NASEO-ASCERTTI

Advanced Manufacturing and Energy: Commercialization of Low-cost Carbon Fiber Technologies

Lee McGetrick
Director, Carbon Fiber Technology Facility
Oak Ridge National Laboratory

Oak Ridge, Tennessee
February 8, 2013

MDF
Manufacturing Demonstration Facility

U.S. DEPARTMENT OF ENERGY

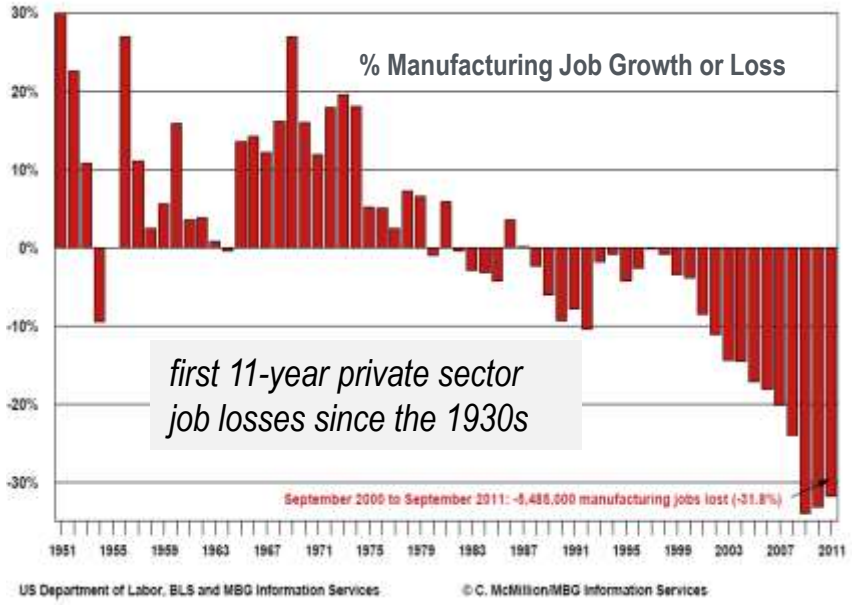
OAK RIDGE NATIONAL LABORATORY
MANAGED BY UT-BATTELLE FOR THE DEPARTMENT OF ENERGY

Manufacturing matters

- 12% of U.S. GDP
- 12 million U.S. jobs
- 60% of U.S. engineering and science jobs
- 57% of U.S. Exports
- Nearly 20% of the world's manufactured value added

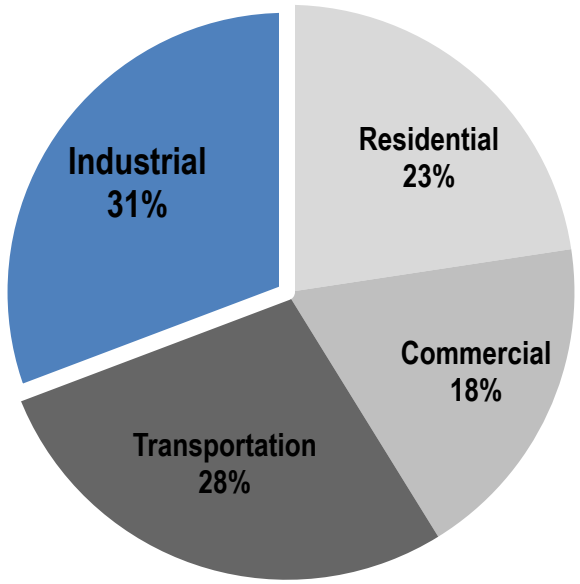
Jobs

31.8% of all manufacturing jobs lost from 2000-2011



Energy

31% of all 2010 U.S. total energy consumption



*Includes total primary energy direct use and electricity use in end-use sectors including losses
Source: *Annual Energy Review 2010*, US EIA

We are focusing ORNL resources to support manufacturing imperatives

- **Manufacturing and materials R&D to:**
  - Reduce the energy intensity of U.S. industry
  - Support development of new products
  - Strengthen our nation's competitiveness and economic vitality
- **Leveraging ORNL's distinctive core capabilities**
  - Neutron scattering
  - High-performance computing
  - Advanced materials
  - Advanced characterization

