Virginia Jobs Project

A Guide to Creating Advanced Energy Jobs

MARCH 2016

AMERICAN JOBS PROJECT

A Letter from the American Jobs Project

It's no secret that America's middle class is in crisis; indeed, "the hollowing out of the middle class" has become a well-worn phrase, causing politicians to rail, bloggers to rage, and citizens to reel. Polls consistently reveal that jobs and the economy are at or near the top of citizen concerns.[1] Over the last few decades, the loss of middle-income jobs in America has been due largely to the global shift in manufacturing ("tradable jobs") to emerging economies.[2] Of the millions of jobs lost during the recession, most were good paying, middle-class jobs.[3] Unfortunately, many of the jobs created during the recovery have been in low-skill, low-paying occupations.[4] These trends are not going to reverse themselves. Leadership is needed, but the gridlocked U.S. Congress has failed in recent years to adopt robust policies to stoke middle-class jobs in America.

In President George W. Bush's autobiography, *Decision Points*, the former president recounts a conversation he had with the then-President of China, Hu Jintao. "What keeps you up at night?" President Bush asked President Hu as an ice-breaker. As we can easily guess, what kept President Bush up at night was worry about terrorism. Hu Jintao's response was telling: what kept him up at night was "creating 25 million new jobs a year" for his people.[5]

Is it possible to create good-paying American jobs in today's global economy? And what if the solutions did not involve Congress at all? What if there were creative middle-class job creation strategies being developed and tested in the laboratories of democracy -- the states and cities? The American Jobs Project seeks to answer these questions and provide a research-based roadmap for action for state and local leaders who are kept up at night trying to figure out how to create jobs for the people they serve.

Our quest starts with identifying the biggest market opportunity of our era: the global demand for advanced energy solutions. That demand -- whether borne out of a need for diverse, reliable and clean power or to achieve energy independence from unstable regimes -- creates "the mother of all markets" for local U.S. businesses to build and sell those solutions.[6] Strategically minded businesspeople looking at global growth projections in advanced energy demand are making major investments and reaping large revenues. In 2014, the private sector reported $1.3 trillion in global advanced energy revenues, the fastest growing year on record.[7] Advanced energy investments are now bigger than the global apparel sector and almost four times the size of the global semiconductor industry.[8] And jobs? Up to 16.7 million jobs are projected to be in the global advanced energy sector by 2030, almost tripling the 5.7 million people employed in the sector in 2012.[9] The question for the United States is: Where will those new jobs be created?

The American Jobs Project is about finding ways to make our states the answer to this question. If countries across the globe, including the U.S., are seeking technical products and solutions for our growing energy needs, how can U.S. businesses take advantage of this demand and build products locally that can be exported to the world? And how can we equip U.S. residents with the skills those businesses need to build their advanced energy products?

It is true that the U.S. will not likely be able to attract back the traditional manufacturing jobs of the past; those jobs are gone—either to low-wage countries or to automation—and we have to accept the fact that they are not coming back.[10] But our research shows that with innovative policies and a smart focus on industrial clusters, states can become hubs of innovation and job creation in specific advanced industries that soar with a state's strengths.

The American Jobs Project gives policymakers the tools to create good-paying jobs in their states. We propose innovative solutions built upon extensive research and tailored to each state. Many are best practices, some are new, and all are centered upon a state's business ecosystem. These solutions are written with an eye towards streamlining bureaucracy and are seasoned with the principles of competition, local control and fewer regulations.

If these recommendations are adopted, the beneficiaries will be those hard-working Americans looking for the dignity of a good-paying job.

Table of Contents

About us

American Jobs Project

The American Jobs Project is a national, interdisciplinary research-based initiative. Our team includes more than 50 student researchers with a broad range of expertise, including law, business, engineering, and public policy. We have ongoing relationships with hundreds of on-the-ground stakeholders and are actively collaborating with university partners and industry allies.

Richard Hirsh, Ph.D. - Academic Partner

A professor of History and Science & Technology Studies at Virginia Tech, Richard Hirsh explores the technical, social, and policy elements of the electric power system. His books include *Technology and Transformation in the American Electric Utility Industry* and *Power Loss: Deregulation and Restructuring in the American Electric Utility System*. In coauthored articles, he has also examined social barriers that impede the widespread acceptance of electric vehicles ("Beyond Batteries," published in *Energy Policy*) and unarticulated reasons for resistance toward wind turbines ("Wind Turbines and Invisible Technology," published in *Technology & Culture*). He holds a Ph.D. in the History of Science and an M.S. in Physics from the University of Wisconsin.

Acknowledgments

This report would not be possible without the support of the JPB Foundation, the Berkeley Energy and Climate Institute, the Fung Institute, the Center for Information Technology Research in the Interest of Society, and Virginia Tech.

We extend sincere gratitude to the dozens of individuals from business, government, non-profits, and universities for meeting with us, exploring ideas, participating in working groups, collaborating on the report, and sharing their vision for the future. Many thanks to Dr. Jon Miles of the James Madison University Wind Center for his valuable review. Charles DeCuir and Jeff Keever of the Virginia Offshore Wind Coalition and Novavis have been extraordinarily helpful; we thank them for their input. Thank you to Al Christopher and the staff at Department of Mines, Minerals, and Energy for their willingness to meet in person or by phone. Dr. David Roland-Holst, Adjunct Professor with University of California Berkeley's Center for Energy, Resources, and Economic Sustainability, was the peer reviewer of our jobs modeling methodology. We thank Dr. Roland-Holst for his guidance and careful eye.

Dozens of hands were involved in the process of researching, writing, and designing the report. The Lead researcher and writer was Mary Collins, the lead editor was Jackie Kimble, the lead analyst was Henry Love, and the graphic designer was Amariah Baker. Other contributors include Tiffany Wong, Peter Florin, Byron Pakter, Justin Marschke, Perwana Nazif, and Charlotte Reid.

We are grateful to the following experts for their collaborative efforts:

Angela Navarro- Southern Environmental Law Center

Dawone Johson- Chesapeake Climate Action Network

Albert Pollard- Energy Foundation

Rory McIlmoil- Appalachian Voices

Hannah Wiegard- Appalachian Voices

Bill Greenleaf- Virginia Energy Efficiency Council

Secretary Maurice Jones- Secretary of Commerce and Trade

Tony Smith- Secure Futures, LLC

William Shobe- University of Virginia

Walton Shepherd- Natural Resource Defense Council

Katherine DeRosear- Virginia Manufacturer's Association

Brett Massey- Virginia Manufacturer's Association

Alleyn Harned- Virginia Clean Cities

Dr. William Frazier- Chief Scientist, Navy Air Vehicle Engineering

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Rick Rugg- Carbon Fiber Solutions

Tom Queen- Feather Carbon

Richard Popkin- Eastern Burlap and Trading Company

Dr. Taylor Eighmy- Institute for Advanced Composites Manufacturing Innovation, University of Tennessee

Craig Barbrow- United States Department of Agriculture, Rural Development

Francis Hodsoll- Virginia Advanced Energy Industries Association

Kevin Chatellier- City of Virginia Beach

Michelle Mende- YesVirginia

Bethany Miller- Greater Richmond Partnership

Annette Hull- Greater Richmond Chamber

Mary Ann Bonadeo- Virginia Tech Intellectual Properties, Inc.

