Oak Ridge National Laboratory

DOE Bioenergy Technologies Office (BETO) Workshop April 14-15, 2021

Advancing Synergistic Waste Utilization as Biofuels Feedstocks: Preprocessing, Co-products, and Sustainability

Maximizing the Value of Biofuel Feedstock through Diverse Applications

Soydan Ozcan, Thrust Lead

Circular Economy for Polymer Composites

Bio-based Materials and Manufacturing

Manufacturing Demonstration Facility

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Outline

- Can polymer composite feedstock create value for the integrated MSW processing?
- Prior research: Improving the economic viability of biomass supply chains by integrating composite applications through additive Manufacturing

Enabling the Circular Economy

"Develop Value Added Recycled Feedstocks for Additive and Composite Manufacturing"

Wind Power Blades | Automotive | Aircraft

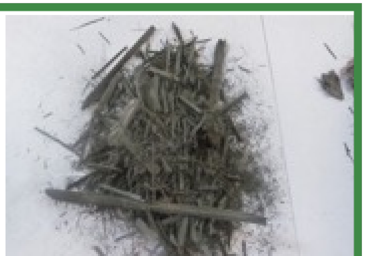
End of life composite waste



Size reduced


Glass fiber composite


Glass Fiber composite


Carbon fiber composite

Recovery Technology


Pyrolysis

- Chemicals
- Syngas
- Fiber

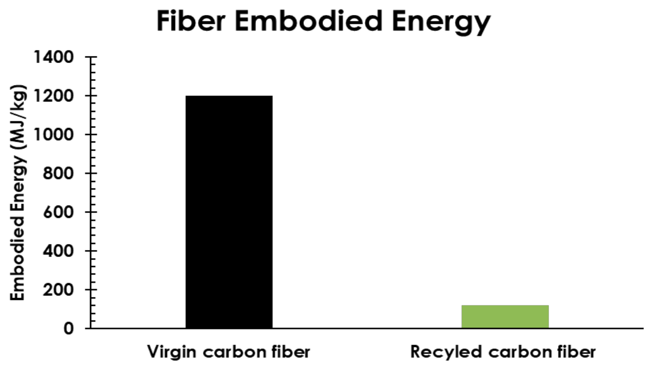
Prototyping and new Applications

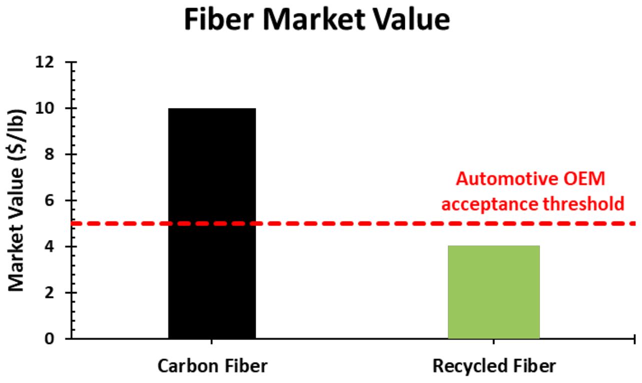

Printed tool using **recycled carbon fiber** composite feedstock

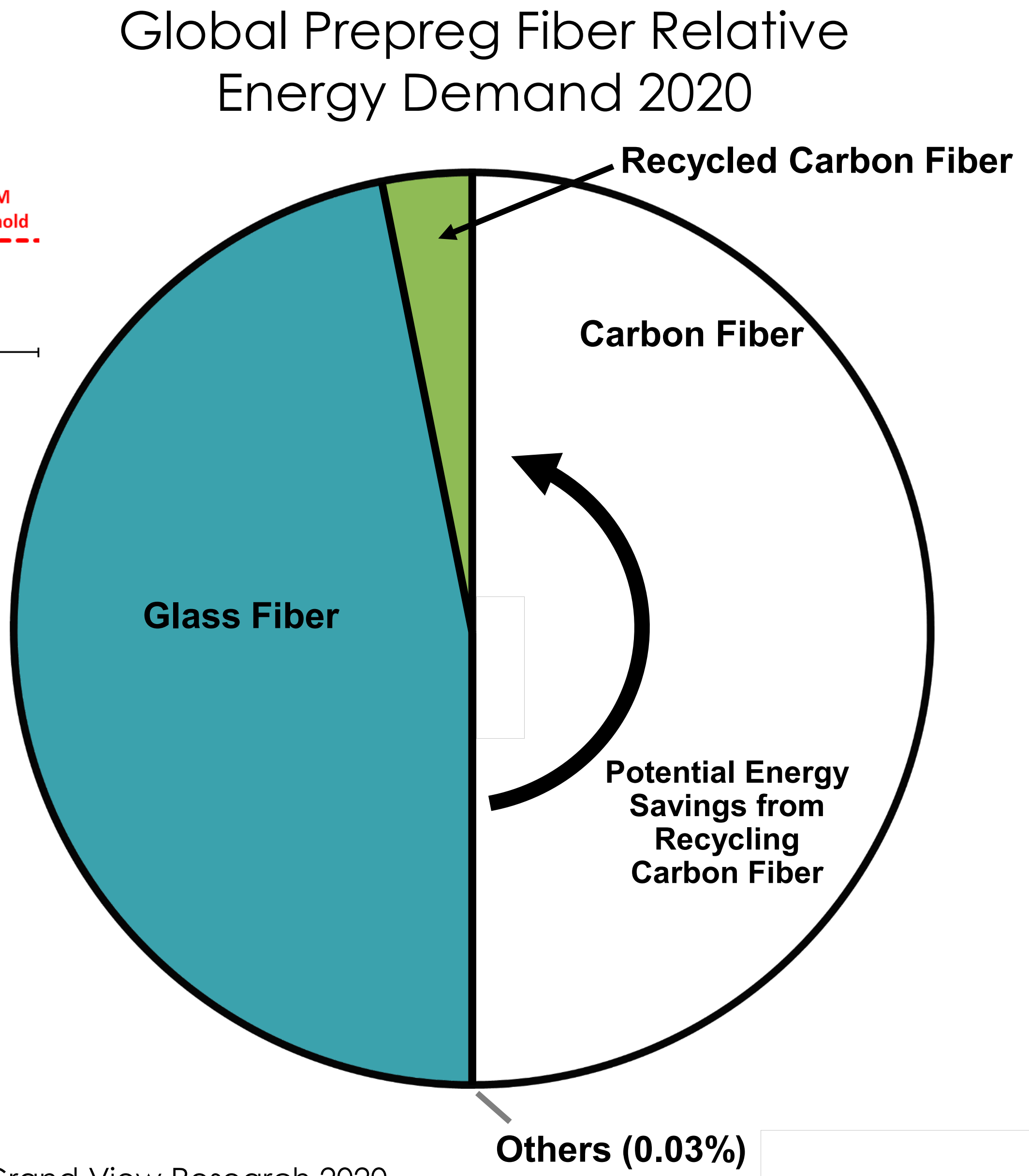

Injection molded automotive fender fabricated **using recycled carbon fiber** reinforced PA6