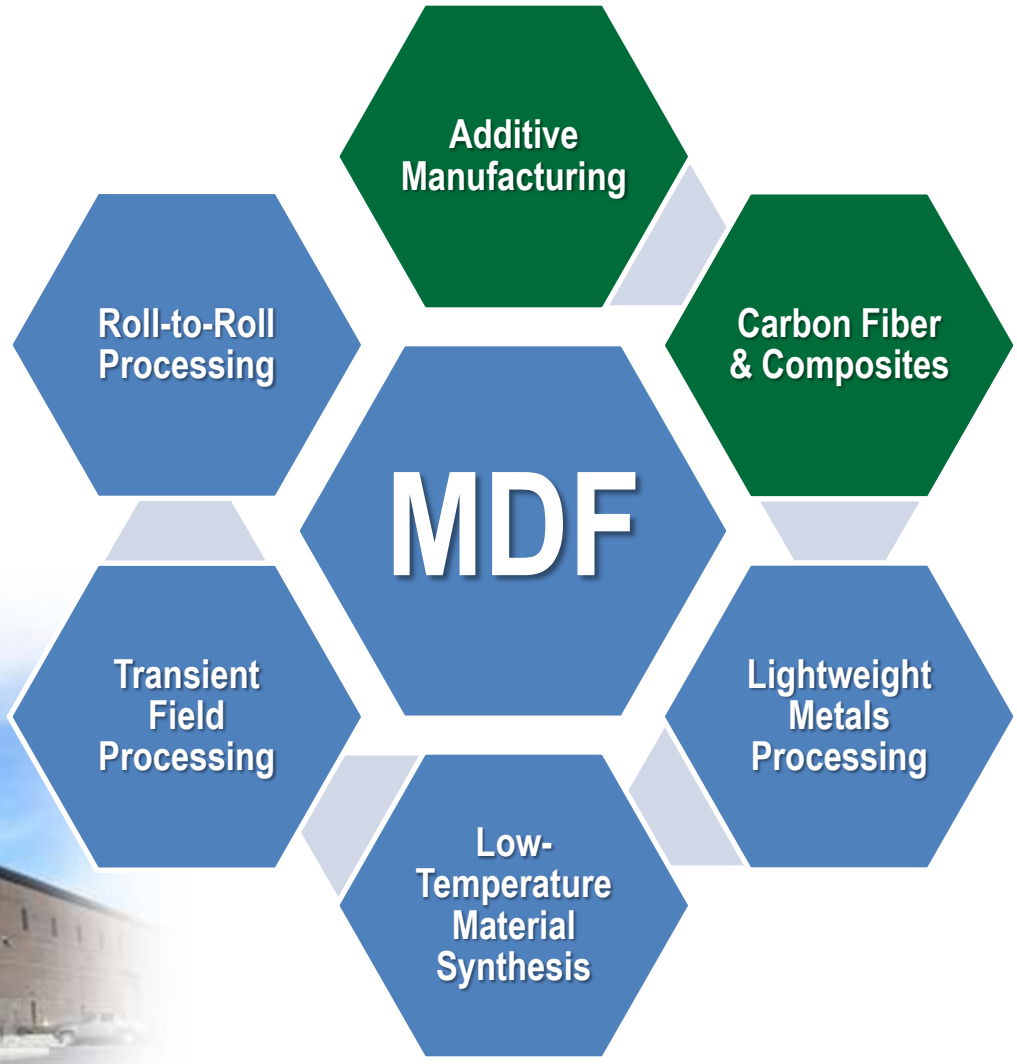
***Manufacturing Demonstration Facility (MDF)*: a multidisciplinary DOE-funded facility dedicated to enabling demonstration of next-generation materials and manufacturing technologies for advancing the US industrial economy**

www.ornl.gov/manufacturing

ORNL's MDF is primarily focused in two key areas– *additive manufacturing and carbon fiber & composites*

Several ancillary technical areas have been incorporated in the MDF as appropriate to the overall mission of the program