Executive Summary

The American Jobs Project was borne of two tough problems: loss of middle-class jobs in America and Congressional paralysis. It seeks to address these problems by taking advantage of one of the biggest market opportunities of our era—the advanced energy sector—and to do so at the state, not the federal level. Policymakers who leverage the unique strategic advantages of their state to grow localized clusters of interconnected companies and institutions are poised to create quality jobs.

The Commonwealth of Virginia is well positioned to benefit from the growing demand for advanced energy given the state's skilled labor force, world-class universities and research facilities, and strength in manufacturing and engineering. The state is already home to many advanced energy businesses that employ over 65,000 Virginians.[11] Opportunities to leverage this momentum to further serve growing regional, national, and global markets offer real benefits for Virginia's economy and high-paying jobs for the Commonwealth's residents.

Extensive research and more than 40 interviews with local stakeholders and experts have resulted in identifying two economic clusters showing particular promise: offshore wind and carbon fiber.

Heating of precursor materials into carbon fibers (Courtesy of the Oak Ridge National Laboratory / DOE)

However, there are several barriers preventing Virginia's advanced energy industries and their supply chains from reaching their full potential. Virginia must address these roadblocks to grow the state's advanced energy clusters and realize economic gains. In order to take full advantage of these opportunities, Virginia's policymakers can enact policies to increase demand for offshore wind and carbon fiber technology and to help the Commonwealth's businesses grow, innovate, and outcompete regional, national, and global competitors.

This project serves as a research-based roadmap for state and local leaders who seek to develop smart policies focused on leveraging the Commonwealth's resources to create high-skill, good-paying jobs. The number of jobs created is highly dependent on action taken by state and local policy makers. With concerted effort at the state and local level, more businesses that sell advanced energy products and services will take root in the Commonwealth. Employees in the advanced energy sector will spend their earnings in the local economy at grocery stores and restaurants, and those local establishments will need to hire more employees to satisfy demand. This creates a multiplier effect throughout Virginia's economy, where a single dollar spent in a community circulates through local businesses and their employees numerous times.

Drawing a wind turbine up for placement (Credit: Dennis Schroeder / NREL)

Summary of Recommendations

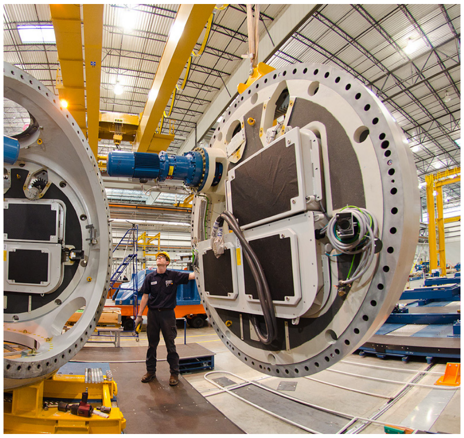
The analysis presented in this report culminates in four thematic sets of recommendations for Virginia's leaders. Each set of recommendations identifies opportunities for barrier removal and future growth in the offshore wind and composite materials clusters. While the recommendations are intended to be complementary and would be powerful if adopted as a package, they can also be viewed as stand-alone options.

Offshore Wind

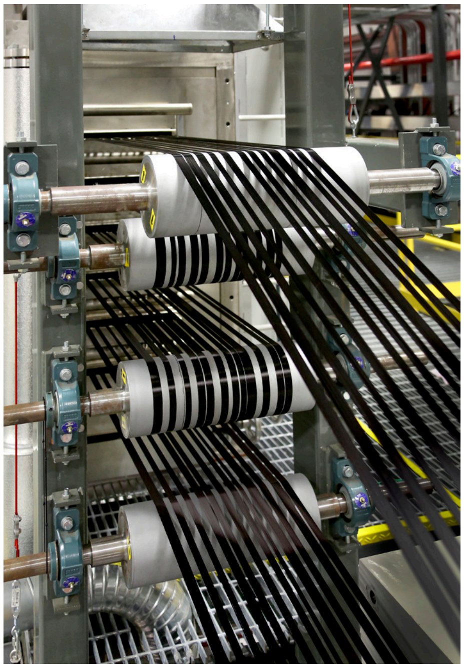
- Target Foreign Direct Investment (FDI) recruitment missions to fill gaps in Virginia's offshore wind supply chain
- Establish the Atlantic Offshore Wind Energy Alliance and facilitate European exchanges
- Reserve 50 percent of Renewable Energy Certificates (REC) purchases from renewable energy connected to an electric distribution grid serving Virginia
- Decrease commercial permitting time by removing excess procedures
- Create a Commonwealth Wind Credit (CWC)
- Coordinate the Virginia Offshore Wind Development Authority and Virginia Port Authority to meet supply chain needs
- Prepare Virginia's ports to meet the needs of the offshore wind supply chain with funds from the Virginia Transportation Infrastructure Bank

Advanced Composite Materials

- Expand Virginia's global push
- Join the Institute for Advanced Composites Manufacturing Innovation (IACMI) and create a Composites Council
- Host an Advanced Materials Technology Competition and Hackathon
- Create an online platform to streamline permits and allow local cost comparisons
- Expand local implementation of "Defense Production Zones" to cluster companies
- Update the Machinery and Tools (M&T) Tax to include a separate classification of equipment used directly in producing energy efficient products or materials



Virginia can capitalize on rising demand for offshore wind (Credit: Douglas Barnes / Wikimedia Commons)



Carbon fiber manufacturing is also an opportunity for the Commonwealth (Courtesy of the Oak Ridge National Laboratory / DOE)

Access to Capital & Innovation Ecosystem

- Establish a Fund of Funds
- Restore funding for the Center for Innovation Technology (CIT)
- Launch a State Technology Transfer Challenge
- Increase technology investment tax credits
- Appoint a Foundation Liaison

