

Recycling of Turbine Blades

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Nebraska
Wind & Solar
CONFERENCE & EXHIBITION



ADVANCED
4 SOLUTIONS

Challenge the Impossible

www.a4solutionsinc.com

OUR MISSION



Change the world by turning today's
wind turbine blade waste into
tomorrow's **NEW** products.

OUR COMPANY

Advanced 4 Solutions, Inc. is a vertically integrated **manufacturing company** that generates its raw material feedstock through the **recycling** of wind turbine blades and other hard to recycle materials.

Founded: June 2021 (incorporated in the State of Delaware)

Corporate Office: Oklahoma City, OK

Manufacturing & Recycling Plant: Woodward, OK



WOODWARD PLANT FACILITIES

Building 1 (119,000sqft)

- Plant Offices, Engineering, R&D Lab
- Recycling/Recovered Material Storage
- Manufacturing
 - Production
 - Finished Goods
- Finished Goods Inventory

Building 2 (14,300sqft)

- Field Service Equip Maintenance



A4S Woodward Plant consists of 80 acres of plant grounds with access to 40 additional acres.





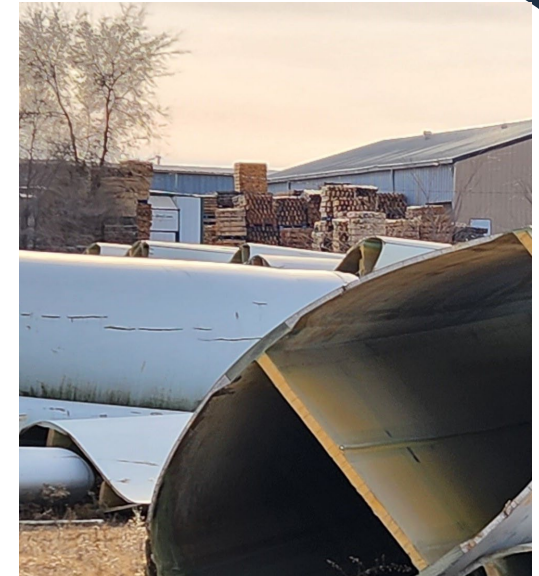
THE PROBLEM

Up to 818,000 tons of additional wind turbine blade waste within next 10 years.

EoL wind turbine blades are difficult to recycle and not considered cost effective to do so.

Current “solutions” are focused on recycling only, with limited marketable off-takes.

Result – blades are being stockpiled for years at recycling facilities, waiting to find off-take solutions.





THE SOLUTION

Is it possible to turn this...



into these?



A4S CIRCULAR SOLUTIONS SYSTEM

Combining vertical integration strategies with circular economy principles

**Field
Services**

*Onsite Blade
Cutting & Removal*

**Recycle &
Recover**

*Fiber and Chemical
Compound Recovery*

**Product
Manufacturing**

*Unlimited Product
Off-Takes*

Research & Development

*Advancement of:
Materials Products Processes Equipment*



FIELD SERVICES

A4S Field Service crews are dispatched to customer location to cut, load and transport blades and nacelle housings back to the A4S recycling plant. A4S utilizes a dustless cutting and containment system, and a final clean up and inspection is completed prior to leaving jobsite.



1

Blades are cut into sections on location



2

Blade sections are tagged & scanned into material tracking system



3

Tagged blade sections are loaded & transported to A4S Woodward Recycling Facility



A4S GUARANTEE: No material collected by A4S will be LANDFILLED



RECYCLING SERVICES

FIBER & CHEMICAL COMPOUND RECOVERY

A4S Pressure Assisted Chemical Solvolysis (PACS):

The Process

The PACS recycling system breaks down the resin to separate and free fibers and matting from composite matrix allowing the recovery of clean, high quality, glass fiber and carbon fiber.

