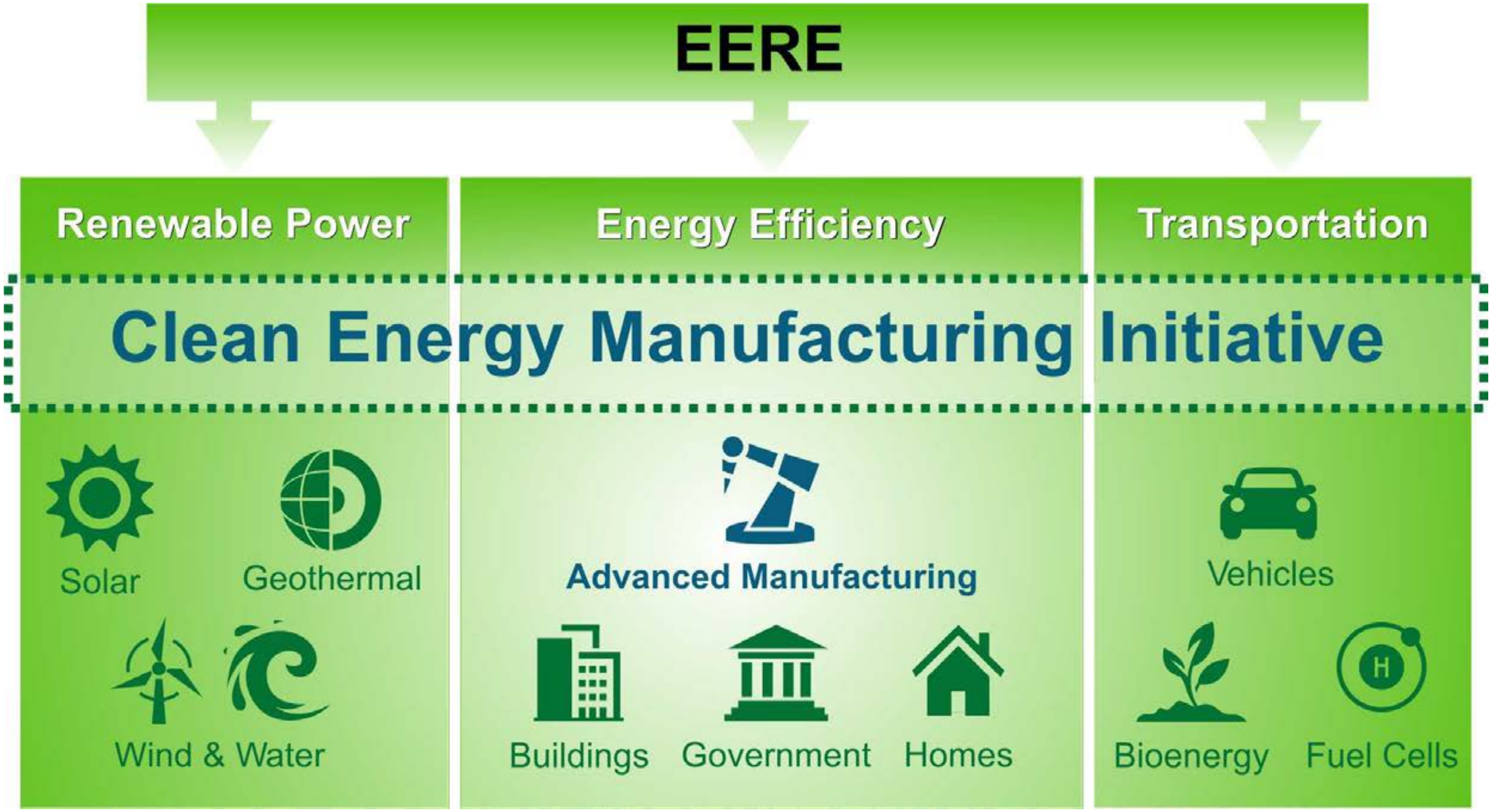
Advanced Manufacturing involves both:

- *New ways to manufacture existing products*; and
- The manufacture of *new products emerging from new advanced technologies*.

Definition from: President's Council of Advisors on Science and Technology, "Report to the President on Ensuring America's Leadership in Advanced Manufacturing," June 2011, p. ii

www.whitehouse.gov/sites/default/files/microsites/ostp/pcast-advanced-manufacturing-june2011.pdf.