- **Recovery:** Develop next generation polymer composites recovery technologies (e.g., gasification or pyrolysis reactors, recycled composites AM)
- **Polymer Science:** New recycled polymer composite intermediate materials drive recycled composite demand and adoption by industry
- **Manufacturing Science:**
  - Additive and composite process development for recycled feed-stream.
  - Streamline iteration of new technologies for circular economy: Unified, in-house composite recovery (e.g., gasification/pyrolysis), preforming (e.g., nonwovens/wetlay, compounding), and manufacturing (e.g., molding, AM) capabilities
- **Supply Chain Integration:** Network between industry partners to establish supply chain feasibility, technoeconomic analyses, and material lifecycle assessments

Recycling Provides Value, Supply, and Energy Savings





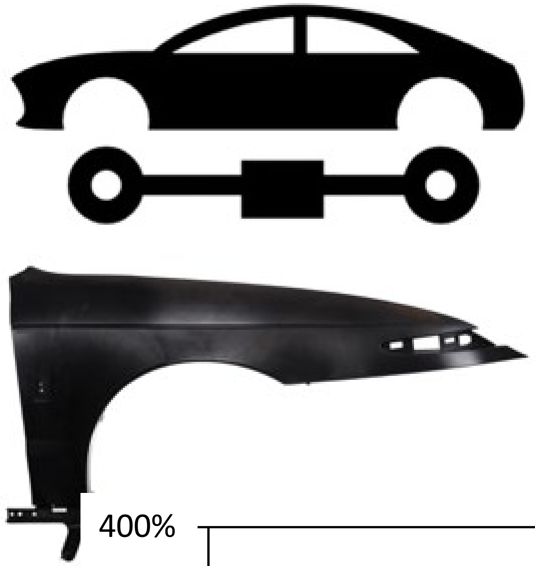


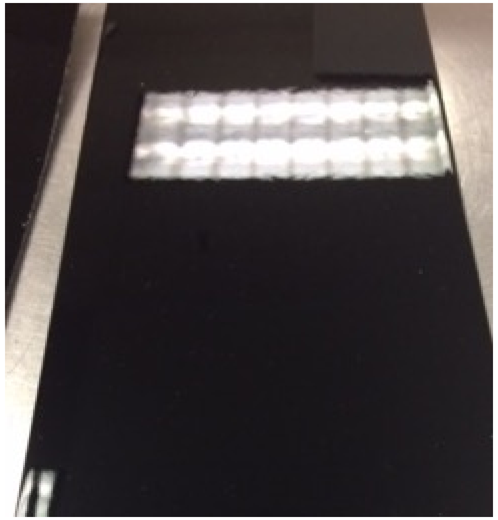
- Recycling CF reduces embodied energy and cost
- By 2040:
  - Waste CF scrap could amount to up to $2B USD.
  - CF production could amount to 4 trillion BTUs of energy
  - Recycling CF could save 3.8 trillion BTUs of energy

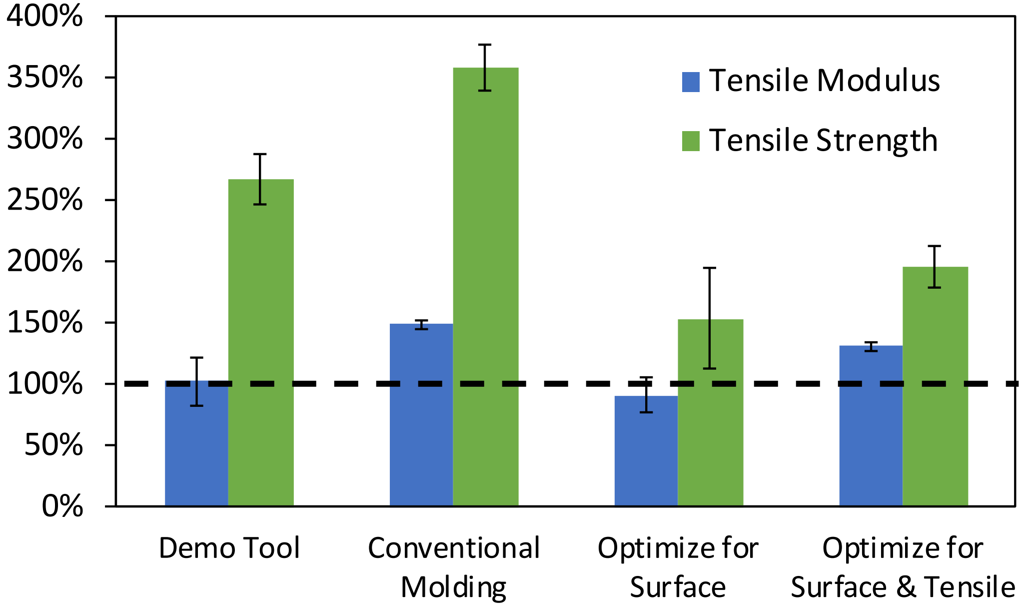
Sources: EPA 2017, Bloomberg 2020, Grand View Research 2020