The Results

Recovered fiber material properties equivalent to virgin fiber and suitable for reuse in FRC product manufacturing

Mild chemical solution is recoverable and reusable

Recovered chemical compounds from resins can be used in the production of new chemical compounds used in numerous applications and industries



MANUFACTURING SERVICES

Recovered glass fiber, carbon fiber, and chemical compounds are used in the production of new fiber-reinforced composite components and finished goods.

Thermosets &
Thermoplastics

Open & Closed
Mold Processes

Unlimited
Product Options

Product Capability Examples:

Fiberglass Products

Pickup truck toppers



Enclosed Trailers



Composite Products

Grating & Platforms



Fencing, decking,
outdoor structures



RESEARCH & DEVELOPMENT



Advancement of Recycled Fiber Material Properties

New Composite Materials Discoveries

Advanced Recycling Technology Processes

Develop (patent) Proprietary Equipment & Processes

Academic & Institutional Partnerships



OUR CUSTOMERS

FIELD SERVICES & RECYCLING

Wind Farm Operators – Blade Owners

OEM Companies

Service & Project Management Companies

Other - Companies that generate FRC waste material



MANUFACTURING

Private Branding Companies

Product Wholesalers – Distributors - Retailers

Raw Material Wholesalers

Industries include

Automotive

Aerospace

Agriculture

Construction

Marine

Medical

Home & Garden

Recreation - Outdoor Adventure



A NEED FOR ACCOUNTABILITY

Land Fills and Blade Graveyards are not the Answer

Oklahoma Legislature Passed HB 2359 in 2023

**Recyclers Required to Have Evidence of Financial Security-
125% of Total Cost to Recycle**

Annual Report Submitted to Oklahoma Corporation Commission

Associated Fees & Fines

**Necessary Guardrails to Deter Bad Actors from Overpromising
& Under Delivering**





LET'S CHANGE THE WORLD
TOGETHER



Challenge the Impossible

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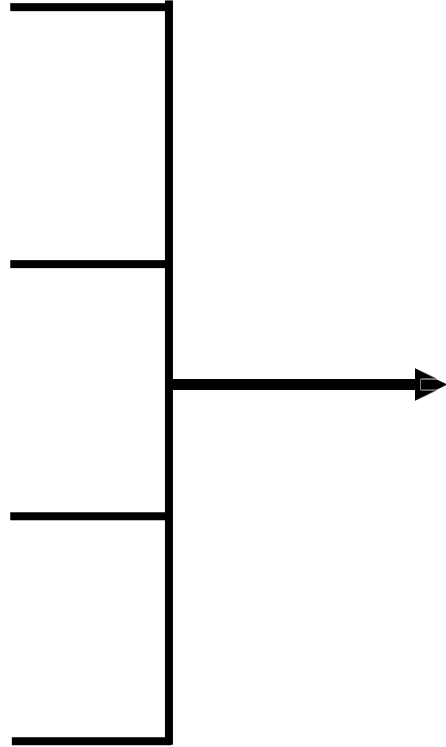
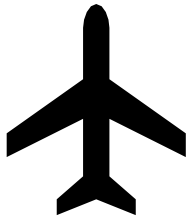
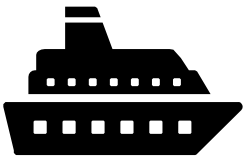
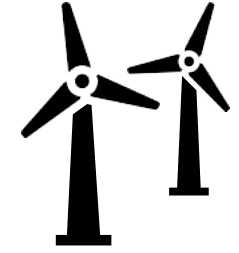