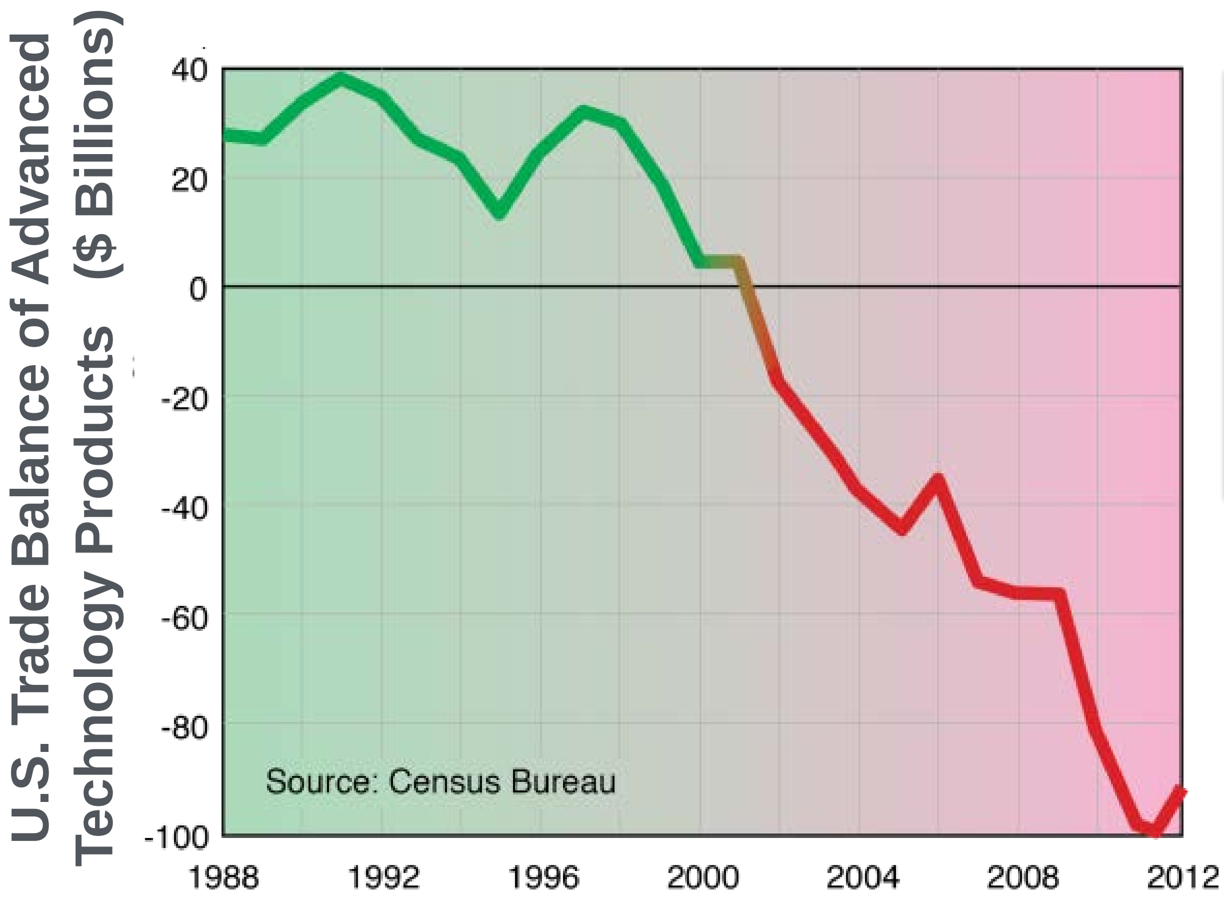
Collaboration and Coordination



Collaboration toward:
Common goal to increase U.S. manufacturing competitiveness while using energy resources more effectively and reducing impact on the environment

Innovation is important for U.S. competitiveness

U.S. Trade Balance of Advanced Technology Products



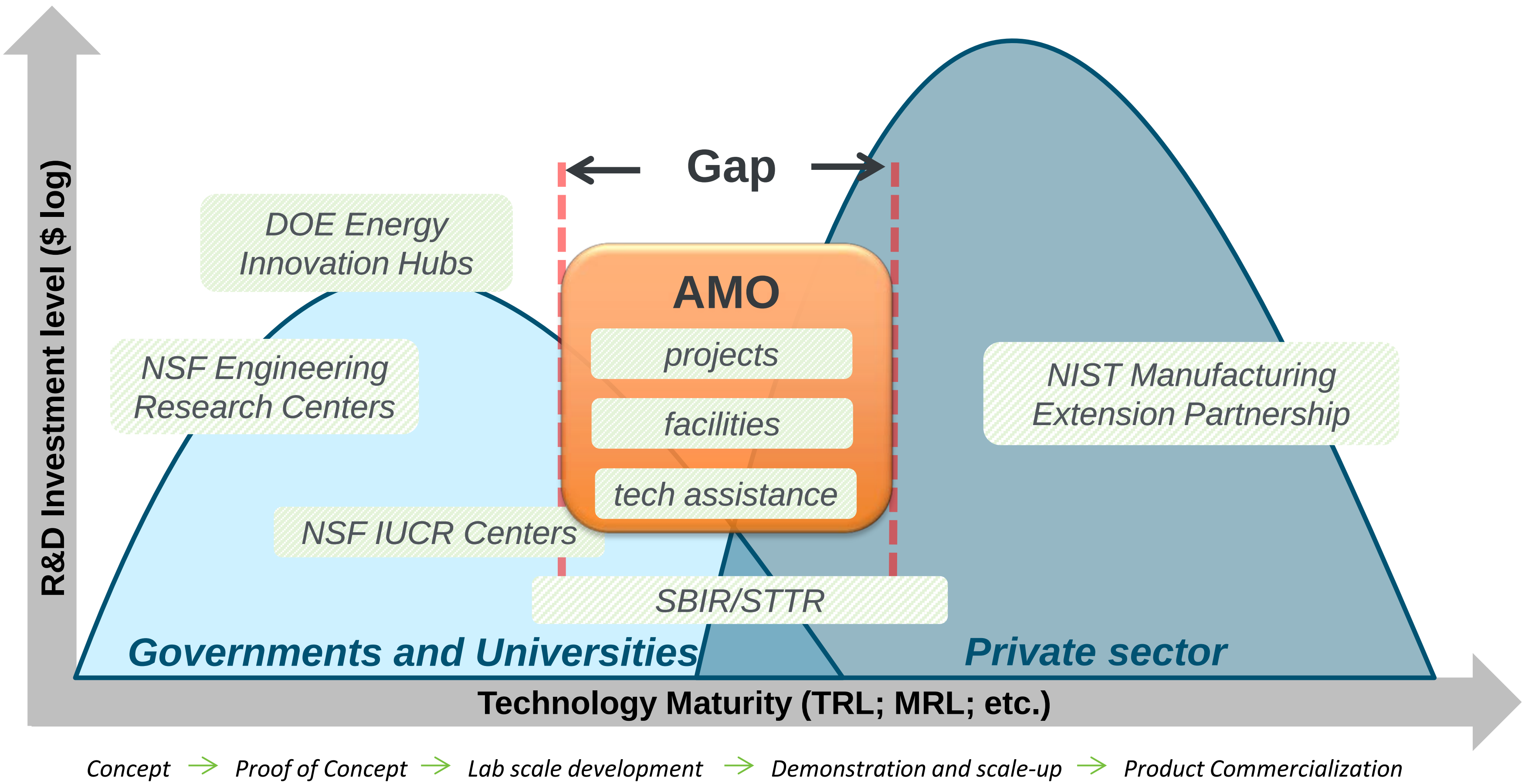
U.S. Manufacturing is:
- 11% of U.S. GDP
- 12 million U.S. jobs
- Approx. half of U.S. Exports
- Nearly 20% of the world's manufactured value added