U.S. DEPARTMENT OF ENERGY | Advanced Manufacturing

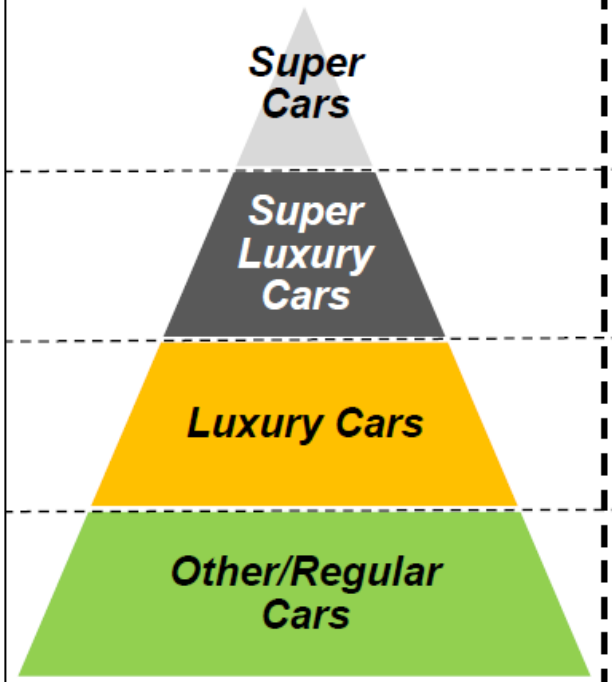


Carbon fiber is enabling for industry

- Structural carbon fiber has a variety of light-weighting applications
  - Defense: Heat shields, aircraft wings and fuselages, lightweight weaponry
  - Automotive: 10% mass reduction equates to 6-7% increase in fuel economy
  - Wind energy: 100 m wind turbine blades for off-shore – mass = k (length)^3
- Nonstructural carbon fiber
  - Single thermal application requires 500 tons of fiber per year
  - Additional application for graphite electrodes would require 500 tons of fiber per year
  - No secure domestic source exists
  - Essentially all thermal applications could use a secure, low-cost domestic source of carbon fiber

Potential automotive market alone is huge for low-cost carbon fiber

Carbon fiber potential in 2017 at 50% of current price



Global Automotive Production by Car Type in 2017	Expected Vehicle Production in 2017	Expected use of CF in Cars	Carbon Fiber Demand (M lbs) @ 0.50 X current price	Carbon Fiber Demand ($ M) @ 0.50 X current price
Super Cars	6K	100% of cars	1.3 M lbs	$7 M
Super Luxury Cars	600K	10%	101.2 M lbs	$506 M
Luxury Cars	4 Million			
Other/Regular Cars	92 Million	1%	202.4 M lbs	$1,012 M
Global Automotive Production in 2017	97 Million		305 M lbs	$1,525 M

Source: Lucintel, ACMA Composites 2012

~ 3X current global CF demand for ALL APPLICATIONS

Focus on low cost carbon fiber

Major Cost Elements

Precursor	~ 50%
Conversion	~ 40%
Other	~10%

ORNL is developing technological breakthroughs for major cost elements

Current cost of carbon fiber (industrial grade): $10 - $15/lb

Automotive targets:

- $5 - $7/lb,
- tensile 250 ksi, 25 Msi, 1% ultimate strain

Industry calls for scale-up facility

75 stakeholders from government and industry attended workshop at ORNL March 2009

Major Finding:

A **demonstration facility…**

"...housed with both equipment and staff could be made available to a variety of researchers and developers.

…provide access to capital equipment, would allow resource sharing, and would mitigate risk and reduce cost

…would speed development of carbon fiber and composites,

….the facility would require a large capital investment"