**THE WORLD LEADER IN FIBERGLASS
COMPOSITES UPCYCLING SOLUTIONS**

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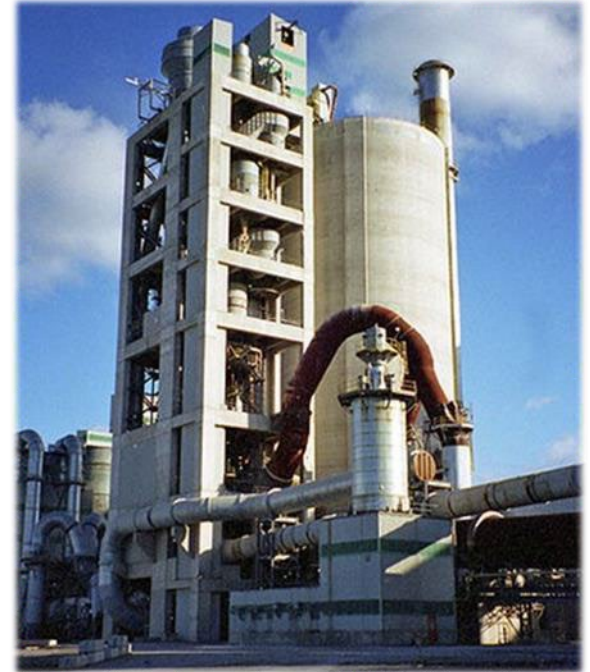
UNAUTHORIZED DISTRIBUTION OR REPRODUCTION PROHIBITED WITHOUT EXPLICIT PERMISSION FROM CARBON RIVERS INC

STATUS QUO: WHAT HAPPENS AT END-OF-LIFE?



Landfill

OR



Cement kiln incineration

~100,000 tons/year
by 2030

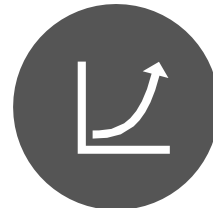
**No current market option offers true, sustainable recycling for composites.*



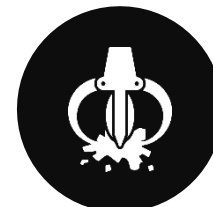
WASTE IS NOT THEIR ONLY PROBLEM. SO IS SUPPLY.



Global glass fiber capacity was 12.9 billion pounds in 2021 with factory utilization rate climbing from 85% in 2020 to 91% in 2021 and expected to reach 95% in 2022. With demand growth in all end use industries, there is a clear need for increased fiberglass production.



For example, the Center for Automotive Research projects a ~67% increase in plastics/composites used for average vehicle structures (body-in-white & closures) by curb weight by 2040. The US fiberglass market for marine grew by 18% in 2021. Meanwhile in wind energy, S&P Global Market Intelligence estimates 27 GW of wind energy to come online in 2022 smashing 2020's previous record of 16 GW and continuing to grow each year.



Our own searching around production scrap has begun to anecdotally support this with some Tier 2 level manufacturers having significantly less scrap than originally anticipated due to factory idling from lack of raw materials / supply chain issues.