Swung to historic deficit, lost 1/3 of workforce

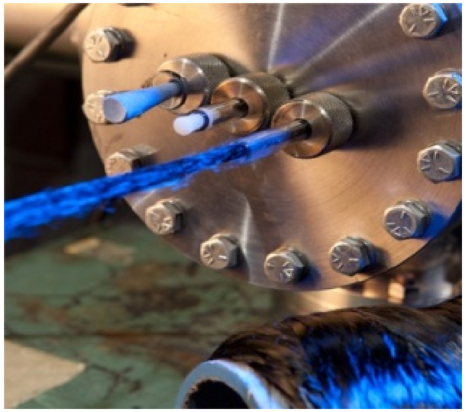
Data Source: http://www.census.gov/foreign-trade/Press-Release/ft900_index.html

AMO R&D: Bridging the Gap

AMO Investments leverage strong Federal support of basic research by partnering with the private sector to accelerate commercialization



Advanced Manufacturing Office (AMO): Focus



AMO's Focus is to Increase U.S. Manufacturing Competitiveness through:

- **Industrial Efficiency for Specific Energy Intensive Industries**
  - *examples: Aluminum, Chemicals, Metal Casting, Steel*
- **Manufacturing Innovations for Advanced Energy Technologies**
  - *examples: carbon fiber composites, advanced structural metals/ joining, wide bandgap semiconductors/ power electronics*
- **Broadly Applicable Industrial Efficiency Technologies and Practices**
  - *examples: industrial motors, combined heat and power (CHP), efficient separations, microwave processing*

Partnership Driven

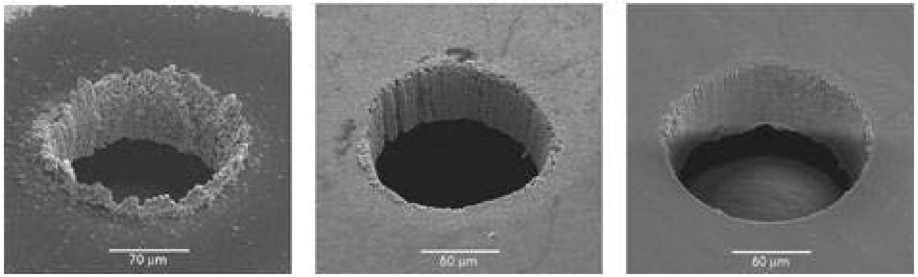
Three primary partnership-based vehicles to engage with industry, academia, national laboratories, and local and federal governments:

1. **Research and Development Projects - to support innovative manufacturing processes and next-generation materials**

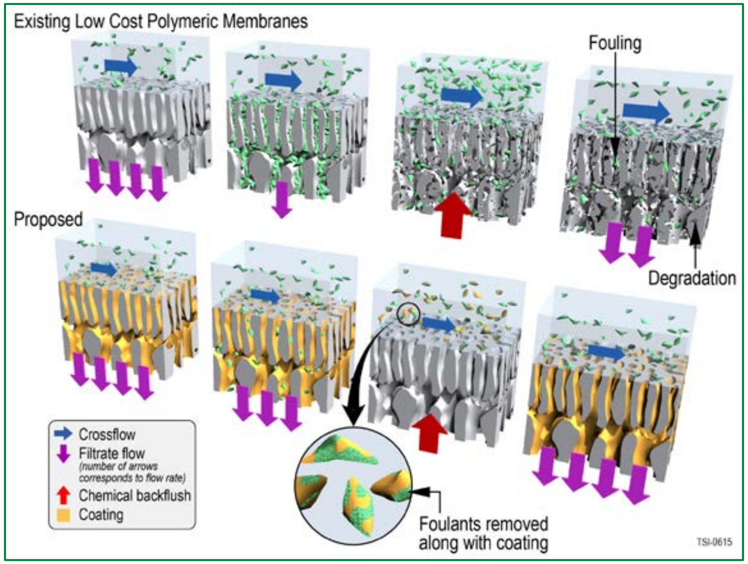
2. **Shared R&D Facilities**

3. **Technical Assistance**

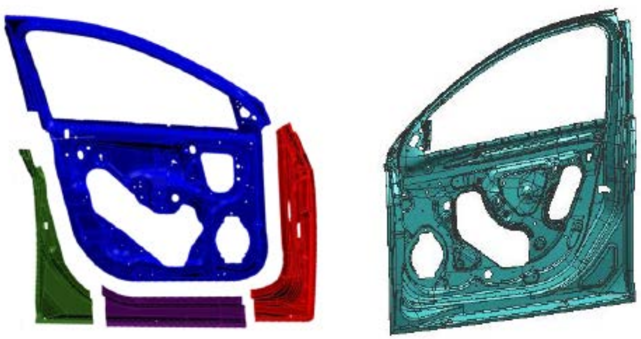
R&D Projects – Manufacturing Processes



Ultrafast, femtosecond pulse lasers (right) will eliminate machining defects in fuel injectors.
Image courtesy of Raydiance.



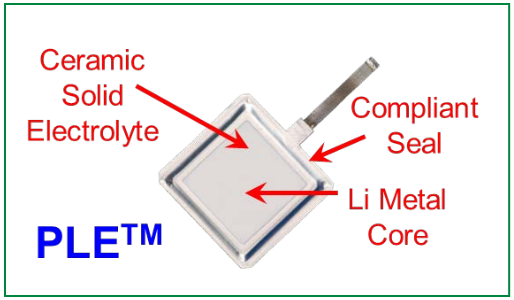
Protective coating materials for high-performance membranes, for pulp and paper industry.
Image courtesy of Teledyne



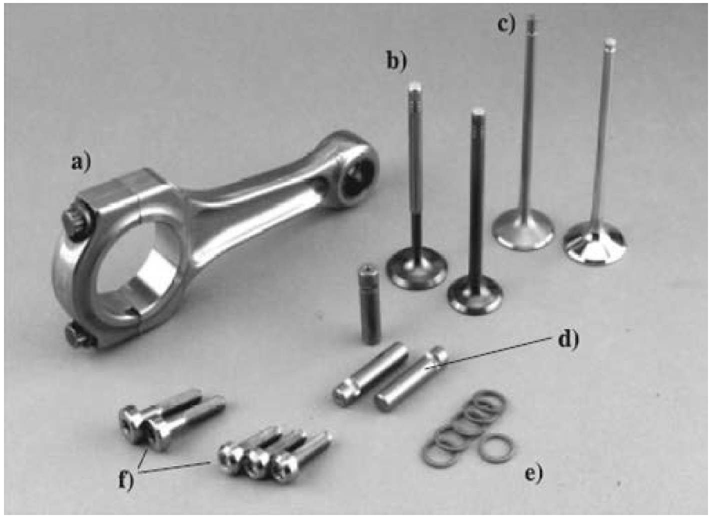
Energy-efficient large thin-walled magnesium die casting, for 60% lighter car doors.

