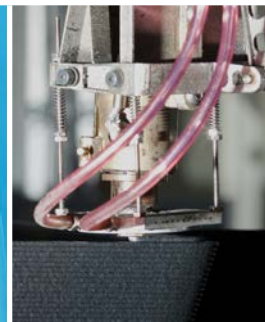




# TRANSFORMING WIND TURBINE BLADE MOLD MANUFACTURING WITH 3D PRINTING



U.S. DEPARTMENT OF  
**ENERGY**

Energy Efficiency &  
Renewable Energy



# WIND POWER

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## **THE FASTEST GROWING FORM OF RENEWABLE ENERGY IN THE UNITED STATES**

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Wind energy provides nearly 5% of the nation's total electricity generation. In 2015 alone, the wind industry generated enough electricity to power 17.5 million average U.S. homes and saved the equivalent of 131.7 metric tons of carbon dioxide. With an increase in generation, the wind industry must meet the challenges of a growing sector. Larger wind turbine blades and more efficient wind farm configurations set the stage for industrial innovation and advancements. Collaboration between the public and private sectors provide a forum for addressing these challenges and opportunities for the future of wind power.

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The U.S. Department of Energy's (DOE's) Office of Energy Efficiency and Renewable Energy (EERE) plays a strategic role in promoting clean energy by increasing our nation's competitiveness through manufacturing clean energy technologies. Investments in the research, development, and deployment of cross-cutting platform technologies have the ability to revolutionize the delivery of clean energy. Wind deployment can provide U.S. jobs, U.S. manufacturing, and lease and tax revenues in local communities to strengthen and support a transition of the nation's electricity sector toward a low-carbon economy.

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## **WORKING TOGETHER TO BUILD A FASTER AND LEANER FUTURE FOR WIND TURBINE BLADE MANUFACTURING**

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Innovation in the design and manufacturing of wind power generation components continues to be critical to achieving our national goals. As a result of this challenge, DOE's Wind Program and Advanced Manufacturing Office (AMO), both within EERE, are partnering with public and private organizations to apply additive manufacturing, commonly known as 3D printing, to the production of wind turbine blade molds. The traditional method of blade design requires the creation of a plug, or a full-size representation of the final blade, which is then used to make the mold. Creating the plug is one of the most time-intensive and labor-intensive processes in wind blade construction, so 3D printing saves these critical resources.

Specific aerodynamic research on wind turbine rotor wakes, funded by the Wind Program, calls for custom blades outfitted with special sensors. These special blades would require a unique plug, mold, and tooling design,

which would be expensive. AMO's existing expertise in additive manufacturing made the Wind Program's perfect partner to develop an innovative solution for manufacturing the research blade mold. By 3D printing the mold, it eliminates the need for a plug and provides the opportunity to pioneer innovative design features, such as air heating through built-in ductwork instead of hand-laid heating wires embedded in the mold. Furthermore, this project engages Oak Ridge National Laboratory's (ORNL) Big Area Additive Manufacturing (BAAM) system. BAAM is 500 to 1,000 times faster and capable of printing polymer components over 10 times larger than today's industrial additive machines. With research blades measuring 13 meters (42 feet) in length, BAAM provides the necessary scale and foundation for this ground-breaking advancement in blade research and manufacturing.





DOE works with wind technology suppliers to promote advanced manufacturing capabilities. Goals include increasing reliability while lowering production costs and promoting an industry able to meet domestic manufacturing demands while competing globally.

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The U.S. wind market has grown substantially over the years, creating a robust supply chain. Numerous facilities across the country specialize in blades, towers, generators, and turbine assembly. In fact, modern wind turbines are increasingly cost effective, reliable, and have scaled up in size to multi-megawatt power ratings. Moreover, as wind plants grow in size, rotor wake research has become critical for power generation efficiency.

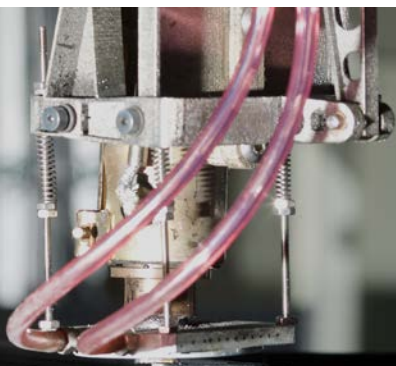
## 1 CHALLENGE

With a rapidly changing world economy and a need to increase the nation's competitiveness in the manufacturing of clean energy technologies through research into new, more efficient technologies, the traditional blade manufacturing sector must strive forward with advanced innovation. For the wind industry, 3D printing could transform turbine blade mold manufacturing, making it faster and leaner than ever before.