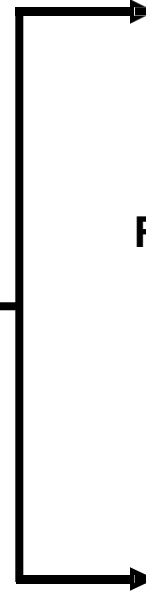
THE G2G SOLUTION: PYROLYSIS-BASED RECYCLING



End-of-Life Waste & Production Scrap



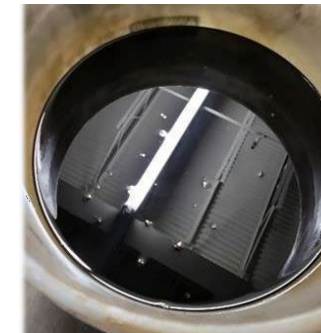
Composites Recycling



Reclaimed Fiberglass



Return to Composites Supply Chain



Fuels & Petrochemicals



Return to Oil & Gas Supply Chain

EXAMPLE REINFORCED PLASTIC PRODUCTS WE ALREADY RECYCLE



AUTOMOTIVE PARTS



WIND TURBINE BLADES



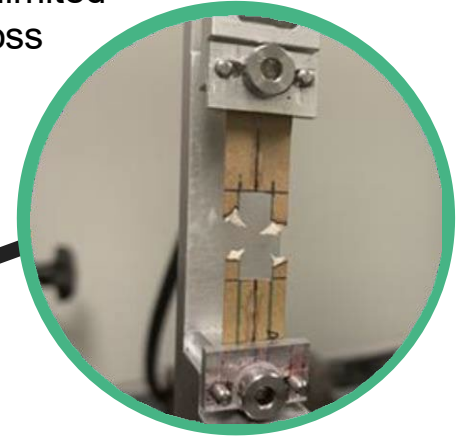
COMPOSITE WINDOW PARTS



Purity greater than 99.9%



Fiber degradation limited to ~10-15% loss



Carbon negative process crediting glass and oil for EE and GHG



****Fiberglass recycled from composites can now be upcycled into new composites for a true domestic circular materials economy.***

POTENTIAL SELLABLE PRODUCTS WE HAVE DEMONSTRATED



RAW STAPLE FIBER



- Est. Market Size: \$13.2 Billion USD
- Fiber can be sold as-is with lengths +2" to 1/2" for fabric/textile applications
- Glass can also be milled for thermoplastic compounding or remelt

NONWOVEN FABRICS



- Est. Market Size: \$1.3 Billion USD
- Can be pure fiberglass or comingled with thermoplastic (or other) fibers for automotive, marine, wind, etc. applications
- Can do heavier mats at 100-400gsm or veils ~30-50gsm