Graphic image provided by General Motors.

A water-stable protected lithium electrode.
Courtesy of PolyPlus

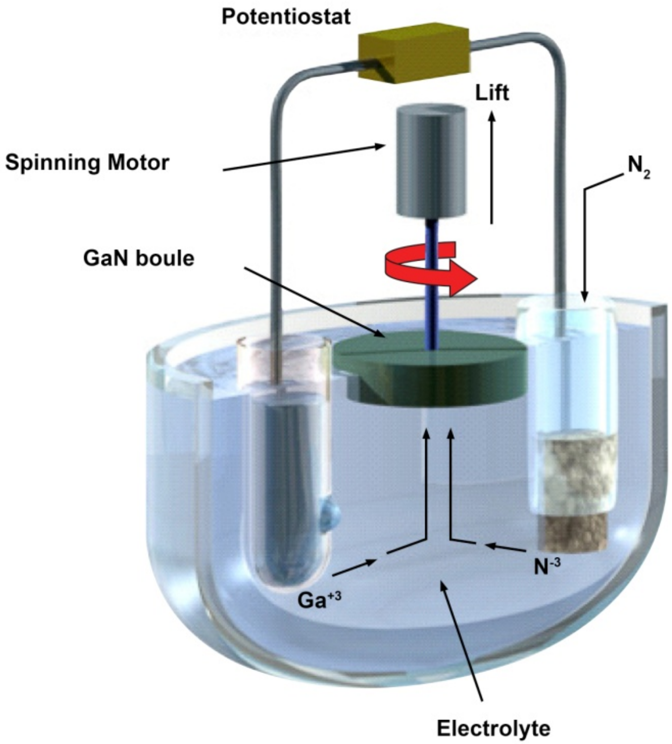


R&D Projects – Materials



Low-cost production process for titanium alloy components.

Photo courtesy Titanium and Titanium Alloys , Leyens & Peters



Electrochemical solution growth of GaN substrates (conceptual diagram).

Image courtesy of Sandia National Laboratory

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Three primary partnership-based vehicles to engage with industry, academia, national laboratories, and local and federal governments:

1. **Research and Development Projects**

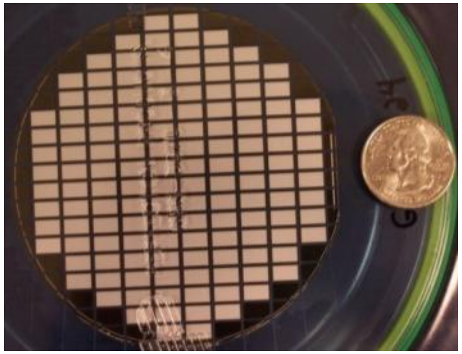
2. **Shared R&D Facilities - affordable access to physical and virtual tools, and expertise, to foster innovation and adoption of promising technologies**

3. **Technical Assistance**

AMO Supported R&D Facilities

- **Manufacturing Demonstration Facility** at Oak Ridge National Laboratory
- **America Makes**, an interagency National Additive Manufacturing Innovation Institute
- **Carbon Fiber Technology Facility** at Oak Ridge National Laboratory
- **Critical Materials Institute**: *A DOE Energy Innovation Hub* at Ames National Laboratory
- **Next Generation Power Electronics Manufacturing Institute** (future)

Wide bandgap semiconductors are smaller, lighter, faster, and more reliable power electronic components for more efficient conversion, distribution, and use of electric power.



Promise of Additive Manufacturing

Unprecedented capability to design and create products

Topology optimization.
Same strength, half the weight

"…in our lifetime at least 50% of the engine will be made by additive manufacturing"
– Robert McEwan GE

America Makes

The National Accelerator for Additive Manufacturing & 3D Printing

Manufacturing Demonstration Facility
at Oak Ridge National Laboratory

Supercomputing Capabilities

Spallation Neutron Source

Additive Manufacturing

Arcam electron beam processing AM equipment

POM laser processing AM equipment

Program goal is to accelerate the manufacturing capability of a multitude of AM technologies utilizing various materials from metals to polymers to composites.

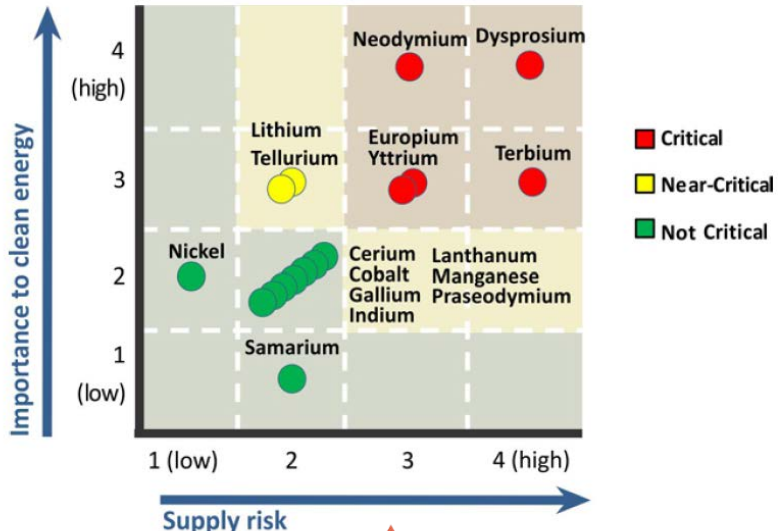
Carbon Fiber

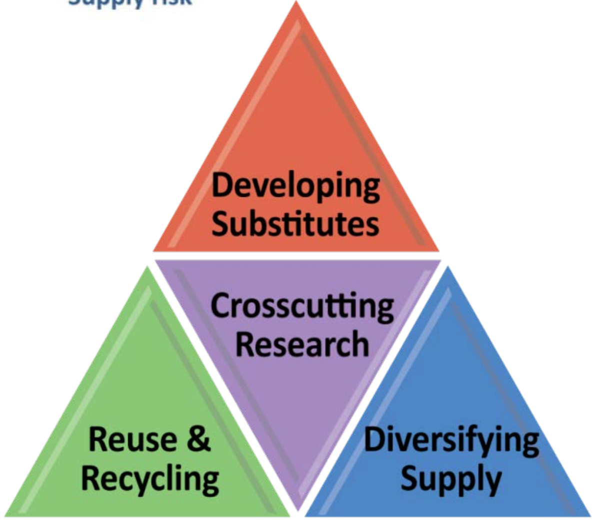
Exit end of Microwave Assisted Plasma (MAP) process, jointly developed by ORNL and Dow

Program goal is to reduce the cost of carbon fiber composites by improved manufacturing techniques such as MAP, which if scaled successfully could reduce carbonization cost by about half compared to conventional methodology.