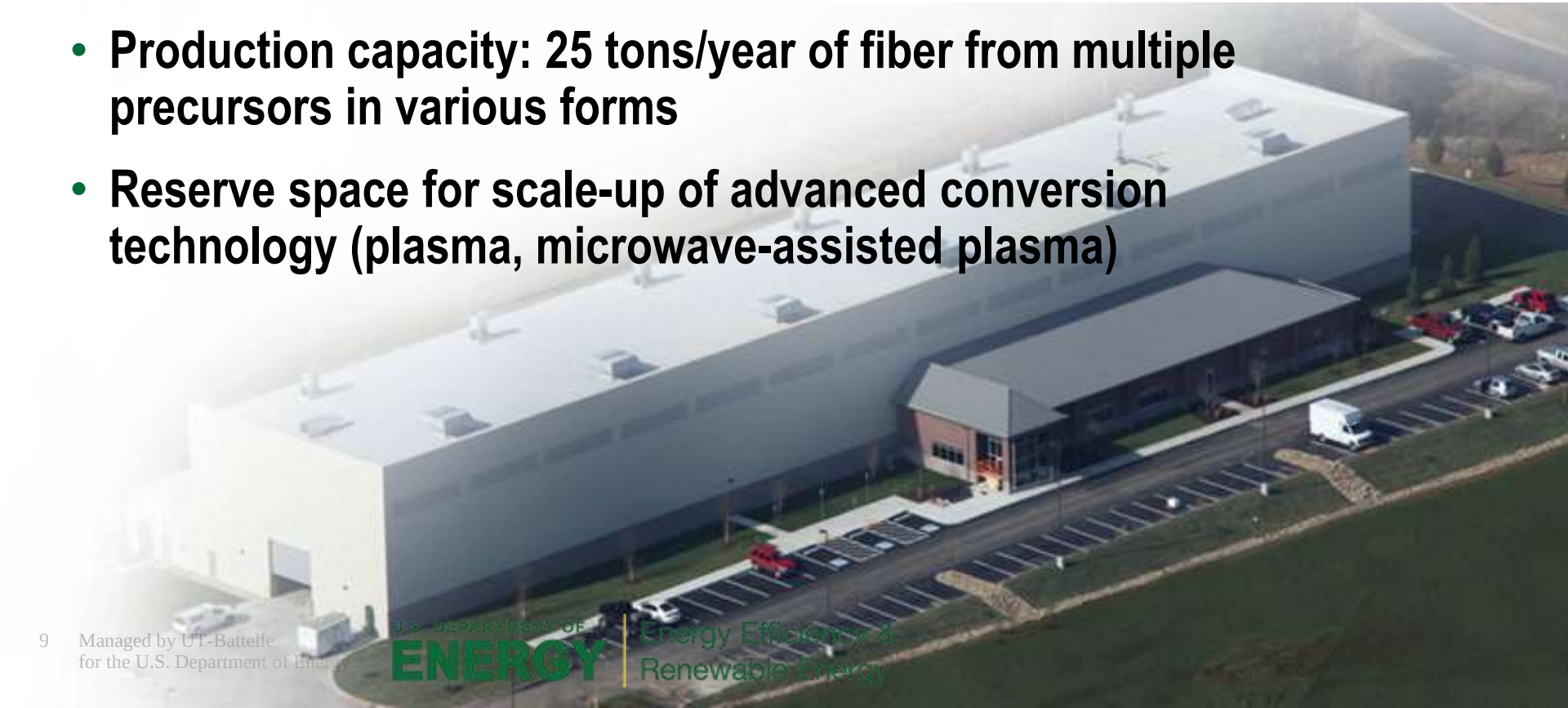
DOE/EERE VTP & ITP (now AMO) Workshop on Low Cost Carbon Fiber Composites for Energy Applications

Science to Application

Carbon Fiber Technology Facility

Focused on demonstrating the scalability of low-cost carbon fiber

- **DOE ARRA funding**
- **42,000 ft^2 facility**
- **Highly flexible "conventional" conversion line**
- **Production capacity: 25 tons/year of fiber from multiple precursors in various forms**
- **Reserve space for scale-up of advanced conversion technology (plasma, microwave-assisted plasma)**



Science to Application

Carbon Fiber Technology Facility (CFTF)

- Demonstrate low-cost carbon fiber (LCCF) technology scalability
- Produce quantities of LCCF for large-scale material and process evaluations and prototyping
- Deploy a training system, with Roane State Community College, for developing the future workforce

CFTF is the bridge from R&D to deployment and commercialization

CARBON FIBER TECHNOLOGY FACILITY

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

Skilled Workforce Development Is Critical for Technology Deployment

Roane State Community College
AMTEC
ORISE
Oak Ridge Institute for Science and Education
ORAU
Oak Ridge National Laboratory
Managed by UT-Battelle for the Department of Energy
CARBON FIBER TECHNOLOGY FACILITY