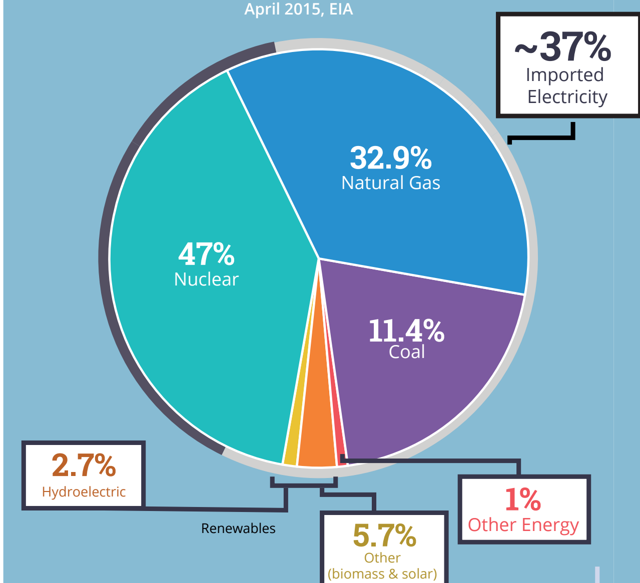
Workforce Development

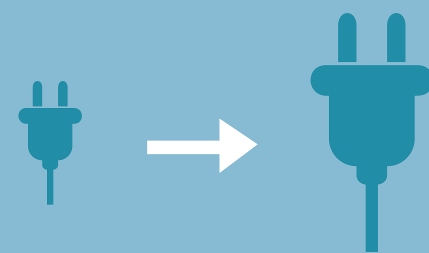
- Establish the North American Offshore Wind Training Academy
- Convene leaders to determine regional strategy, allocate training specialties among community colleges, and encourage participation from all Eastern colleges
- Identify "mobile" training needs and solutions, e.g., Mobile Welding Labs
- Offer high school composites training to make students employable upon graduation in the South and Southwest regions
- Create a part-time advanced manufacturing training program in South and Southwestern community colleges
- Expand Military2Manufacturing to train veterans for advanced manufacturing careers
- Establish early colleges with work-based learning curriculums

Virginia's Electricity Infrastructure

ELECTRICITY GENERATION

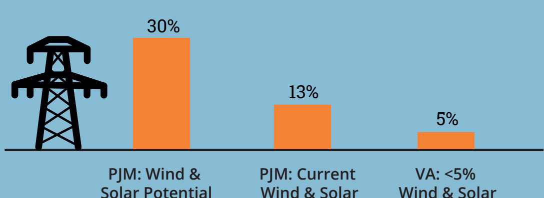
April 2015, EIA





VA will need an additional 14,000 MW by 2024

PJM--Virginia's grid operating system--can reliably operate with up to 30% wind and solar



Dominion Virginia Power and Appalachian Power control 84 percent of the utility market.

Municipal and Cooperative
Dominion
Appalachian

2006

- Creation of the Virginia Energy Plan

2007

- Voluntary Renewable Portfolio Standard of 15% of 2007 production by 2025

2009

- Renewable Energy Jobs Tax Credit
- Coastal Energy Research Consortium
- Clean Energy Manufacturing Incentive Grant Fund

2010

- Creation of the Offshore Wind Development Authority
- Use of Renewable Energy Certificate (RECs)
- Triple RPS credits for offshore wind energy

Virginia's Energy Economy

IMPORTS

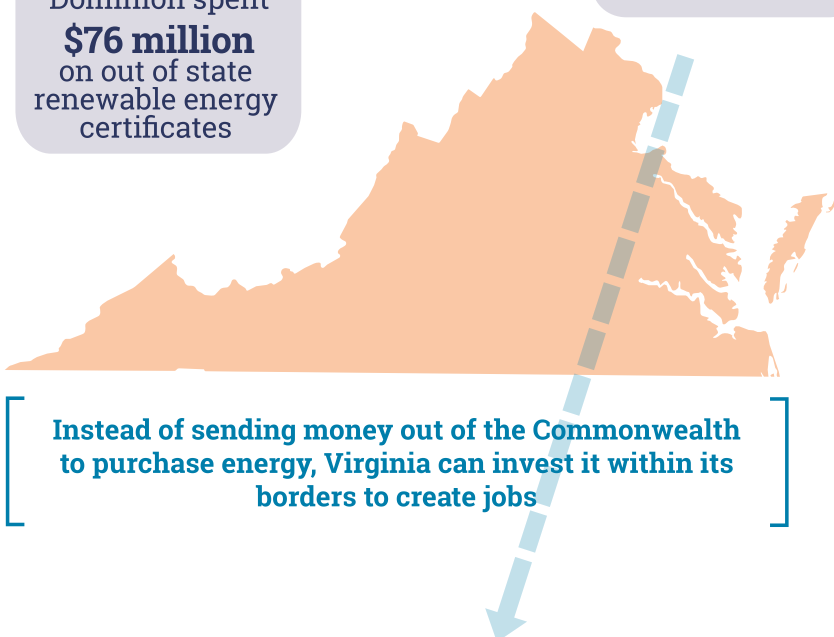
$13.7 billion
spent on imported energy

From 1998—2008 imports increased
1.4%
per year

Virginia imports
55%
of its energy needs

In one year, Dominion spent
$76 million
on out of state renewable energy certificates

$95 million
spent on coal imported from Colombia



Instead of sending money out of the Commonwealth to purchase energy, Virginia can invest it within its borders to create jobs

$51 million
in federal grants were awarded to Dominion for offshore wind development

For about the same price that Virginia spent on imported Colombian coal in 2008, the Commonwealth could have built 20 MW worth of offshore wind turbines—enough to power 5,000 homes.*

KEY POLICIES

2011

•Passage of HJ 605, proposing the creation of a National Offshore Wind Technology Center in Hampton Roads, Virginia and expressing the support of the General Assembly for the development of offshore wind energy resources adjacent to the shores

2014

• Exemption of Machinery & Tools Tax on solar equipment
• Offshore wind energy generation deemed in the public interest

2015

• Exemption of Machinery & Tools Tax on renewable energy equipment
• 500 MW of solar deemed in the public interest

*4.750 million for one MW of capital cost, assuming economies of scale reached; 250 homes powered by one MW. Source: NREL, Energy Analysis of Offshore Systems; BOEM, Offshore Wind Energy

SOURCES

1. Virginia Energy Plan, 2010, 2014; 2. GE Energy Consulting, 2014; 3. EIA, Virginia State Energy Profile, 2013; 4. Union of Concerned Scientists, 2010; 5. Virginia Legislative Assembly, Legislative Information System, 1995-present; 6. Virginia Conservation Network, 2014; 7. Dominion Virginia Power, 2014

Chapter 1: Introduction

The American Jobs Project aims to spur job creation in the advanced energy sector by identifying innovative and state-specific policy and technology roadmaps. This national initiative takes advantage of the emerging global demand for advanced energy products. The American Jobs Project team analyzed the advanced energy economy in the Commonwealth of Virginia and designed recommendations specifically tailored to the Commonwealth's strengths. These recommendations were informed by extensive research and over 40 interviews with local stakeholders and experts.