Critical Materials Institute
A DOE Energy Innovation Hub

- **Critical materials*** – elements that are key resources in manufacturing clean energy technologies
  – wind turbines, solar panels, electric vehicles, and efficient lighting
- **Mission –** Eliminate materials criticality as an impediment to the commercialization of clean energy technologies for today and tomorrow
- **Funding – investing up to $120 million over five years (2013-2017)**
  – Consortium of 7 companies, 6 universities, and 4 national laboratories
  – Led by Ames National Laboratory





* As defined by U.S. Department of Energy. 2011. *Critical Materials Strategy*. Washington, DC: DOE.

Partnership Driven

Three primary partnership-based vehicles to engage with industry, academia, national laboratories, and local and federal governments:

1. Research and Development Projects

2. Shared R&D Facilities

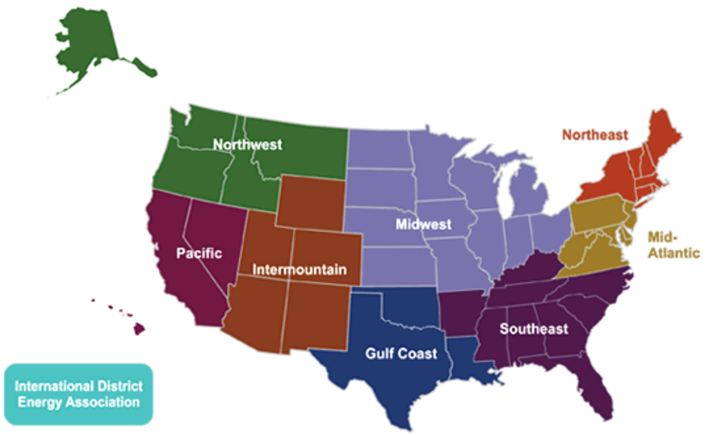
3. **Technical Assistance – driving a corporate culture of continuous improvement and wide scale adoption of technologies, such as combined heat and power, to reduce energy use in the industrial sector**