COMPOUND PLASTICS



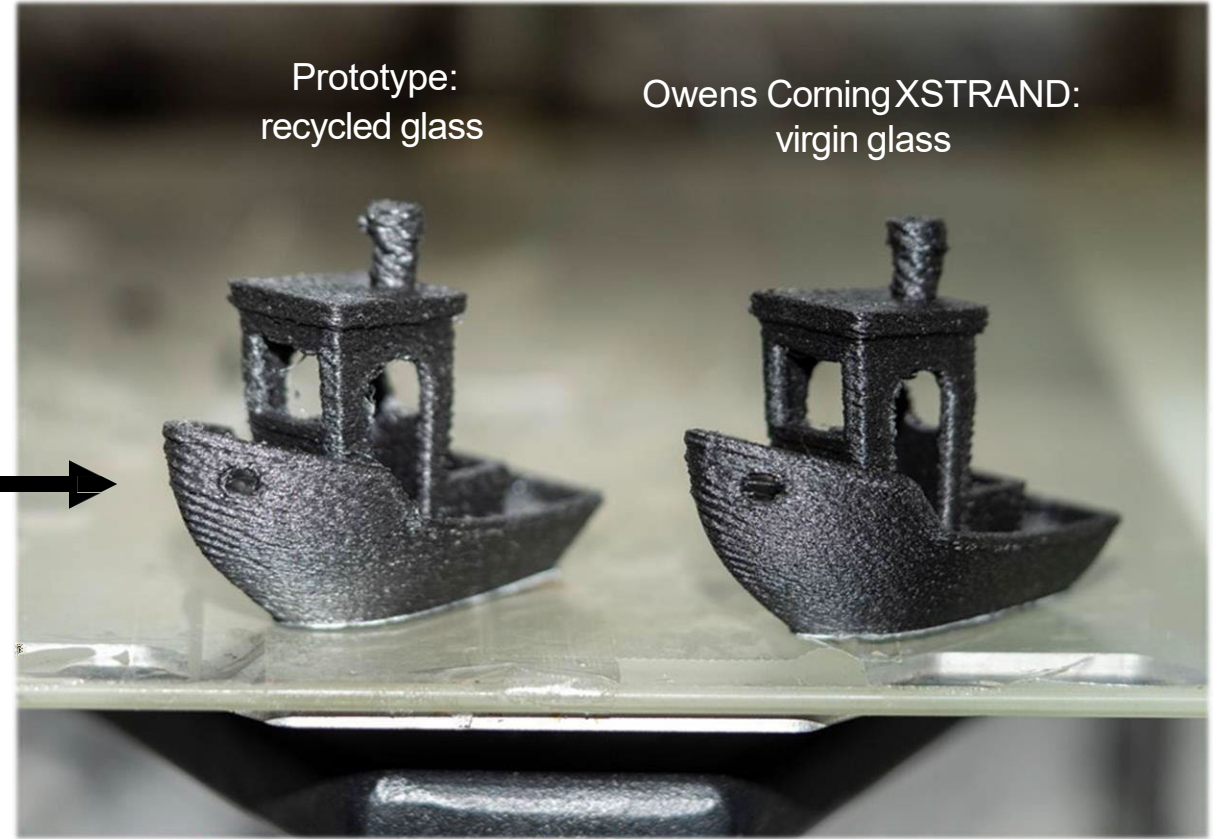
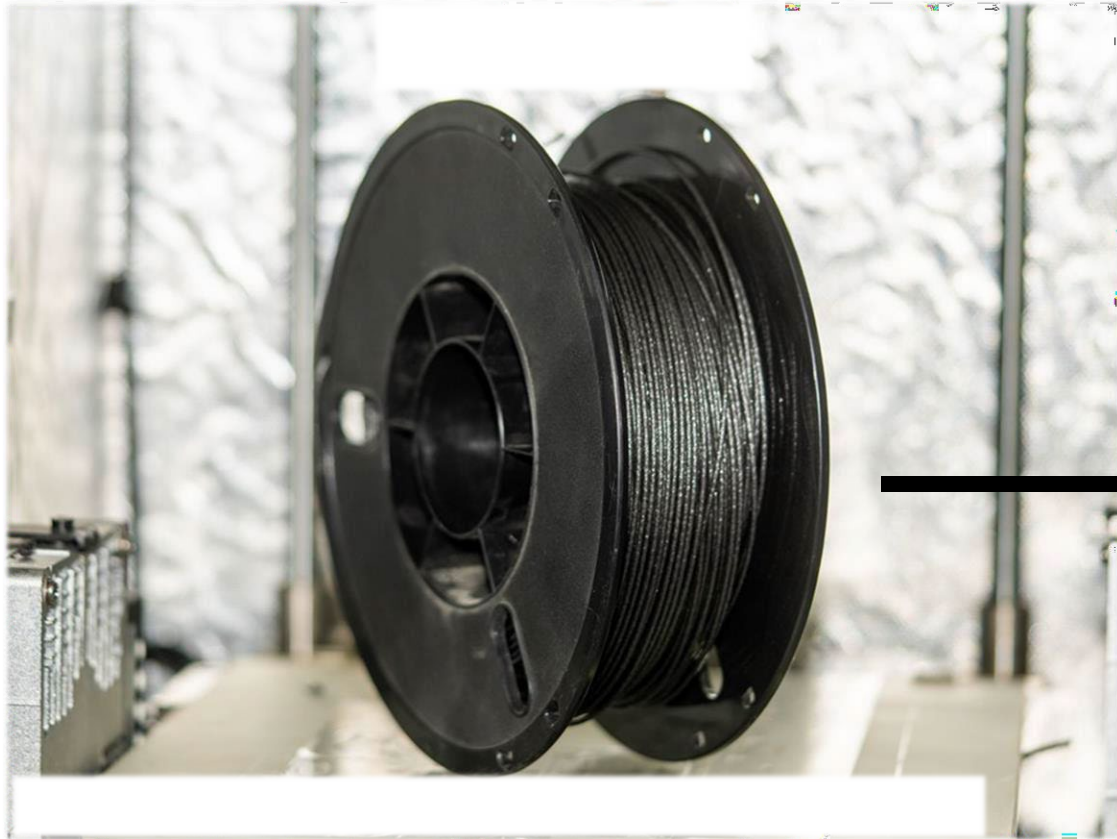
- Est. Market Size: \$24.1 Billion USD
- Able to compound fiber with common plastics such as polypropylene and nylon for AM or injection molding
- Currently able to compound up to 30wt% fiber loadings with existing equipment