This report identifies opportunities to spur growth in two economic clusters in the advanced energy sector that could ultimately create thousands of good-paying manufacturing jobs to alleviate the employment crisis facing America today. State and local leaders who seek to leverage the state's resources to create skilled, good-paying jobs can use this report as a foundation for action.

Market Opportunity

Demand for advanced energy has skyrocketed in recent years and is poised for continued growth. Since 2004, new investment in the advanced energy sector has totaled $2.32 trillion worldwide.[12] In the United States alone, over $386 billion was invested in advanced energy between 2007 and 2014; over $51 billion was invested in 2014.[13] In nationwide polls, Americans increasingly support renewables over other forms of energy[14] and demand for renewable energy will continue to grow. By 2030, states will need to significantly reduce pollution from power plants which will make an even stronger case for advanced energy technology, renewable energy resources, and increased energy efficiency.[15] Projections show that renewable energy will add more to generation between now and 2030 than has been added in the past 16 years.[16] These trends lead to one clear market signal: demand for advanced energy will soar over the next 15 years.[17]

Economic Clusters

Economic clusters encompass a variety of linked industries and institutions—including suppliers of specialized services, machinery and infrastructure—which form a supply chain.[18] Clusters also extend to manufacturers of complementary products as well as to industries related in skills and technologies. By placing themselves in close proximity to industry allies, companies benefit from each others' unique expertise and

See Appendix A for more information on Virginia's Energy Profile

"Clusters are geographic concentrations of interconnected companies and institutions in a particular field."

– Michael Porter, *Competitive Advantage of Nations*[19]

skilled workers.[20] Companies in a cluster enjoy closer access to specialized skills and information, helping them increase productivity.[21]

The geographic proximity of and repeated exchanges between these various companies and institutions help foster an environment of coordination and cooperation. Business clusters are shown to increase the productivity of companies in the cluster, drive innovation in the field, and facilitate the commercialization of this innovation by increasing communication, logistical support, and overall interaction between cluster entities.[22] Clusters also help build a strong foundation for creating and retaining employment opportunities.

Economic Cluster

Economic Clusters are created when industries and institutions become linked with suppliers of specialized services, machinery, and infrastructure that are within close proximity, forming a supply chain. Key elements to a successful cluster include Policy Certainty, Workforce Development, Innovation Ecosystem, and Access to Capital.

Policy Certainty

- Provides a clear market signal
- Reduces business risk
- Allows for long-term planning

Workforce Development

- Invests resources in people
- Bridges skills gap
- Develops training programs and industry partnerships

Innovation Ecosystem

- Promotes research and development
- Facilitates new technology to market
- Incubates early-stage businesses

Access to Capital

- Provides funding for new and growing businesses
- Connects investors with market opportunities
- Attracts entrepreneurs

Jobs Potential

Maximizing job creation within the Commonwealth is highly dependent on local action. An original equipment manufacturer (OEM) and its local suppliers employ workers from their community. Those employees spend much of their earnings at businesses in the local economy, such as grocery stores and restaurants. Local businesses also hire employees from within the community, who spend their earnings at other local establishments. This results in a multiplier effect, where a single dollar of spending in a community circulates through local businesses and their employees numerous times. Thus, recruiting advanced energy OEMs and their suppliers to a community can result in increases in local spending that are many times greater than the actual expenses of those companies. If Virginia makes a concerted effort to recruit the offshore wind and carbon fiber composite industries, the Commonwealth can support over 19,000 jobs per year through 2030.[i]

Report Structure

The report is divided into four complementary chapters, each covering key elements of building advanced energy economic clusters in offshore wind and carbon fiber composite materials. Chapters 2 and 3 offer an assessment of Virginia's potential for advanced energy jobs within each cluster. Addressing the need for policy certainty, these chapters offer specific policy recommendations tailored to Virginia's needs. Chapter 4 analyzes Virginia's innovation ecosystem and access to capital and provides recommendations for improving the state's innovation pipeline. Chapter 5 provides recommendations for better preparing the state's workforce for advanced energy jobs. Extended learning sections covering Virginia's energy ecosystem and technology roadmaps for offshore wind and carbon fiber composite materials are provided at the end of the report.

i See Appendix G for more information.

Chapter 2: Offshore Wind Energy

Virginia's Offshore Wind Future

"All's clear!" shouts the dockmaster, and the giant barge roars to life. The barge is carrying wind turbine blades that were manufactured in a warehouse near the dock out to the sea, where they will be used to build an offshore wind farm large enough to power 720,000 homes.

John, the operations manager, is carefully monitoring the delivery through video streaming to the onshore command center. On one screen, he can see a jack-up vessel, a ship with long legs and a large crane, slowly lifting the rotor and blades in place on the turbine. Another display shows workers welding turbine components 100 meters in the air, all while strapped into a safety harness. A third monitor shows a team using horizontal drilling techniques to drill underneath the sea wall to install pipe ducts for subsea cables, which will connect the turbines to Virginia's energy grid. John walks across the command center to check in with the chief data analyst, who is carefully studying the output from sensors in the middle of the sea to ensure the turbines will capture as much energy as possible. In the next room, a team of data analysts filter information from the turbines to verify the turbines are functioning at maximum capacity.

When John's team completes construction, there will be 300 state-of-the-art turbines standing over 100 meters high 24 miles off the coast of Virginia. This massive project has brought together thousands of workers and dozens of suppliers, nearly all of them working at or near the coast. Hundreds of workers built specialty ships for installation, and thousands of trained technicians carefully manufactured the components of the wind turbines. These middle class jobs would not have been possible without the initiatives taken by Virginia's leaders.

How Does A Wind Turbine Create Electricity?

As wind blows past the blades, the geometry of the blades creates "lift," causing the blades to spin. The spinning of the blades moves a large metal shaft, which is connected to a gearbox. A smaller, quicker spinning shaft exits from the gearbox, which in turn spins a generator. The generator then converts the mechanical energy of the spinning shafts in to electrical energy.