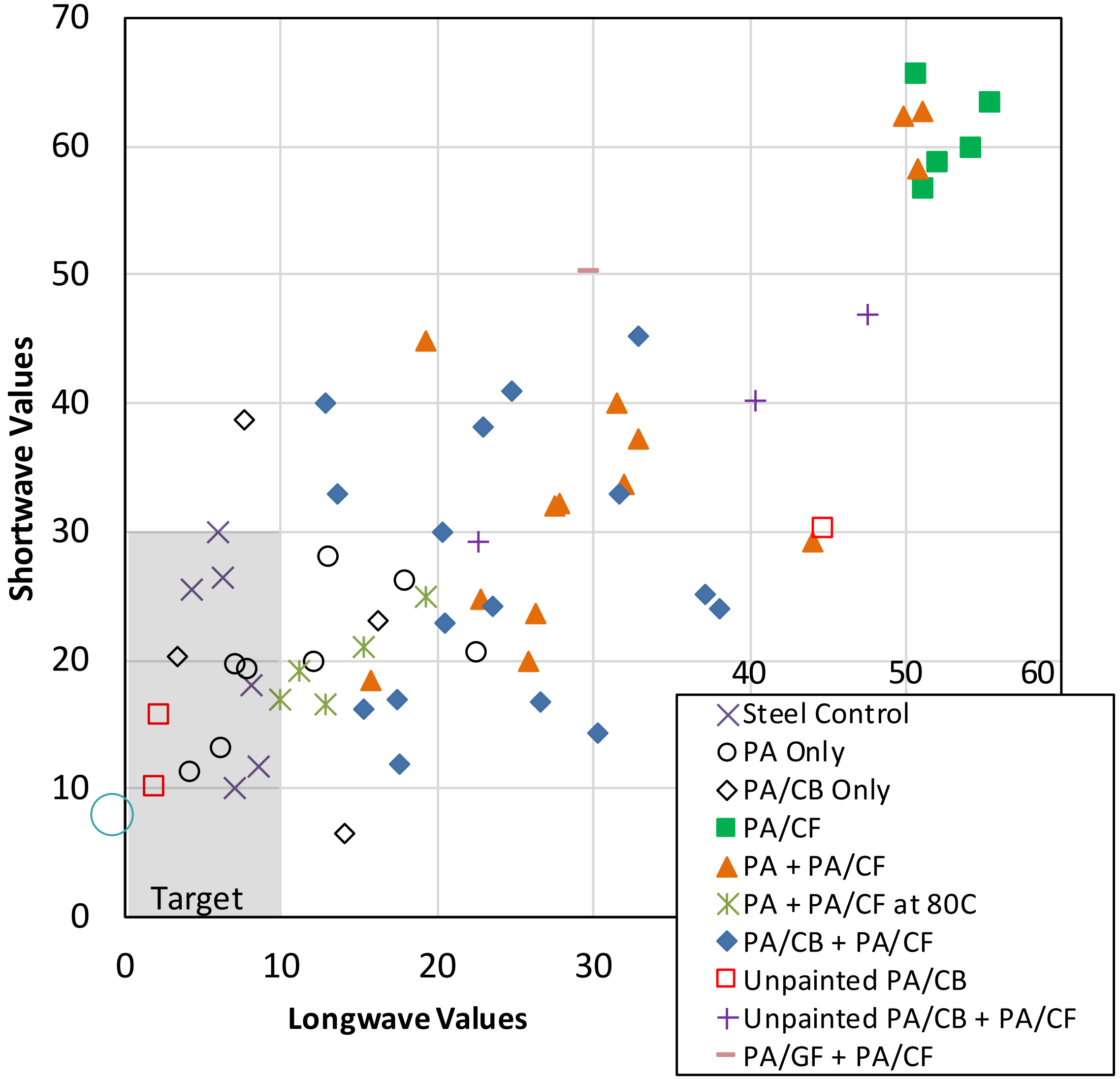
Class A Finish Automotive Part

"Develop Value Added Product"









BASF
We create chemistry

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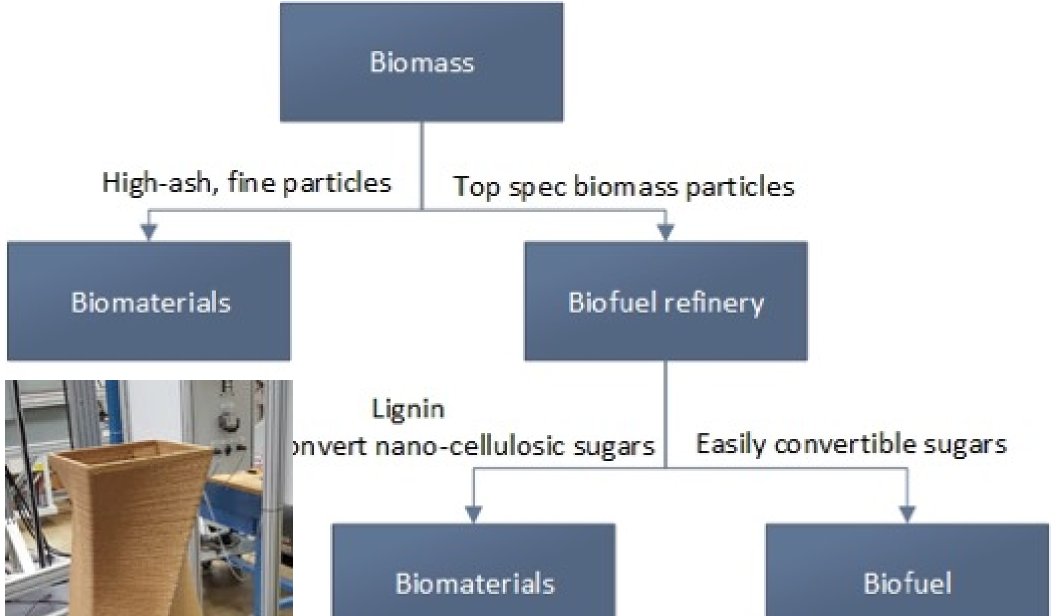
Bioderived materials offer high-impact applications for feedstock and biorefinery coproducts

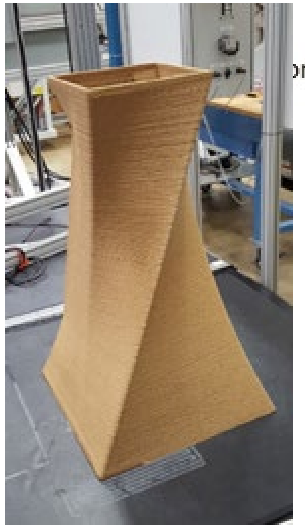
Why materials as a coproduct?

- Strong market demand from multiple industries
- High-volume and high-value markets
- Need for alternative to petroleum derived plastics
- Sequester carbon in long-term products



Research questions:

1. Is biomass a suitable replacement for carbon fiber in bioderived composites for large-scale 3D printing?
2. Can we design integrated biomass supply chains for fuels and materials to reduce biofuel feedstock costs?