## 2 OPPORTUNITY

Trends toward larger wind turbine blades—which currently average over 45 meters in length—and our drive for global competitiveness are inspiring us to explore new manufacturing technologies. Additive manufacturing promises to lower costs and enable innovative blade designs that will push the limits of energy production.

*An up close view of the BAAM nozzle layering carbon fiber composite material.*



## PROJECT GOALS AND OBJECTIVES

- Demonstrate the utility of BAAM as a platform technology for renewable energy systems.
- Explore innovation that leads to reduced costs in wind blade manufacturing.
- Increase U.S. manufacturing competitiveness through innovative applications that advance clean energy technologies.



### 3 COLLABORATION

Public-private partnerships accelerate development and collaboration among EERE's Wind Program, Advanced Manufacturing Office, Oak Ridge National Laboratory, Sandia National Laboratories, and TPI Composites. This partnership applies individual strengths to create a 3D printed blade mold, which will have far-reaching benefits for the entire industry.

### 4 INNOVATION

The blade mold was built by the Big Area Additive Manufacturing machine (BAAM). BAAM is not only faster than traditional manufacturing methods, but it is also 500 to 1,000 times faster than other industrial additive machines.

### 5 IMPACT

Success will enable the rapid development of innovative, more efficient blade designs that can be built using a cost-effective 3D printed manufacturing process. This innovation will open new opportunities in the United States for growth in the rapid, low-cost manufacturing of large composite structures in industries beyond wind. In fact, any industry that requires large composite structures—marine, transportation, and petroleum to name a few—could benefit from this groundbreaking technology.

## ADVANCING MANUFACTURING AND CLEAN ENERGY—TOGETHER

The new innovative wind blade mold will be used to create four research wind blades. Three blades will be flown on a test turbine at the Scaled Wind Farm Technology (SWiFT) facility at Texas Tech University, while a fourth blade will be utilized for static testing at the National Renewable Energy Laboratory (NREL) with results expected in late summer 2016.

The revolutionary 3D-printed blade mold research will provide information necessary to build a new, fast, and, cost-effective way to make large wind energy components and investigate wind farm power generation efficiency. Not only will the project investigate the rejuvenation of U.S. manufacturing through ground-breaking innovation but also potentially increase the deployment of wind power nationwide—and provide more clean, affordable, reliable and domestic energy for the United States.

DOE is leading our nation toward a clean energy future and increasing industry competitiveness through research, development, and deployment of innovative technologies such as 3D printing.

## WHAT IS 3D PRINTING?

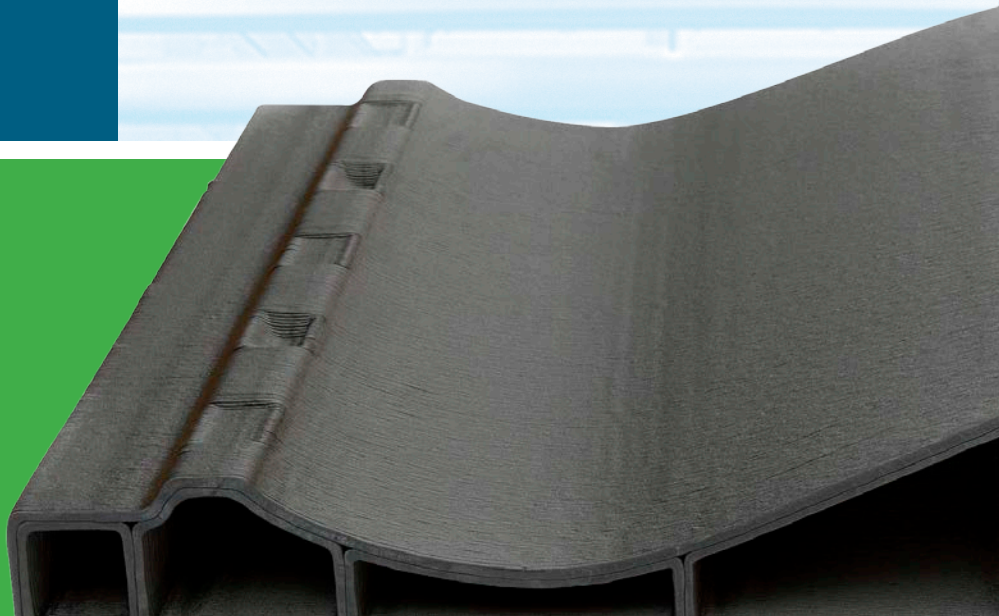
3D printing, or additive manufacturing, is the process of producing a three-dimensional, solid object from a digital file.