Industrial Technical Assistance

Efficient On-Site Energy

Clean Energy Application Centers

(to be called Technical Assistance Partnerships



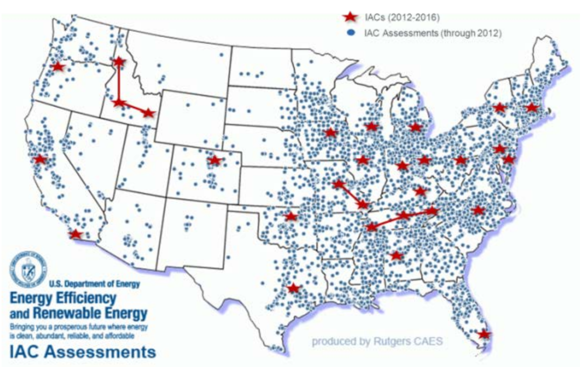
Energy-Saving Partnership

Better Buildings, Better Plants,

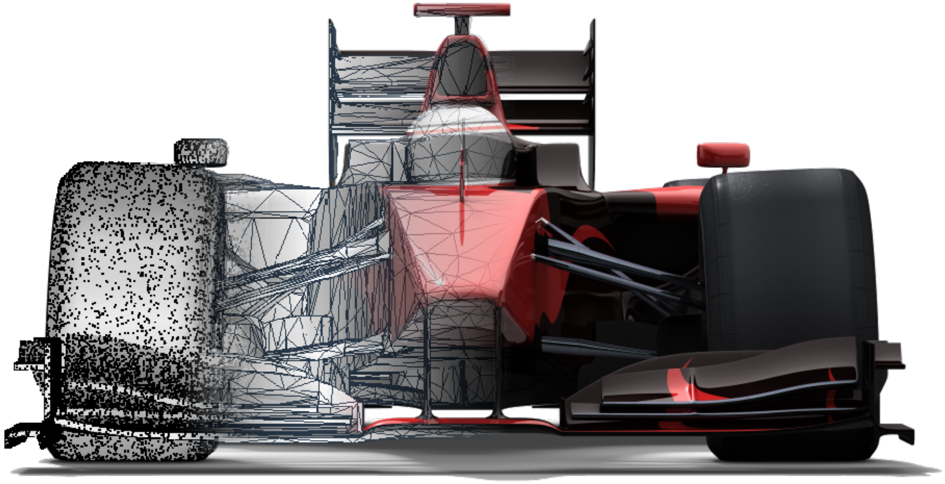
Industrial Strategic Energy Management

Student Training & Energy Assessments

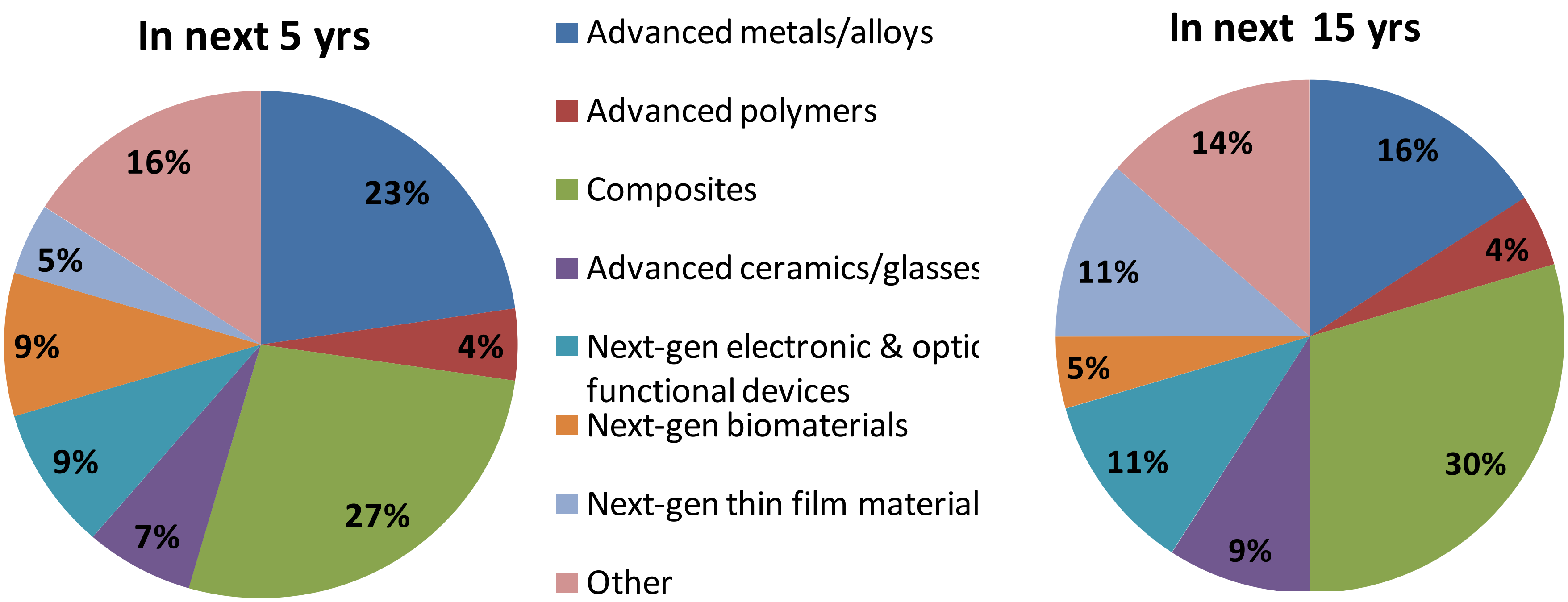
University-based Industrial Assessment Centers



Composites



Material Types with Energy Savings Potential



Survey respondents' selection of material with greatest energy saving potential

Source: Expert elicitation by ORNL – 2012; 93 experts from industry, academia and national labs

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Composites for Clean Energy Cross Cut

Feedstock Diversification

Challenge: High cost of raw materials with a principally foreign manufacturing base for carbon fiber.

Advanced Conversion

Challenge: Costly and energy intensive carbon fiber production process.

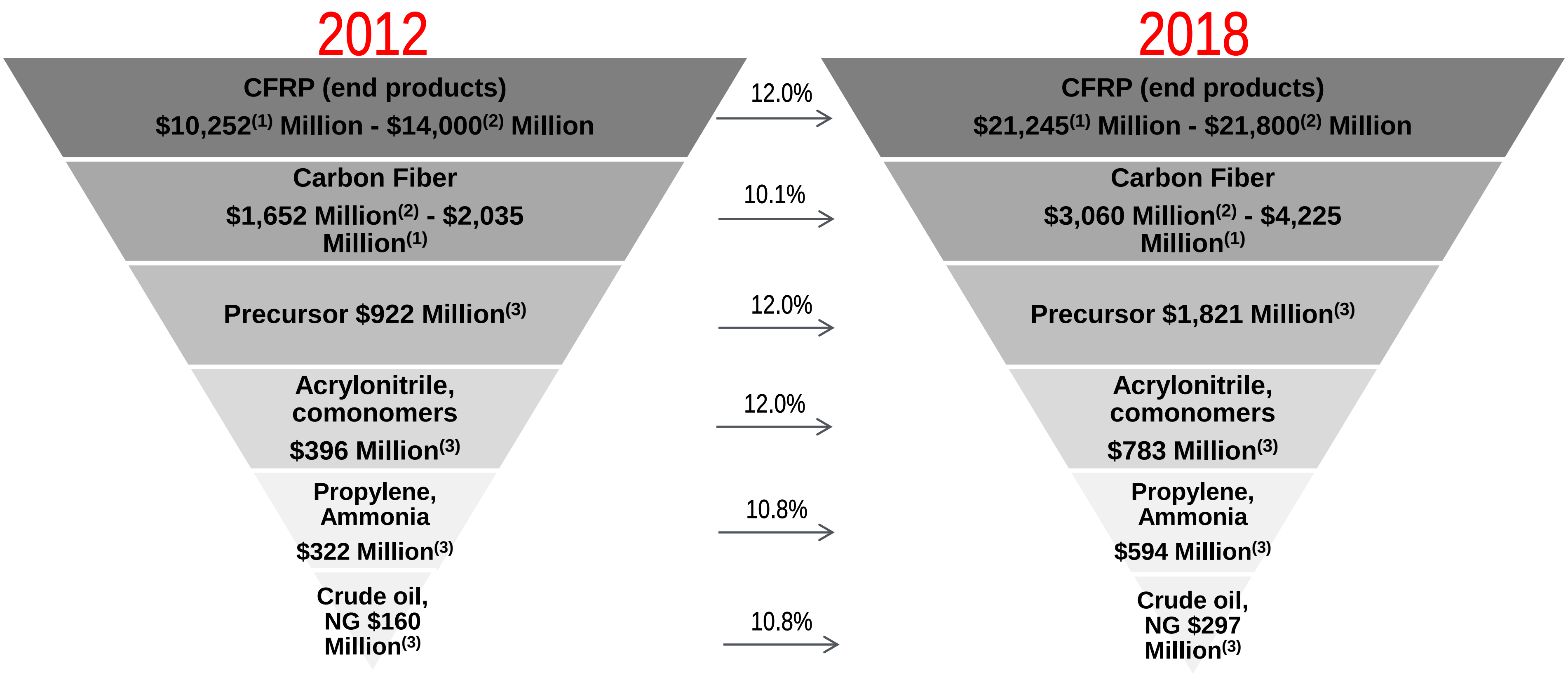
Composite Manufacturing

Challenge: Need for high speed and efficient production technology.