Poplar reinforced biocomposite

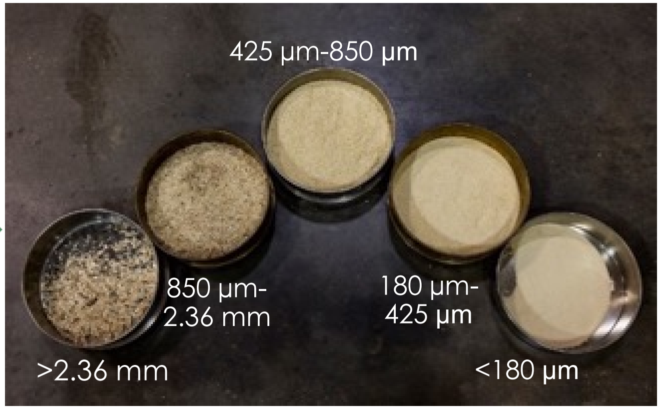
Lignin-derived polymer

Technical Approach
Biomass Preprocessing

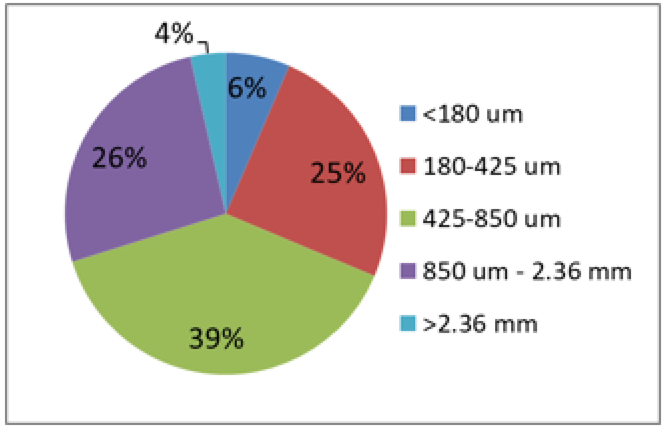
- Mechanical processing, size reduction and particle fractionation, to create feedstocks for fuels and materials
- What particle size fractions are best for materials? For biofuel conversion?

Debarked poplar logs

2-stage size reduction: chip and mill



Particle size separation by vibratory shaker



Nominal particle size for pyrolysis (NREL Design Report, 2015) = 2 mm

Which particle size is best for biomaterials?

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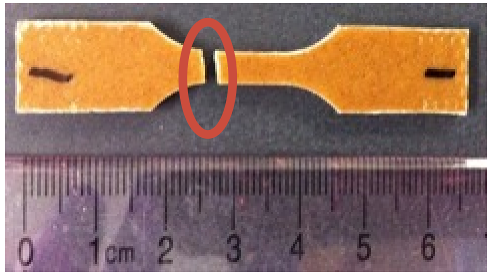
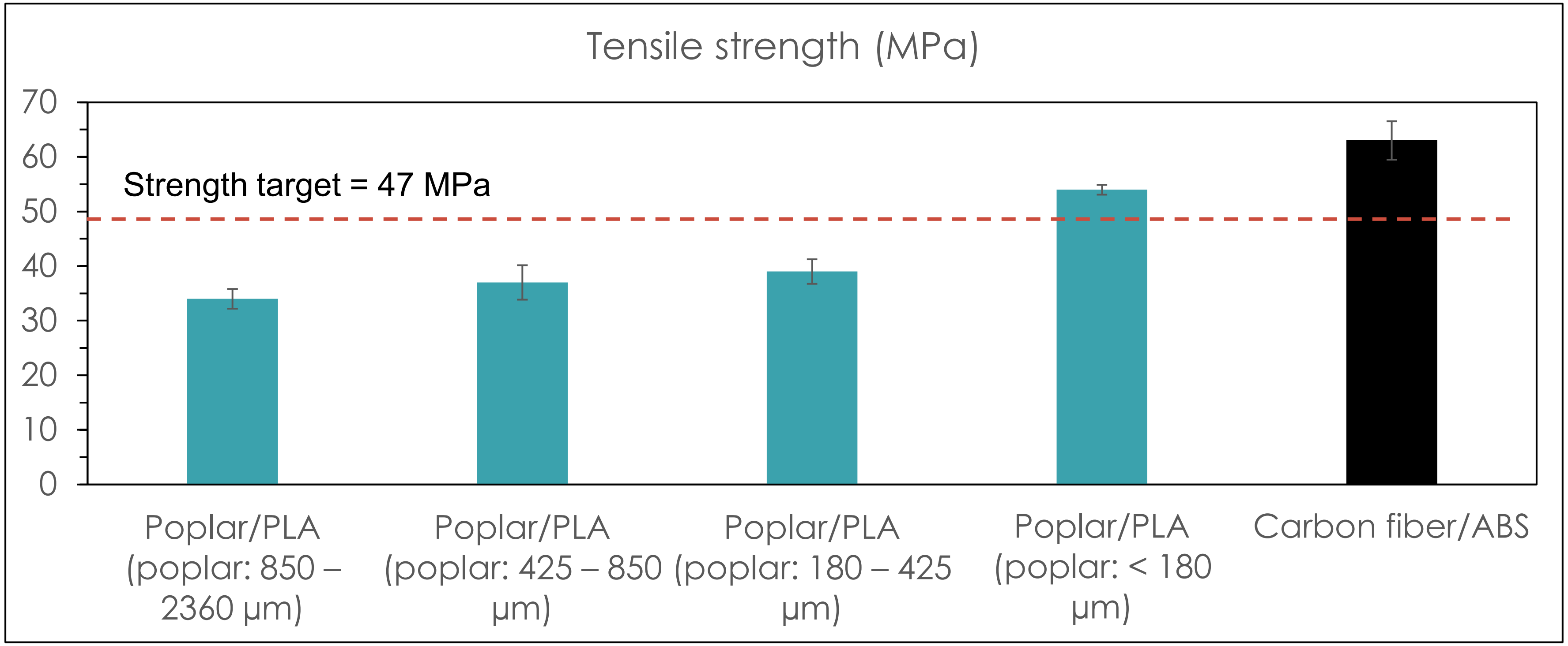
Technical Accomplishments/Progress/Results
Composite strength

- Compared composites with 20% by weight fiber reinforcement (poplar/PLA vs carbon fiber/ABS)
- Strength target (FY19 Go/No Go) is 75% of CF/ABS





ABS w/ 20% carbon fiber
~$5.5/lb

PLA w/ wood flour
~$3/lb


+


With particle size <180 µm, composite of 20% poplar and 80% PLA had tensile strength 89% of carbon fiber/ABS

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Technical Approach
Cost Analysis

- Poplar for biomaterials price target
  - Current value of CF/ABS ~ $6/lb
  - At 50% of CF/ABS, biocomposite price target = $3/lb
  - At 20% fiber fill
    - Compounding process ~ $0.65/lb
    - PLA ~ $0.80/lb
    - Leaves $1.55/lb (of composite) for fiber equivalent to $3,410 /dry ton