A 3D printer layers molten carbon fiber material into the computerized shape—a process that offers improved design flexibility, decreased energy consumption, and reduced time to market.

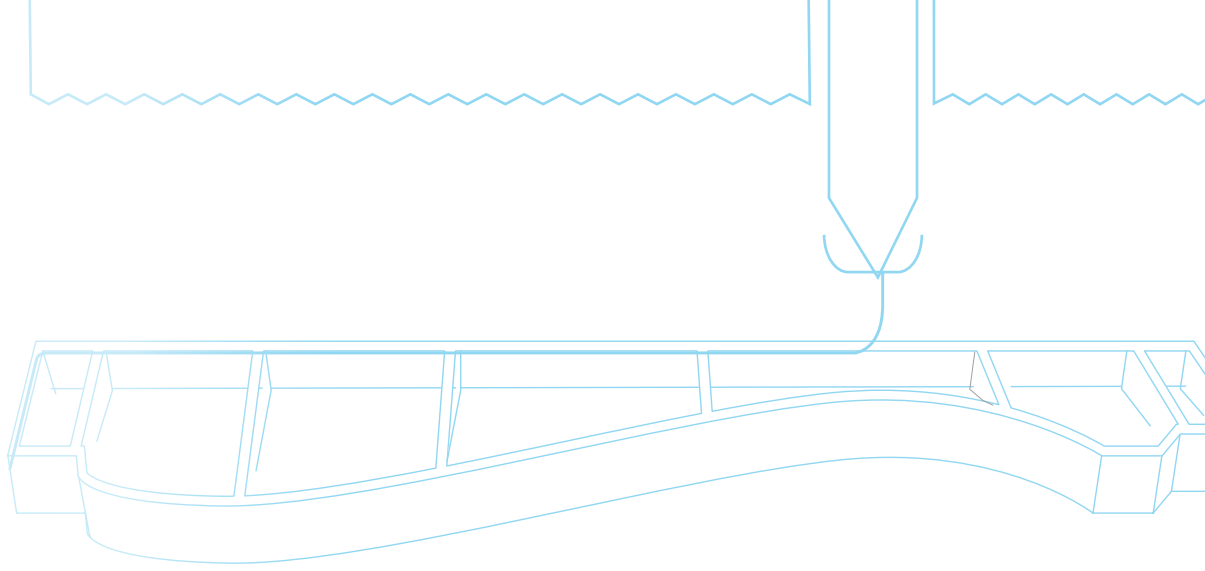
## INNOVATIVE NEW PROCESS USES 3D PRINTING TO CREATE MOLDS

1. The mold is designed using computer-aided design (CAD) and a file is generated for BAAM to follow.
2. BAAM layers the carbon fiber composite material into the mold shape based on the design. This process occurs for each piece of the mold.
3. A layer of fiberglass is applied on top of the mold, and excess material is machined off to achieve the desired shape and smoothness.
4. Heating duct work is installed and the mold pieces are assembled together.
5. The research blades are produced from the completed mold.