- Carbon fiber (CF) and carbon fiber reinforced polymer (CFRP) important enabling materials for several EERE initiatives:
  - Transportation lightweighting (fuel savings in aero, auto, rail, marine)
  - Wind turbine blade length extension (capture more wind energy, develop new wind resources)
  - Pressure vessels for H_2 and natural gas storage in vehicles and stationary applications
  - Emerging applications, e.g. civil infrastructure, oil & gas, etc.
- "*Identify key opportunities in the CF supply chain where U.S. can achieve or maintain a competitive advantage*"

Supply Chain Value – Innovation Opportunities

- CF value chain disaggregated at six key levels based on data from various sources (1,2,3)
- Most value added at top (i.e. CFRP) level, in aggregate about 5-8X value of CF market
- Commodities and raw material chemical inputs used in fiber manufacturing (oil, NG, propylene, NH_3, AN, comonomers) relatively small share of value chain

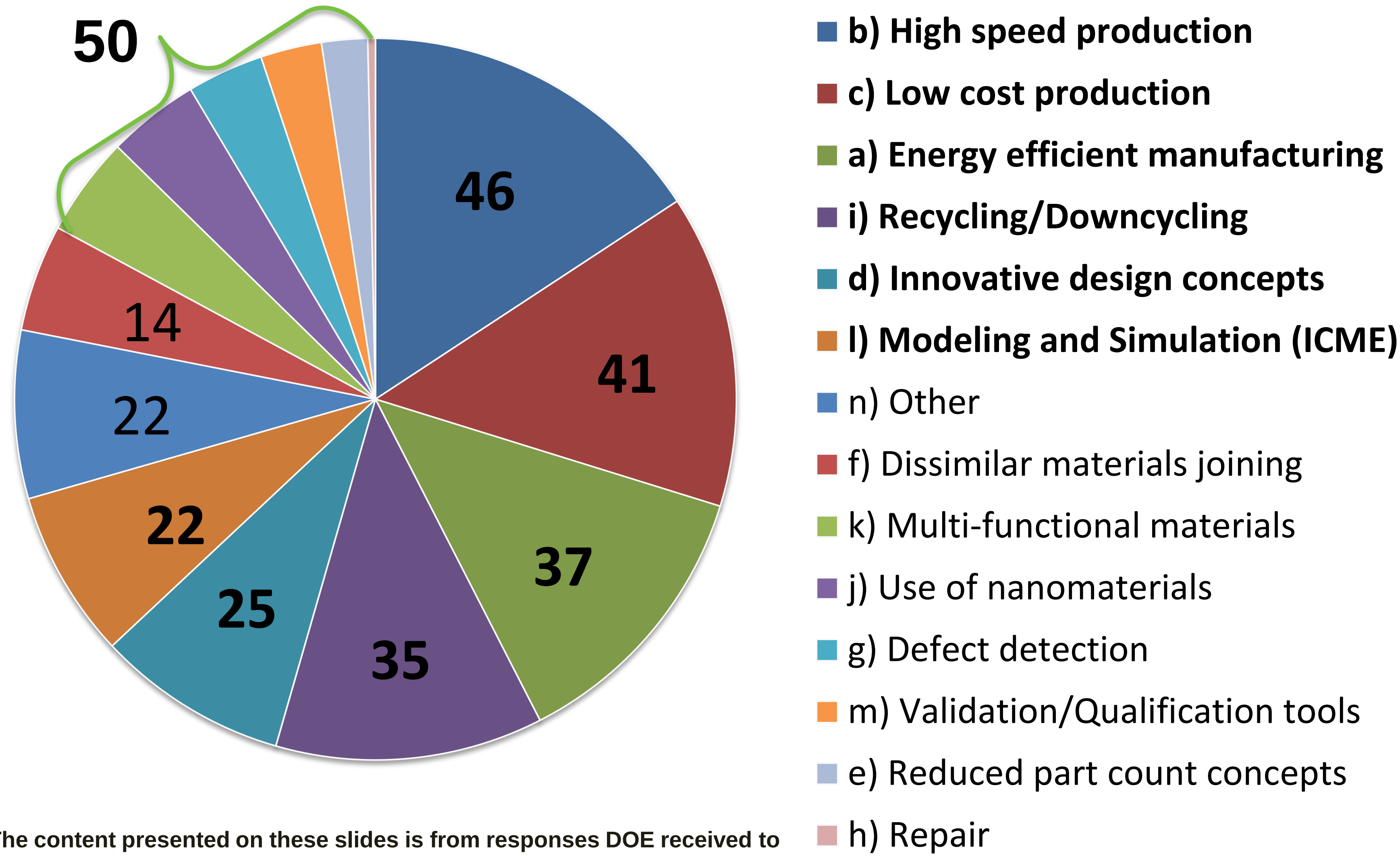


(1) Industry Experts (2013). Carbon Fiber & Carbon Fiber Reinforced Plastics (CFRP) – A Global Market Overview
(2) Lucintel (2013). Growth Opportunities in the Global Carbon Fiber Market 2013 – 2018.
(3) ORNL Low Cost Carbon Fiber Cost Model (2012).

Composites - Information Gathering

- RFI 1: Released August 2013
  - Broad questions to identify areas with R&D needs related to DOE mission and understand industry needs and challenges
  - 37 Responses representing 59+ respondents
- RFI 2: Released December 2013
  - Reflect back the information available and received in the first RFI, give the community an additional chance to respond
- Brings us to today…

RFI 1 Results: R&D Needs



Legend: Number of Responses

The content presented on these slides is from responses DOE received to Request for Information DE-FOA-0000980. It is presented for information only and is not meant to represent DOE's position.