ADDITIVE MANUFACTURING FILAMENT MADE WITH RECYCLED FIBERGLASS

ON THE REEL



PRINTING COMPARISON



** rGF/Polypropylene prototype AM filament*

**Thanks to our process and the power of 3D printing, wind blade waste can now become almost anything.*



Thermoplastic Materials

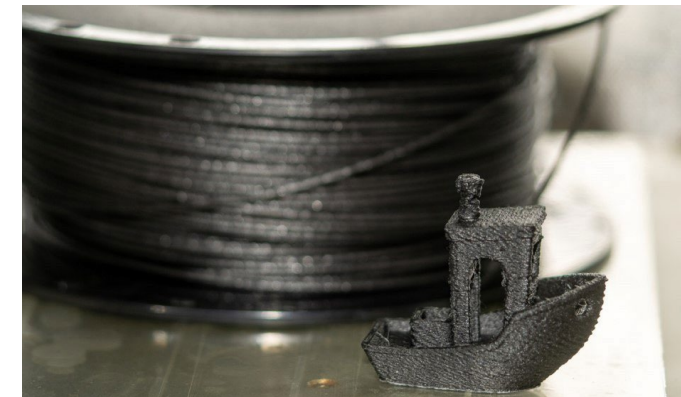
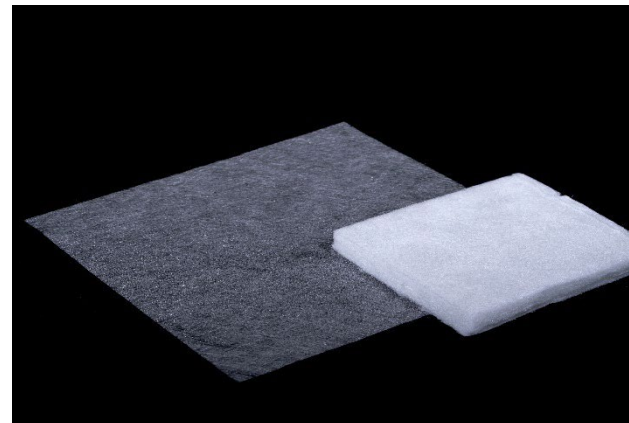
Carbon Rivers has Experience Using Graphene in the Following Materials

- Polypropylene
- ABS
- HDPE
- PA 6
- Ultem 1010
- PPS
- PPSU
- PEEK



Carbon Rivers has Experience Using The Following Processes

- Extrusion Compounding (Twin and Single)
- Injection Molding
- 3D Printing (FDM) - Graphene Coated Filaments Lead to Improved Print Strength



FIRST 200MT FACTORY



PLANNED 200 TPD PLANT IN KINGSTON, TN

- Deploy first 20 ton per day (tpd) recycling line followed by nine more in parallel.
- Secure 400-acre DOE site for factory (trimodal: existing road, rail, & barge access).
- Facility can receive 55,000+ metric tons per year and yield 25,000+ metric tons per year.
- The facility provides an ESG circular economy for the wind, automotive, and building material industries.
- 2024-25 additional facilities planned for TX, IA, PA, ID, NV, and UK / EU.



ESTIMATED GLOBAL MARKET NEED FOR RECYCLING



NORTH AMERICA

(based on 2019 numbers)



55 plants required

EUROPE

(based on 2018 numbers)



40 plants required

ASIA

(based on 2019 numbers)



95 plants required

Estimated Global Number of Recycling Plants Needed:

~200 plants (200 tpd plant size)



UPCYCLING TODAY'S WASTE FOR TOMORROW'S FUTURE

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