Poplar delivered cost

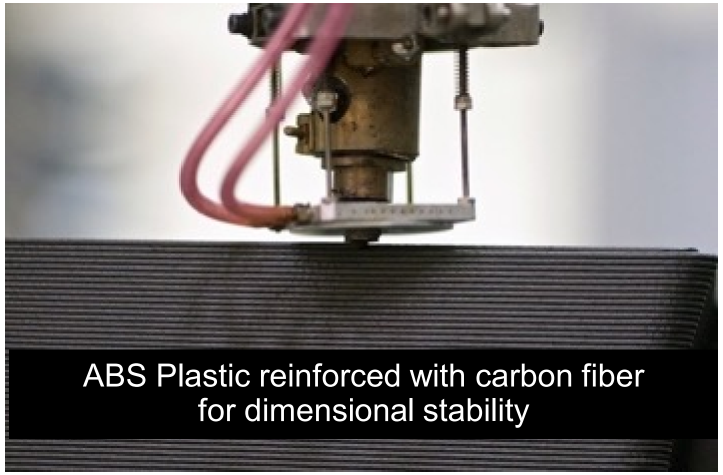
Operation	$/dry ton
Production & maintenance	100
Harvest	25
Skidding & chipping	25
Delimbing and debarking	10
Transportation	27
Hammermill	20
Particle size fractionation	10
TOTAL	217

Supply chain was designed for delivering top-quality wood.
Cost estimates are conservative.

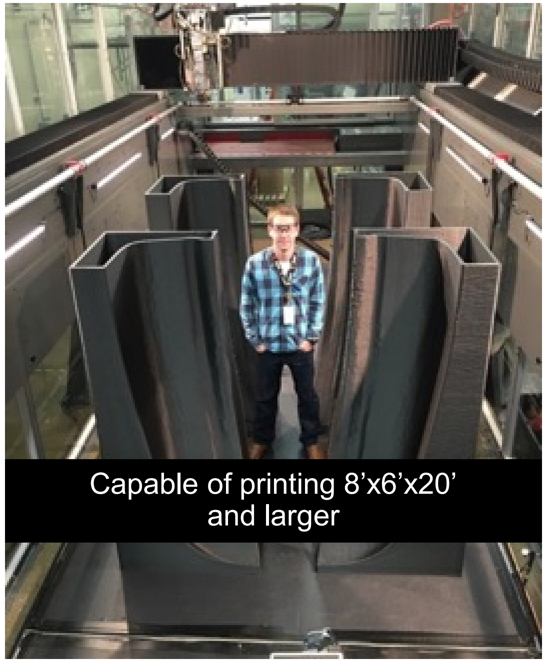
Project Overview
Large-scale polymer additive manufacturing

Bigger, faster, cheaper, smarter


Extruder attached to gantry system


ABS Plastic reinforced with carbon fiber for dimensional stability


Pelletized feed replaces filament


Capable of printing 8’x6’x20’ and larger

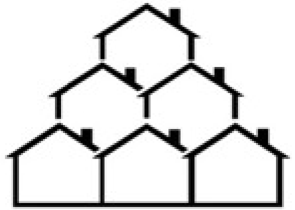
Rapid Progress in BAAM leads to

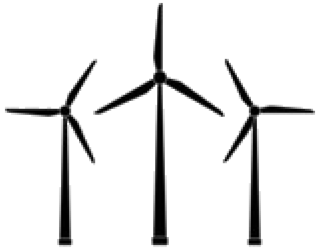
Defining the Future of AM

2010 | 2014 | 2018 | 2022

20 lb/hr

100 lb/hr





State of the Industry

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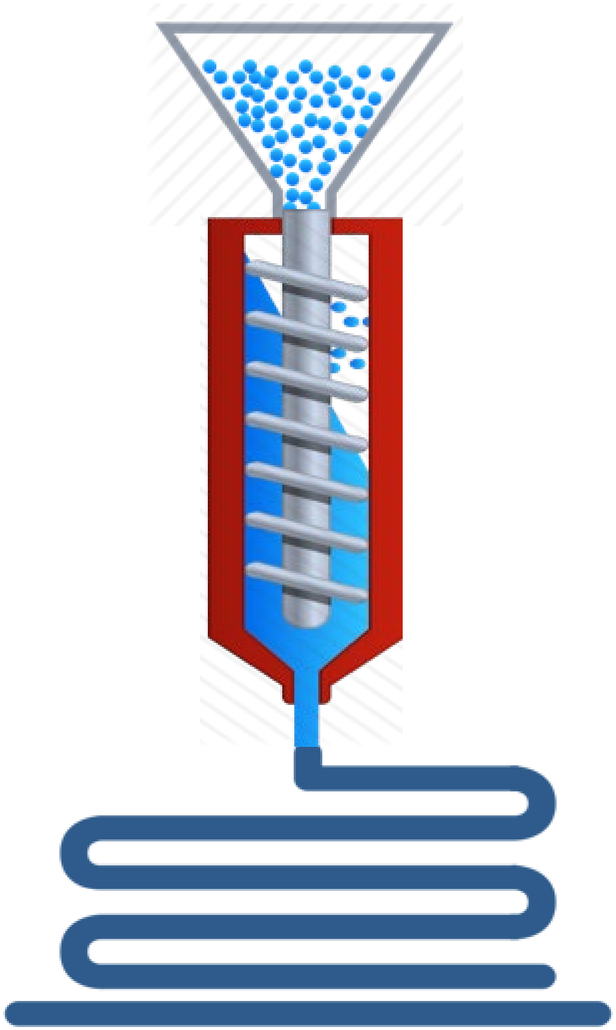
CINCINNATI

THERMWOOD

INGERSOLL



500 lb/hr +

System that can print 100ft long products

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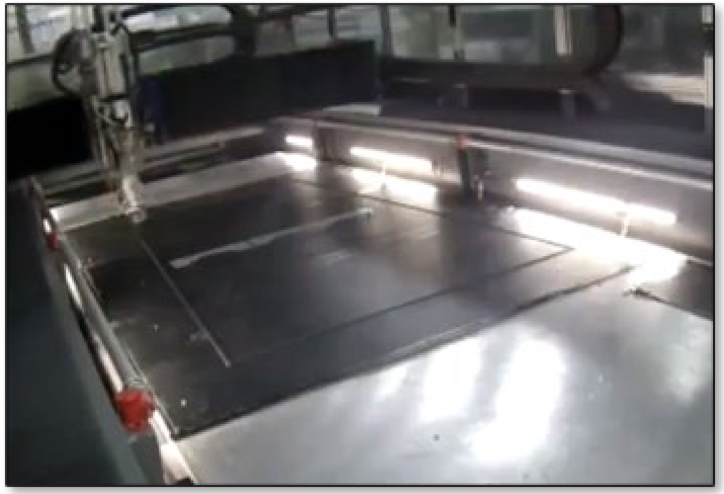
Courtesy of Autodesk and Gate Precast