RFI 1 Results: Training and Workforce Development

- Certified: **Manufacturing/Technical Workforce**
  - Professional level, re-education of designers and engineers
  - Community college and trade schools for technicians for manufacturing with hands on training

- Increased Universities focus: **undergraduate & graduate**
  - Identified knowledge areas:

    Materials science courses in general focused on composites
    Design and simulation for composites,

    Robotics, automation, industrial controls, textiles, interfacial and surface science, nanomaterials

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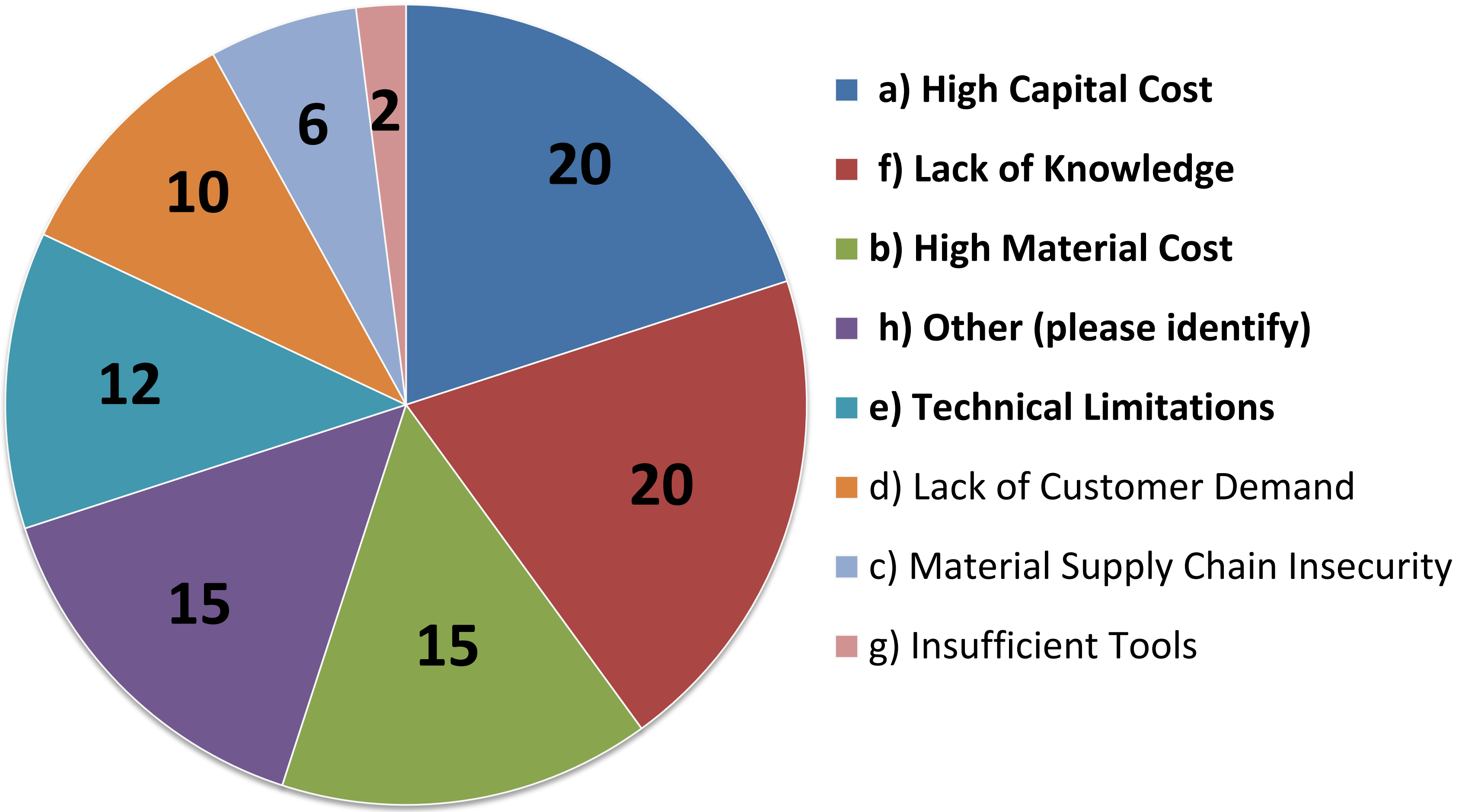
RFI 1 Results: Significant Obstacles



Legend: Number of Responses

RFI 2 – Appendix A Overview

Main R&D Areas for Low-Cost Composites:

- **Manufacturing throughput** without degrading performance
- **Energy use** for composite materials and structures fabrication
- **Recyclability** for both in-process scrap and end-of-use.
- **Enabling technologies and approaches** to support improvements to composite manufacturing.

Proposed Objectives for Composites

- **Cost:**
  - Reduction of the production **cost of carbon fiber composites** for targeted applications (vehicles, wind, high-pressure gas storage) **by >25% in five years**, on a pathway to a reduction of **cost >50% over 10 years**;*
- **Energy:**
  - Reduction **of life cycle energy and greenhouse gas emissions** by more **than 50% for fiber reinforced polymer composite applications** over a ten year time frame;*
  - **Reduction of the embodied energy** and associated greenhouse gas emissions of carbon fiber composites **by 50%** compared to today's commercial **thermoplastic** technology and **75%** to today's commercial **thermoset** technology **in five years**; and
- **Recyclability:**
  - Demonstration of innovative technologies at sufficient scale for **80% recyclability of both glass and carbon fiber** reinforced polymer composites **in five years**, and **>95% in ten years** into useful components with projected cost, quality and production volumes at commercial scale competitive with virgin materials.

Application Areas and Carbon Fiber Targets

Application	Current CFC Cost	CFC Cost Reduction (2018)[1]	CFC Ultimate Cost[a,b]	CFC Tensile Strength[c]	CFC Stiffness[c]	Production Range/Cycle Time
Vehicles (Body Structures)	\$26-33/kg	35%	<\$11/kg by 2025[63] ~60%	0.85GPa[d] (123ksi)	96GPa[d] (14Msi)	100,000 units/yr <3min cycle time (carbon) <5min cycle time (glass)[63,64]
Wind (Blades)	\$26/kg	>25%[64]	\$17/kg ~35%	1.903 GPA (276ksi)	134GPa (19.4Msi)[67]	10,000 units/yr (at >60m length blades using carbon fiber)[64]
Compressed Gas Storage (700 bar – Type IV)	\$20-25/kg	30%[64]	\$10-15/kg ~50%[68]	2.55 Gpa (370ksi)	135 Gpa (20Msi)[69]	500,000 units/yr (carbon fiber)[64]

RFI 2 Responses - Themes

- Inclusion of bio-based materials, renewables, natural fibers
- Integrated approaches are important
- Natural gas tanks, infrastructure, transmission lines and other markets discussed
- Don’t lose focus on glass fibers
- Thermoplastics becoming more important
- Resin recycling also important

What's Next Today

- Hear from across DOE
- Hear from across AMNPO & across Government
- Hear from You: Industry and Research Community

Thank You