Identifying Virginia's Strengths, Weaknesses, Opportunities and Threats in the Offshore Wind Sector

Netherlands' Princess Amalia Wind Farm (Credit: Ad Meskens / Wikimedia Commons)

Offshore Wind Manufacturing in Virginia

STRENGTHS	WEAKNESSES
• Large wind resources • Support from the private sector • Federal support for the 12 MW Virginia Offshore Wind Technology Advancement Project (VOWTAP) • The Port of Virginia's favorable depth and location along the east coast • The Virginia Offshore Wind Development Authority (VOWDA) • Existing transmission infrastructure near the coast	• Lack of waterside facilities for offshore wind manufacturing • Limited local supply chain • Large capital requirements required • VOWTAP delayed • Risk of hurricanes along Virginia coast • Shortage of skilled workers
OPPORTUNITIES	**THREATS**
• Growing demand for renewable energy in neighboring states • The regional grid operating system is ready for a large renewable energy load, meaning Virginia can export wind energy	• Lengthy permitting process • Foreign investors are hesitant to invest in U.S. offshore development due to regulatory uncertainty and a lack of policy support

Offshore wind turbine installation (Credit: Siemens / AG)

Wind energy continues to grow in the United States due to falling prices, technological advancements, favorable government policies, available financing, and increased consumer demand for diverse and renewable sources of energy. Virginia's advanced manufacturing base, leading universities, and research centers represent significant strengths that the state can leverage to play a prominent role in on- and offshore wind manufacturing and technology development. The state's wind energy sector currently boasts 33 businesses involved in onshore or offshore wind manufacturing.[1] With an established base, Virginia is well positioned to expand its existing wind businesses to capitalize on growing economic opportunity in offshore wind and spur business creation and job growth across the state.

Rhode Island's Deepwater Wind Will Provide Energy to 17,000 Homes

On July 26, 2015 Rhode Island's Deepwater Wind attached the first of the steel foundations to the ocean floor. The Block Island wind farm will power up to 17,000 homes (30 MW) by fall 2016 with a cost of $360 million. To comply with federal Jones Act regulations, U.S. barges will deliver the European-manufactured Alstom turbine components from the port-side holding site to a European installation vessel, which will install the turbine components. All activities were approved by U.S. Customs and Border Control.

Sources:
Providence Journal, "French company Alstom to build 5 turbines for Deepwater Wind project," February 2014.
TurnTo10.com, "Deepwater Wind begins construction of Block Island Wind Farm," July 2015.
Deepwater Wind, "Block Island Wind Farm Now Fully Financed," March 2015.

Virginia Offshore Wind Technology Advancement Project (VOWTAP)

Dominion Virginia Power won the 2013 Bureau of Ocean Energy Management (BOEM) competitive lease for offshore wind space. Then in May 2014, the Department of Energy (DOE) awarded $47 million—in addition to the 2013 $4 million grant—to Dominion and its partner, Virginia Offshore Wind Technology Advancement Project (VOWTAP),[i] to fund the construction of two 6 MW test turbines.[2] The Alstom turbines would stand almost 400 feet tall and bring power to about 3,000 homes.[3]

However, on April 24, 2015 Dominion Virginia Power announced it would pause the construction of the two 6 MW test turbines for another year due to high cost.[4] Dominion announced it will not seek approval from the State Corporation Commission in July as planned,[5] though it completed a series of stakeholder meetings in the summer of 2015 to discuss cost reduction methods and identify potential partners in offshore wind energy development,[6] the results of which were reported to the Virginia Offshore Development Authority (VOWDA) in fall 2015.[7]

If VOWTAP proves successful, a full-scale commercial wind farm could bring up to 2,000 MW of energy—enough to power 700,000 homes and employ more than 10,000 Virginians.[8]

If the project is permanently scuttled, there is no doubt that other states – Rhode Island in particular – will seek to fill the demand for offshore Atlantic wind. Whichever state wins the race to offshore wind will have seized the opportunity to create thousands of jobs. If not Virginia, then other Atlantic states will most certainly seize the opportunity.

Rising Demand Around the Globe

Demand for offshore wind energy is growing nationally and globally. Worldwide, almost 5 GW of offshore wind have already been installed, while another 5 GW are under construction and 30 GW already approved.[9] Japan aims to reach 37 GW of offshore wind power by 2050.[10] In Europe, the target is 40 GW of offshore wind by 2020, a goal which will create almost 300,000 jobs.[11]

Although offshore wind is advantageous to onshore wind and popular among developed nations, offshore development in the United States has been slow to develop. Two commonly cited

i VOWTAP consists of 7 groups: Alstom Power Inc., a global supplier of goods and services to power markets and wind turbine manufacturer; KBR, an engineering firm with experience in offshore wind; Virginia Department of Mines, Minerals and Energy; National Renewable Energy Laboratory; Virginia Coastal Energy Research Consortium, Newport News Shipbuilding; and Tetra Tech, an environmental consultant.

reasons for the lack of development include complicated logistics, such as the need for specialized installation vessels, and the lack of policy support.[12] The success of offshore wind in so many other developed nations demonstrates that these problems are surmountable. Offshore wind is no longer a new technology and the United States can incorporate best practices from nations around the world.

As shown in Figure 1, demand for offshore wind in the U.S. is likely to steadily increase through the year 2050. Overall, the U.S. is projected to have 20 GW of offshore wind capacity by 2030.[13] Virginia alone can develop 19,000 MW of offshore wind resources and grow its economy by exporting turbines and services to neighboring states.[14] States such as New Jersey, Maryland, Massachusetts, and Maine have offshore wind energy targets together totaling over 9 GW by 2030,[15] while the entire east coast is predicted to have 14 GW of offshore wind installed by 2030.[16] An annual demand of 100 wind turbines per year (500 MW) for five years is enough to justify Virginia's investment in offshore wind turbine manufacturing facilities.[17]

Five Advantages of Offshore Wind over Onshore Wind

- Ocean winds are stronger and more consistent than onshore winds, resulting in more reliable energy generation
- Unlike onshore turbines, offshore wind turbines do not interfere with agriculture or development activities
- Offshore turbines can be built several times larger than onshore turbines, maximizing energy output
- Populations tend to live in coastal areas, with little access to renewable energy
- Most offshore farms are past the horizon line, and cannot be seen from shore