New Mold Manufacturing Process

3D Printing



Machining

Mold

Casting setup

Concrete casting

Precast parts

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ORNL/MDF - Gate Pre Cast - AES joint project

More Economical Printing Materials

ABS w/ 20% carbon fiber

~$5.5/lb

PLA w/ wood flour

~$3/lb

+

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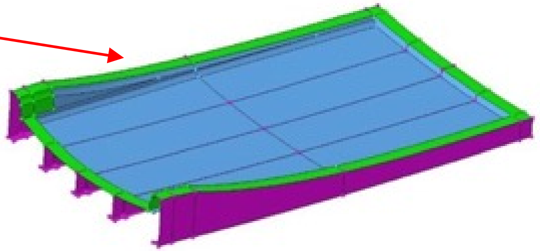
3D printed tool from Bio-based Materials

Hodgdon Boats 10.5m (35ft) Limo Roof Mold:
Roof : 12.3 m^2
6” Vacuum Flange : 2.3 m^2
Support Structure : 7.3 m^3

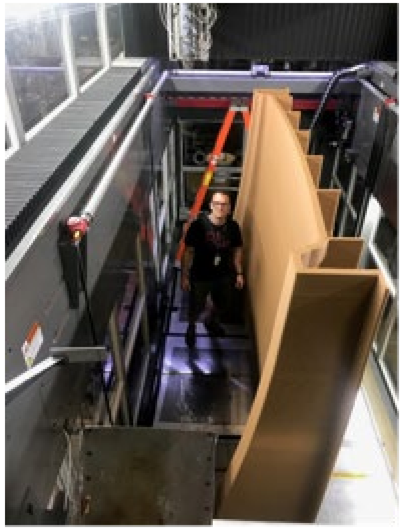
THE HINCKLEY COMPANY

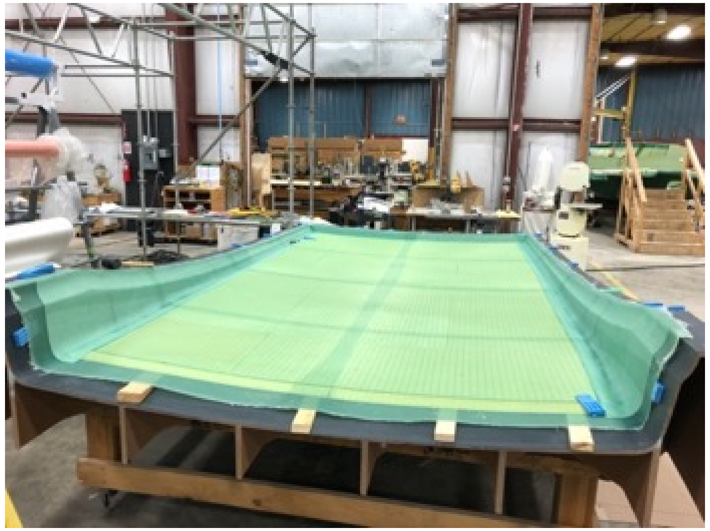
SABRE Yachts

HODGDON YACHT SERVICES



16’ x 8’, approx. 1200lb material





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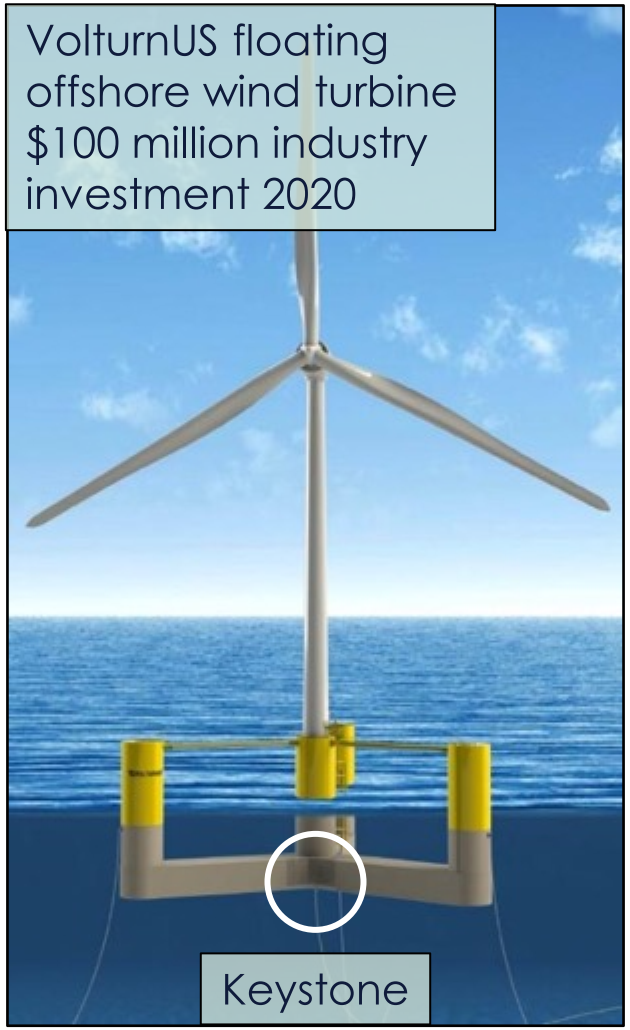
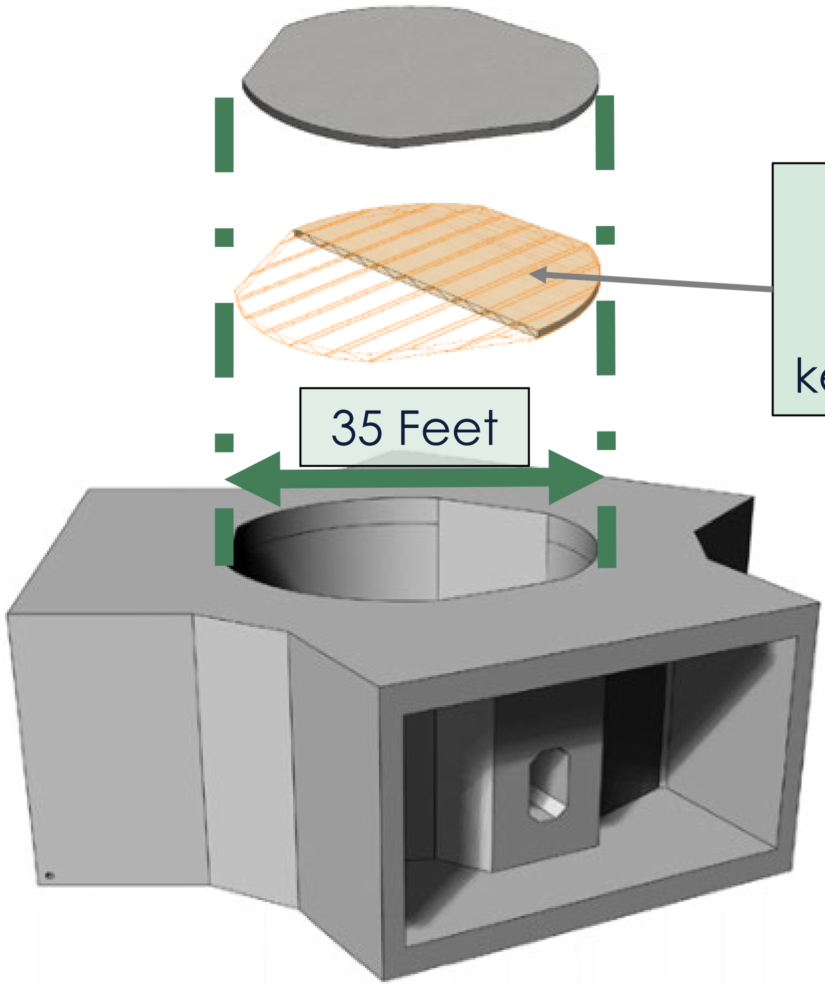
3D Printing Offshore Wind Components