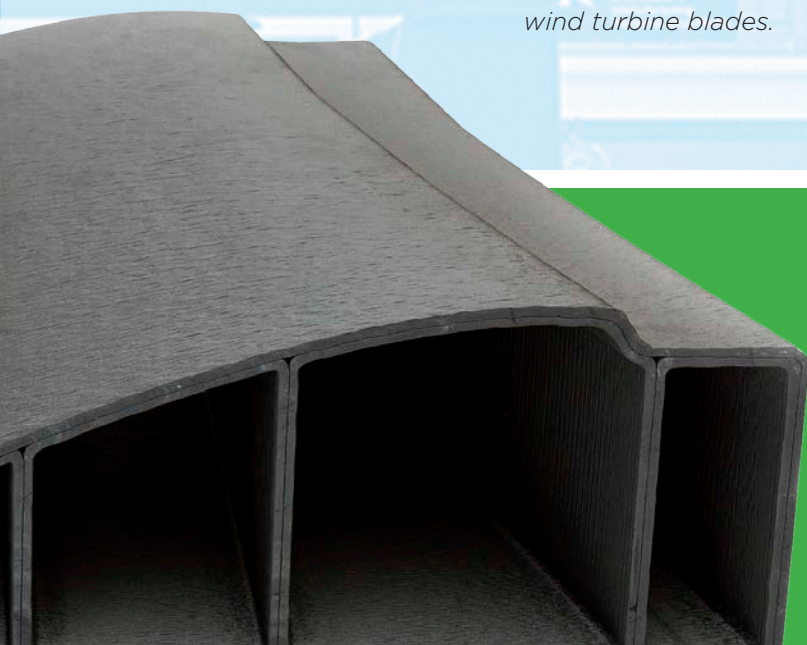
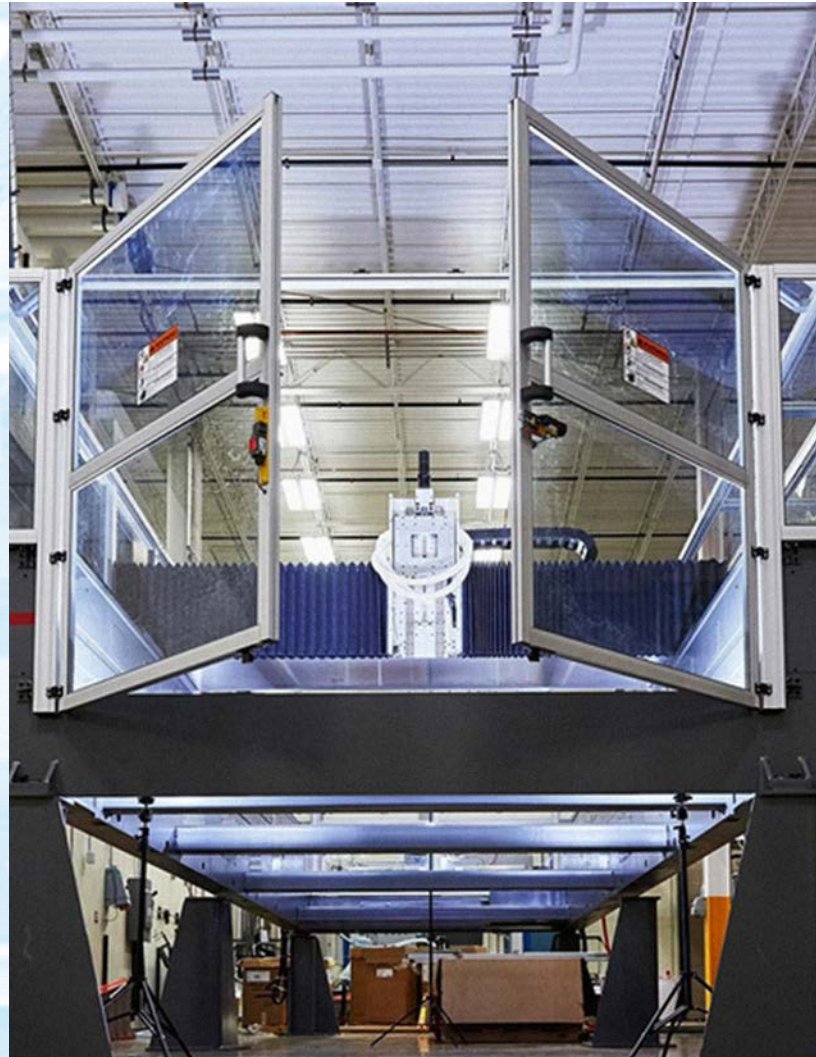
*A side view of a section of the mold. The hollow design allows for an innovative use of hot air to heat the mold during the curing of the blade.*







*A view of the Big Area Additive Manufacturing machine that will house 3D print molds for manufacturing wind turbine blades.*



Wind and Water Power Technologies Office and Advanced Manufacturing Office collaborate with public and private sector partners. These organizations provide a wealth of technical expertise and experience to this project.



Oak Ridge National Laboratory (ORNL) delivers expertise in additive manufacturing and houses the BAAM machine.



Sandia National Laboratories (SNL) develops and supports aerodynamic design of the blades and research blade testing at SWiFT.



TPI Composites manufactures the blades and collaborates with ORNL and SNL on the mold design and construction.



Energy Efficiency & Renewable Energy

**For more information, please visit:**

U.S. Department of Energy's Wind and Water Power Technologies Office: [energy.gov/eere/wind](http://energy.gov/eere/wind)

U.S. Department of Energy's Advanced Manufacturing Office: [energy.gov/eere/manufacturing](http://energy.gov/eere/manufacturing)

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