Pool of Candidates

- DOL grant funded
- Located at ORNL
- Industry focused training
- For qualified unemployed or under-employed

Technician Internship Program

- High-quality STEM learning experience
- Collaboration with researchers in field of interest
- Growth of S&T talent
- Hands-on experience on complex CF line
- Learn S&T underpinning ORNL research
- Develop skills directly transferrable to industry

Longer term Vision:

(i) Develop workforce training system for future carbon fiber manufacturing partners

(ii) Develop internship and other training programs from high school through university graduate level

Photo courtesy of Michael Patrick & Knoxville News-Sentinel

Training for carbon fiber technicians has been deliberate and extensive

Chemistry & Mathematics

- Correct process upsets
- Prevent excursions

Mechanical Skills

- Equipment adjustments
- In-process maintenance

Safety Aspects

HAZARDS:

- Chemical
- Thermal
- Mechanical
- Electrical
- Environment

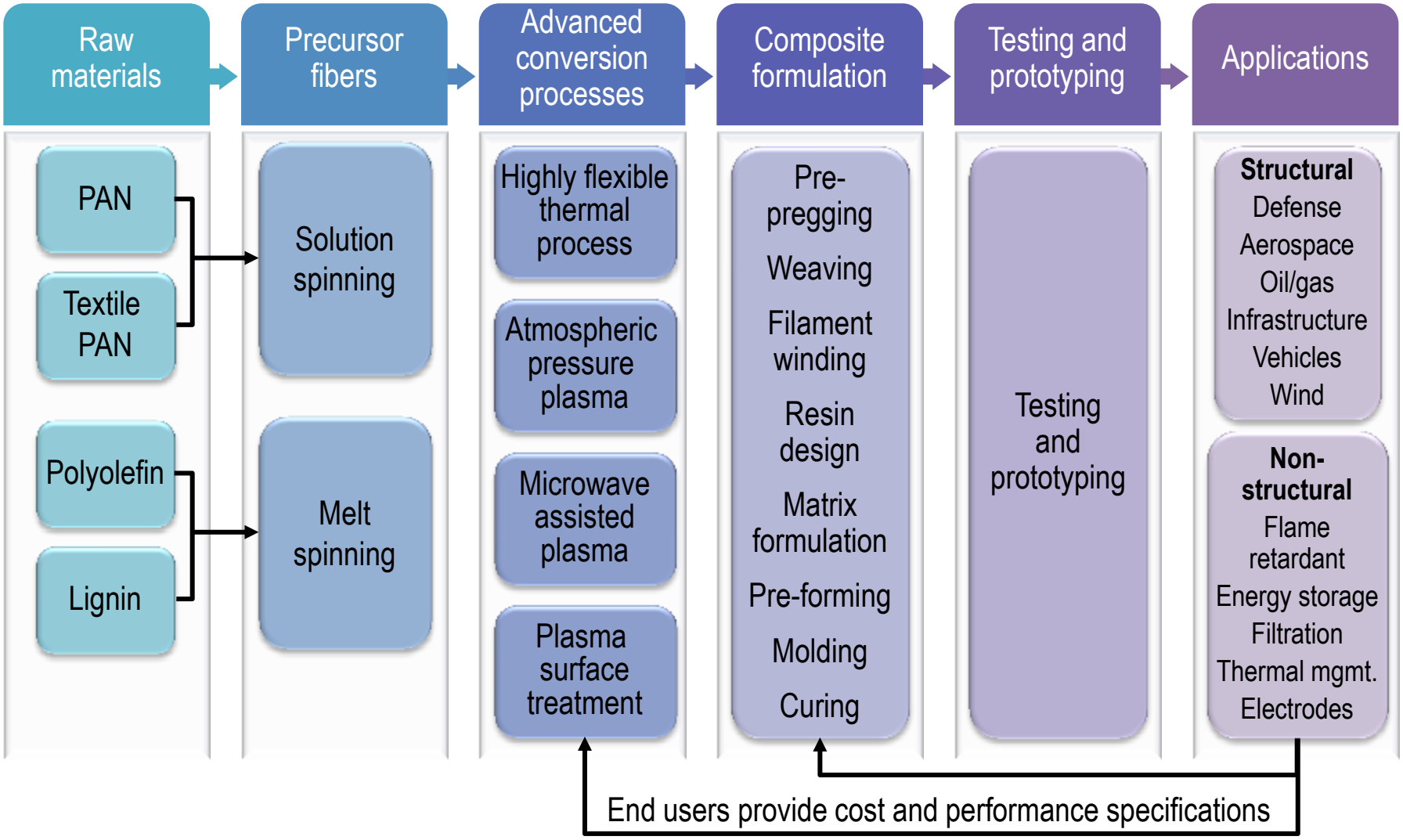
Process Controls

- Alarm response
- Controls logic
- Process adjustments

"Black Art"

- Pressure & flow balancing
- Splicing
- Tow repairs

Building a sustainable carbon fiber commercialization strategy



Science to Application

Dow and Ford partner with ORNL to scale up low-cost carbon fiber

- Dow and Ford team up to bring low-cost, high-volume carbon fiber composites to next-generation vehicles
  - Reducing weight of new cars and trucks by up to 750 lbs by the end of the decade
  - Foundational work at ORNL on low-cost precursors key to automotive applications
  - DOE and state of Michigan fund research agreement to develop lower cost carbon fiber production process using polyolefin in place of conventional polyacrylonitrile (PAN) as feedstock
  - Novel process could reduce production cost by 20%
  - High-volume commercial launch anticipated outcome

Lignin-derived high temperature thermal insulation for industrial furnaces

- Prototype Fabrication – Fabricated two 18” diameter thermal insulation prototypes (first production of lignin-based carbon fiber articles at the one-foot scale)
- Prototype Evaluation – Performance evaluations of 18” diameter thermal insulation prototypes indicate that key thermal performance properties are comparable to those of commercial thermal insulation

courtesy GrafTech International

Lignin pellets