Full Scale Design



Formwork supports concrete keystone cap

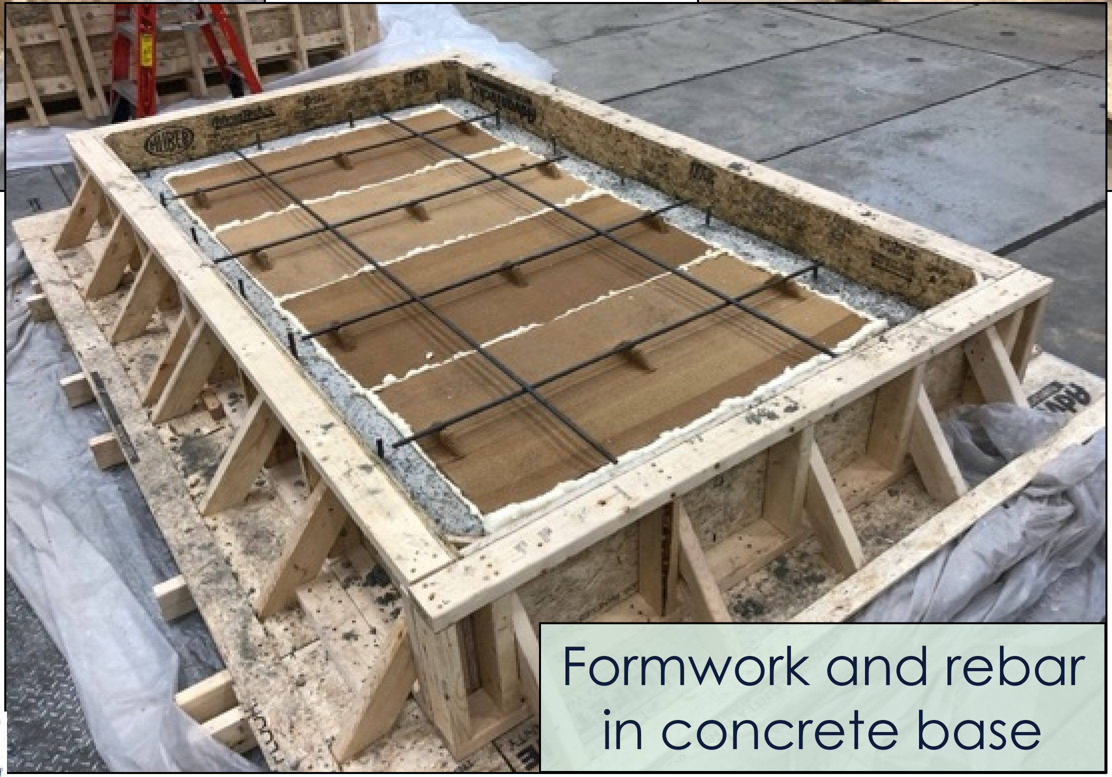
Test Scale Design

Oak Ridge National Laboratory | Manufacturing Demonstration Facility | The University of Maine

3D Printing Offshore Wind Components


Concrete base


Final concrete "keystone"

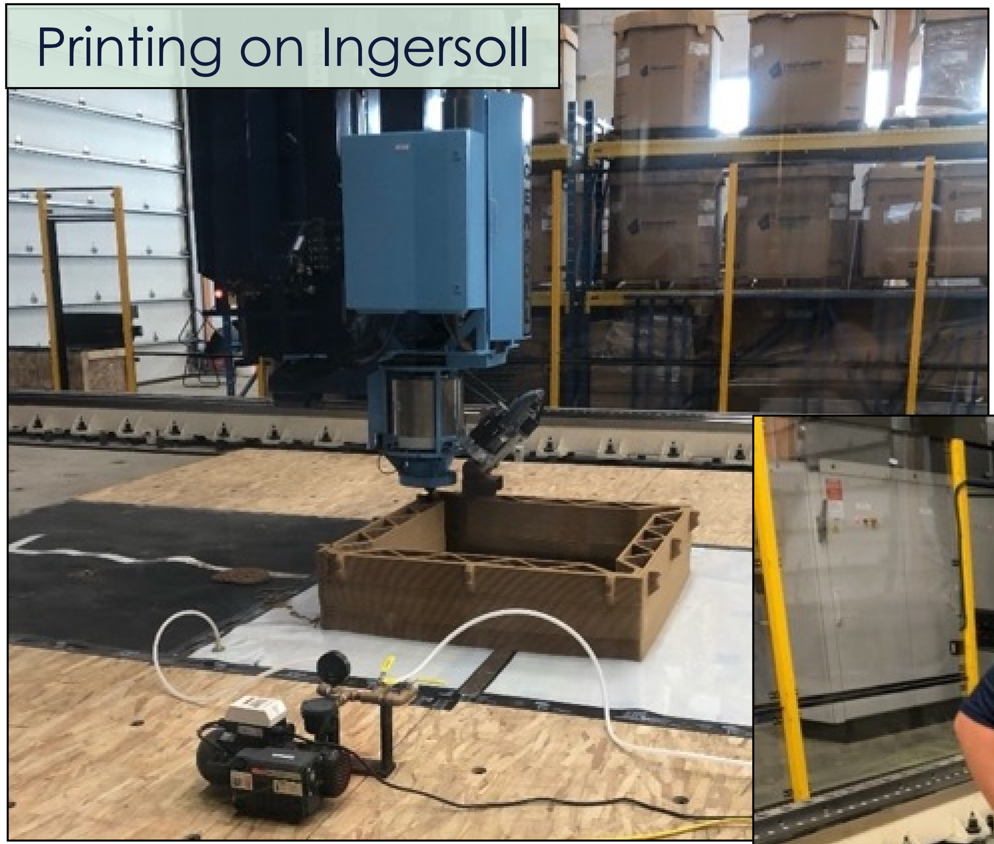

Formwork and rebar in concrete base

Printing stay-in-place formwork presents a **26.7%** cost saving considering material, time, labor, etc.