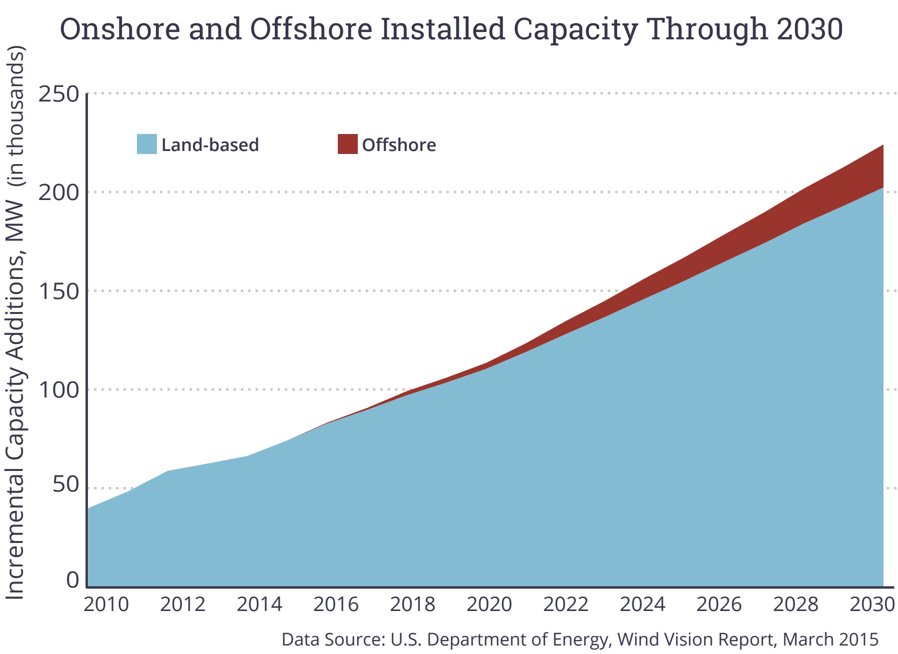
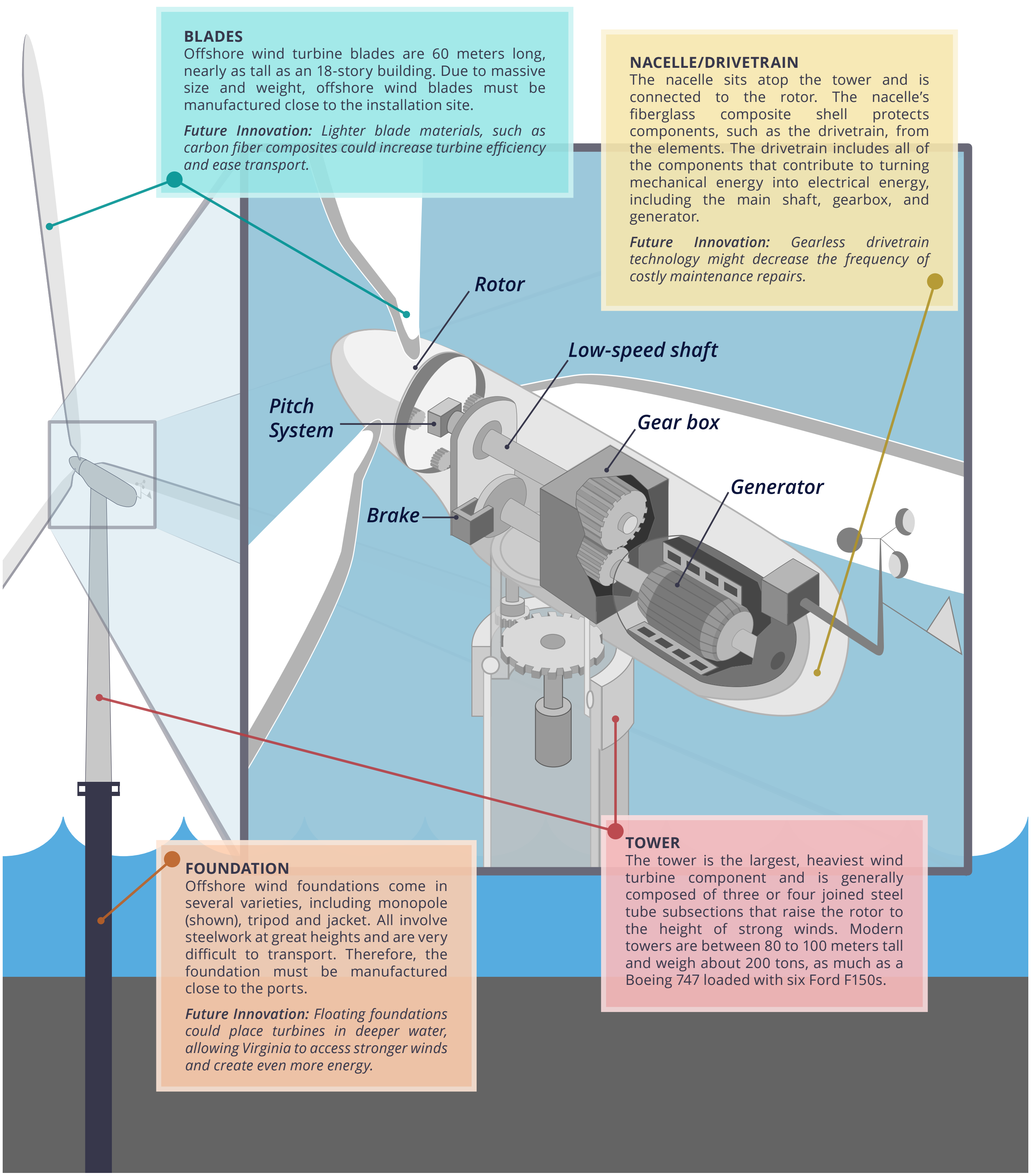


Figure 1. Installed capacity for offshore wind will reach 20 GW by 2030

Anatomy of an Offshore Wind Turbine



Falling Cost of Wind-Generated Electricity

The "Levelized Cost of Energy" (LCOE) is the net cost—including installation, maintenance, and transmission—of energy produced from a source, divided by the expected lifetime energy output. The LCOE is a useful concept to value clean energy systems – those that have high up-front capital costs but no fuel costs – because it can be used to compare different types of generation technologies, particularly fossil fuel based systems that have capital *and* fuel costs. The LCOE conveys what the price of the clean fuel must be to "break even" by the end of a turbine's lifetime.

Falling LCOE for U.S. Offshore Wind Power

Figure 2 highlights an expected drop in LCOE for offshore wind energy. With the majority of studies estimating a 20 to 30 percent fall in LCOE by 2030 compared to current-year LCOE, wind energy is expected to decrease in LCOE by 2.7 percent on average per year.[18] The majority of this cost decrease will come from both improved technology and improved siting decisions, but also it includes improvements in overall operations and maintenance of the turbines.