Lignin fiber melt blowing

Lignin fiber stabilization

Milled lignin-based carbon fibers

(courtesy GrafTech International)

Carbon Fiber Composites Consortium—

A public-private partnership enabling innovations in carbon fiber and composites

- 3M Company
- ABC Group Sales & Engineering
- Advanced Composites Group
- Alpha Industries
- ATK Launch Systems
- BASF Corporation
- Chomarat NA, LLC
- Composite Applications Group
- Continental Structural Plastics
- Cytec Carbon Fibers
- Dow Chemical Company
- Despatch Industries
- Faurecia
- Fibria
- Ford Motor Company
- General Electric
- Global Composites Solutions
- Graftech International
- Hanwha Azdel
- Harper International
- Hills, Inc.
- Innovation Valley Inc.
- Innventia
- INOAC USA
- Lignol Innovations
- Materials & Chemistry Laboratory
- Metalsa Structural Products
- NFT, Inc.
- NovusFolium
- Plasan Carbon Composites
- Sabic Innovative Plastics
- SGL Carbon Fibers
- Sodra Innovation
- SSOE Group
- Steelcase
- Swift Engineering
- Toho Tenax America
- United Technologies Research Center
- United States Enrichment Corp. (USEC)
- UT-Battelle
- Virdia, Inc.
- Volkswagen Group of America

Working with ORNL's MDF

- **Identify opportunities aligned with ORNL's MDF technology thrust areas**
- **Discuss ideas with MDF director**
- **Jointly pursue funding to support collaborative activity**

	Assess	Assist	Collaborate
Type of Agreement	User Agreement (Non Proprietary)	Work for Others Agreement (Proprietary)	Cooperative Research & Development Agreement
Length of Engagement	Up to 12 months	As defined by agreement	Longer-term basis of a year or more
Cost to Company	NO COST	Full cost recovery	Cost-share required
Intellectual Property Rights	Each party owns its own inventions. Jointly developed inventions will be jointly owned.	Companies own intellectual property made or created using corporate funds as a result of these engagements.	Companies own inventions they make during the collaboration and have an option to negotiate an exclusive license in a specific field of use to inventions made by ORNL.
Protection of Generated Information	Information generated is publicly available.	Companies paying for services with corporate funds can treat all generated data as their proprietary information.	Commercially valuable information generated under a CRADA may be protected for up to 5 years, depending on funding source.

Discussion