This formwork eliminates a 1.75" deflection as compared to traditional formwork. This represents a **14.6%** saving in concrete usage.

Indirect & Direct Applications

Stay-in-place concrete formwork for offshore wind turbine keystone

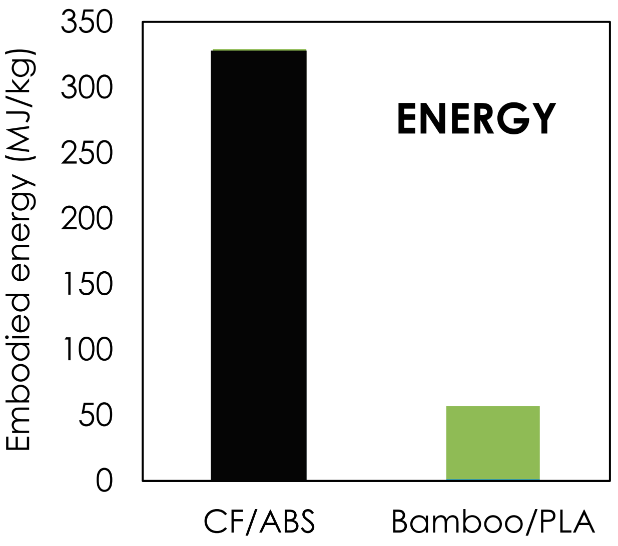


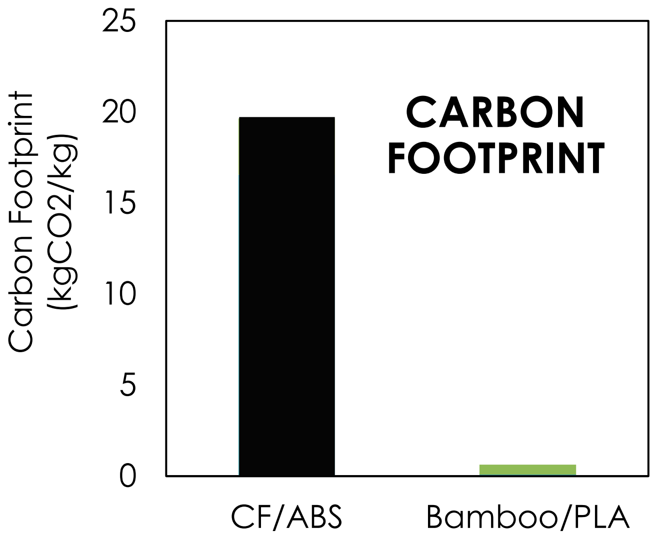
Printing on Ingersoll

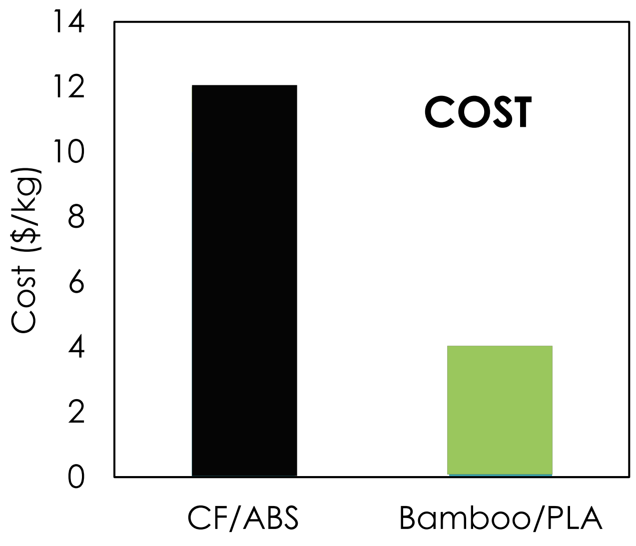
Printed part with operator

Cut and laid formwork parts

3D Printing Sustainable Structures





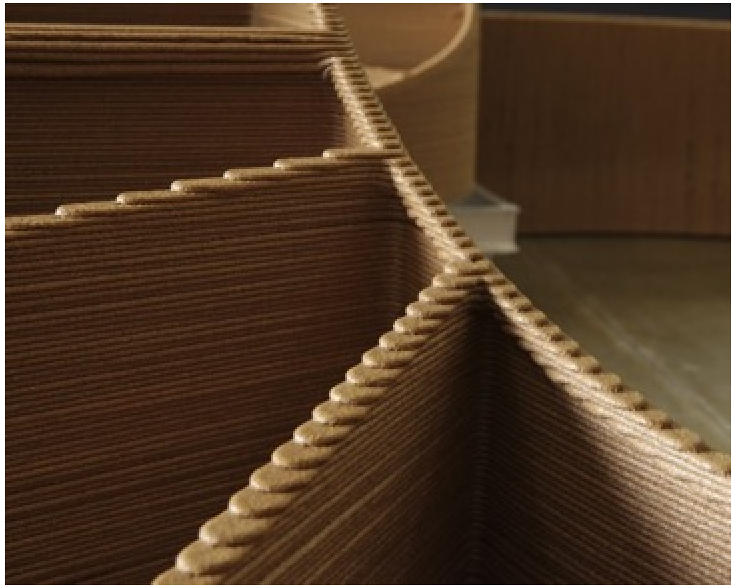


University of Nairobi

Design Miami Show

Concluding Remarks

- There are opportunities to develop low-cost, sustainable diverse material selection for large-scale 3D printing for applications that do not require the full strength of carbon fiber/ABS
- a new, high-value feedstock coproduct stream that reduces biofuel costs by sharing feedstock supply chain resources and costs with biofuel feedstocks
- Biomass for bio-derived materials can complement biofuel feedstock supply chains



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Acknowledgement

U.S. DEPARTMENT OF ENERGY | Office of ENERGY EFFICIENCY & RENEWABLE ENERGY

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