Offshore Wind Levelized Cost of Energy Through 2028

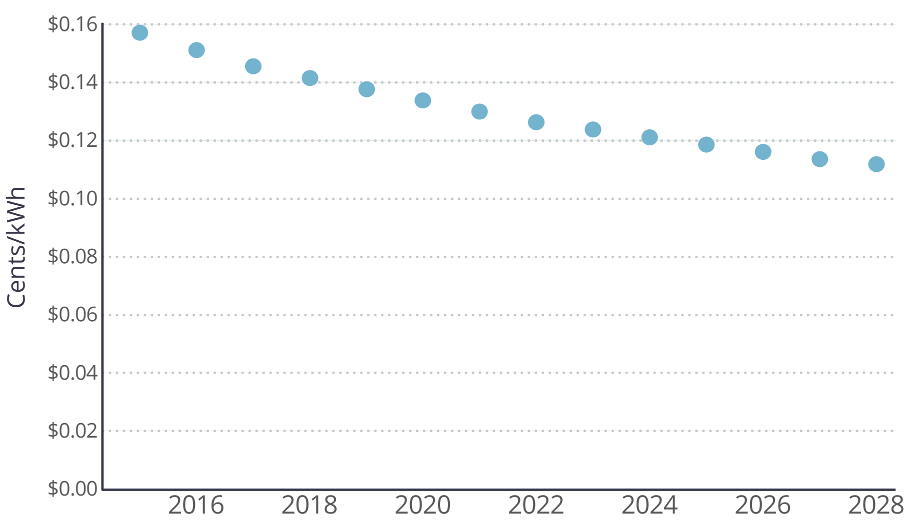


Figure 2. LCOE for offshore wind will decrease by 30 percent by 2030 (Source: Navigant)

Offshore Wind Employment Potential

As demand for wind energy skyrockets, Virginia has the opportunity to expand the offshore wind economy, increase in-state spending, and employ an average of over 14,000 Virginians annually over the next fifteen years. If optimistic projections prove to be correct and Virginia's offshore wind companies are able to fill a larger share of their supply chain needs with in-

Why Use Job-Years?

By using job-years, our analysis can take into account the length of a job. In energy projects, many construction and installation jobs are short-term, while manufacturing and maintenance jobs may be long-term. Using job-years allows us to accurately count both types of jobs. For example, if ten full-time welders are expected to each spend 208 hours on an offshore wind project, this is measured as one job-year. Alternatively, if one full-time engineer is expected to spend fifteen years operating that same offshore wind farm, this is measured as fifteen job-years. In our analysis of Virginia's offshore wind supply chain, total job-years are aggregated over the 2016 to 2030 period.

What is a Job-Year?

A job-year is one full-time equivalent job for one year (i.e., forty hours per week for fifty-two weeks, which is 2,080 hours per year). If two people each work a part-time job for twenty hours per week for fifty-two weeks, this is counted as one full-time equivalent job for one year, i.e., one job-year. If one person works forty hours per week for ten years, this is counted as ten job-years.

Direct, Indirect, and Induced Job-Years

In order to estimate the potential economic impact of Virginia's offshore wind supply chain, direct, indirect, and induced job-years are measured.

- **Direct job-years:** reflect jobs created in the offshore wind industry to meet demand
- **Indirect job-years:** reflect jobs created at supply chain companies resulting from increased transactions as supplying industries respond to increased demand from Virginia's offshore wind industry
- **Induced job-years:** reflect jobs created throughout the local economy as a result of increased spending by workers and firms in Virginia's offshore wind and wind supply chain industries

state purchases, up to 223,000 direct, indirect, and induced job-years would be supported. While nearly 49,000 of those would be direct job-years in the state's offshore wind industry, nearly 175,000 indirect and induced job-years could be supported if wind companies were able to procure more of their supplies from in-state companies.

These projections for job-years potential in Virginia's offshore wind industry are based on tools and analysis by the National Renewable Energy Laboratory (NREL) and the Department of Energy's Office of Energy Efficiency and Renewable Energy (EERE). Additionally, the Jobs and Economic Development Impacts tool (JEDI) was utilized to estimate job-years at different levels of local supply chain concentration for offshore wind.

To highlight why clustering supply chain businesses in Virginia is so important, we have estimated the number of direct, indirect, and induced jobs based on future demand and the percentage of supply chain purchases made within the state. Figures 3 and 4 show how the number of offshore job-years vary as the local share changes. The figures show the number of direct, indirect, and induced jobs based on local share percentages of 30 percent, 40 percent, 50 percent, 60 percent, and 70 percent.

Since projections often vary, we analyzed how those supply chain differences affect four reputable estimates of future demand for offshore wind energy: REF's High Demand Baseline as a low-demand scenario, EERE's Wind Vision forecast as a high-demand scenario, and both REF's 80 percent Renewables ITI forecast and REF's High Demand 80 percent Renewables forecast as intermediate-demand scenarios. Figure 3 presents estimates for offshore wind construction jobs. Figure 4 presents estimates for operations and maintenance jobs.

In all of the demand scenarios, increasing the percentage of local spending by Virginia's offshore wind companies creates thousands of job-years. For example, in the low-demand scenario, increasing in-state supply chain purchases from 30 percent to 70 percent would create over 43,000 direct, indirect, and induced job-years. In the high-demand scenario, increasing in-state supply chain purchases from 30 percent to 70 percent would create over 123,000 direct, indirect, and induced job-years.

If a concerted effort were made by the state to fill in the supply chain and strengthen the offshore wind cluster, Virginia companies could meet the expected demand for offshore wind, supporting up to 223,000 job-years, an average of 14,000 jobs per year. Increasing the number of supply chain businesses can create thousands of good-paying, skilled jobs and make Virginia a leader in the offshore wind industry.

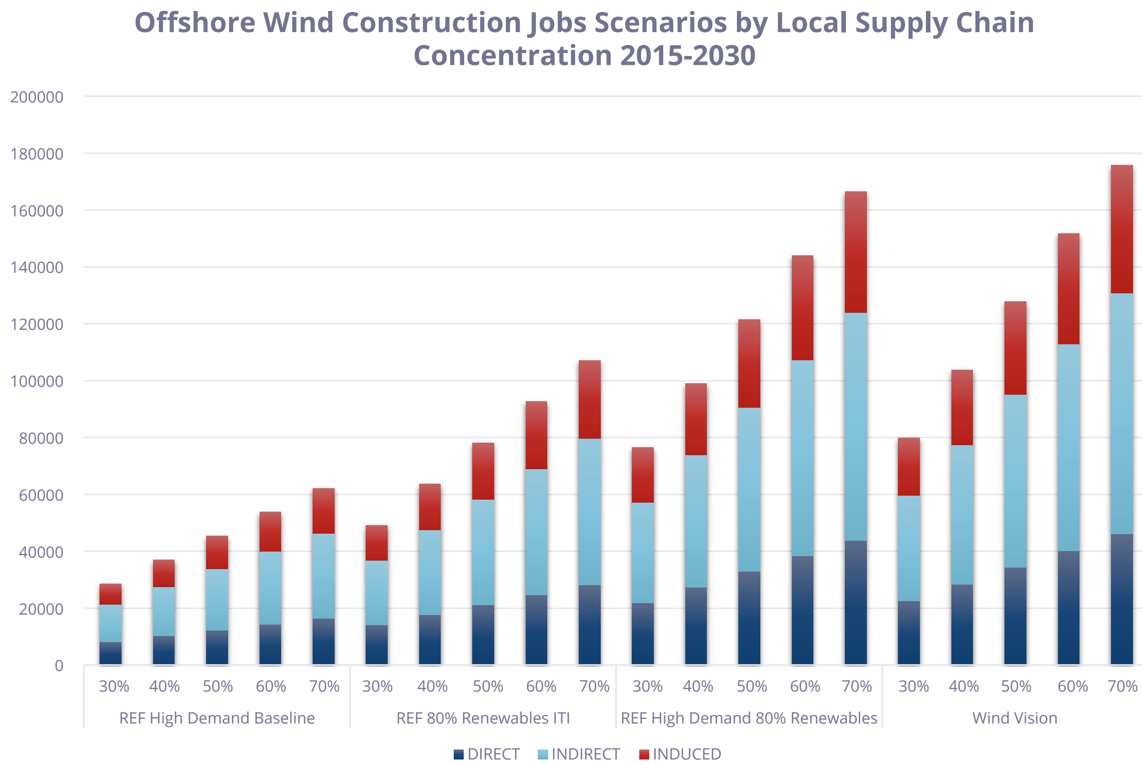


Figure 3. A higher concentration of the offshore wind supply chain will result in more construction jobs for Virginians.

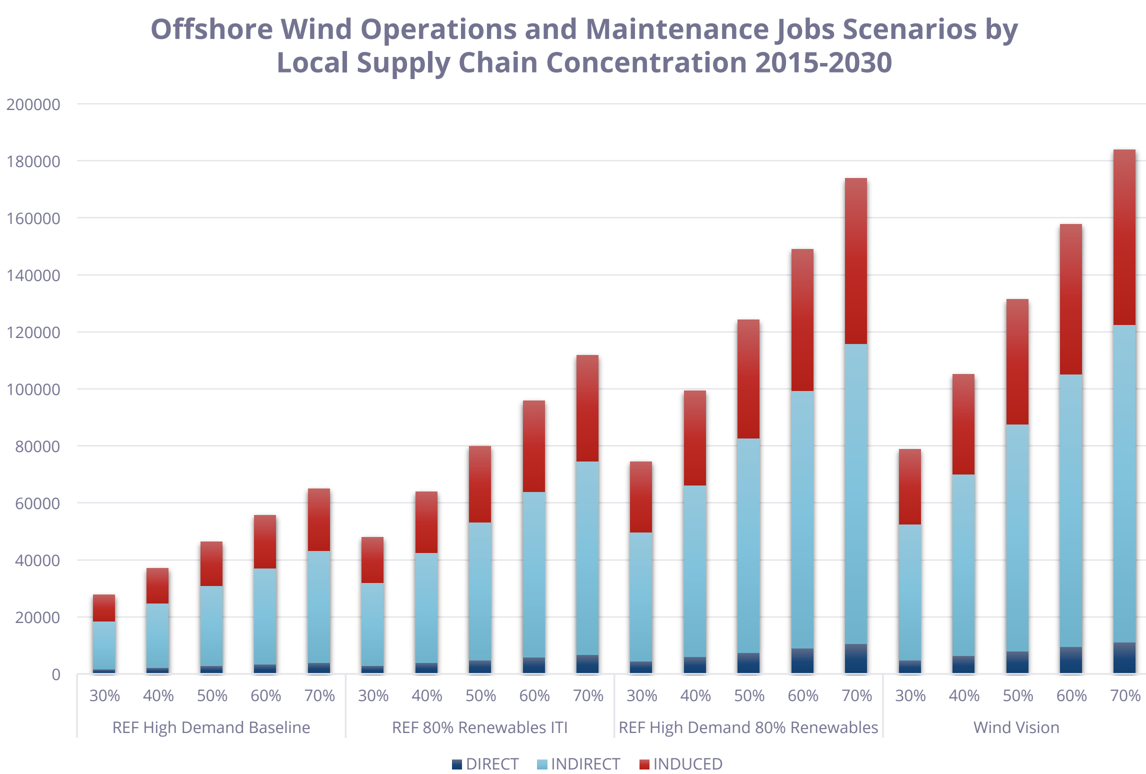


Figure 4. Operations and maintenance jobs will increase as Virginia secures a greater portion of the nation's offshore wind supply chain.

Virginia's Offshore Wind Industry: a Strong Anchor With Room to Grow

Due to upfront costs and the complexities of offshore permitting, offshore wind energy generation has yet to take off in the United States; the U.S. offshore wind supply chain is therefore in its infancy.[19] Virginia has competitive advantages in its offshore wind supply chain due to its anchor companies, robust shipbuilding sector, steel manufacturing, and emerging drivetrain component manufacturers. Gaps in the supply chain, such as tower fabrication, represent substantial growth opportunities in the Commonwealth.

Virginia's Supply Chain Strengths

Virginia's coastal location makes it ideal for an offshore wind supply chain due to complicated logistics of on-land transportation of large wind turbine components. For example, offshore wind turbine blades are as tall as an 18-story building, and therefore must be manufactured close to ports where they can be loaded onto ships. Moreover, Virginia's offshore wind supply chain is anchored by several large wind companies, like Alstom Power, with a turbine generator engineering and

Table 1. Companies in the Virginia Offshore Wind Supply Chain

TYPE OF FACILITY	NUMBER OF COMPANIES	DETAILS
Manufacturing		
Drivetrain	5	main shaft, gearbox, generator
Rotor	4	blades, pitch system, spinner
Tower	0	tower and supporting components
Structural	3	main structural frames, fasteners
Electrical	7	power inverter, logic boards, control systems
Materials	2	composite material, steel foundries
Power Transmission	1	equipment to connect wind farm to grid
Foundation	0	steel foundation for offshore applications
Service		
Project Developers	7	resource assessment, land assessment for small projects
Education	3	universities with specific wind focuses
Non-profits	3	advocacy and supply chain development support
Distributed Wind Turbines	3	small wind turbines, small wind turbine components
Total Companies	38	Key: Strength and Opportunity for recruitment*

*Strengths and opportunities for recruitment were based on the size and strength of companies. For example, several small start-up companies are not as advantageous as a large supplier, like Alstom Power that has the capital to produce at economies of scale.

manufacturing facility in Richmond, Virginia.[20] General Electric has several locations throughout the Commonwealth in various sectors,[21] and is a partner on the Virginia Offshore Wind Technology Advancement Pilot project.[22] Furthermore, the Commonwealth has strong support for offshore wind from local groups such as the Virginia Offshore Wind Coalition, a trade association formed to advance development of offshore wind in the Commonwealth.[23] One of Virginia's largest advantages in the offshore wind supply chain is its strong shipbuilding and repair industry. Located in the Hampton Roads region, the maritime industry traditionally targeted U.S. Navy shipbuilding and repair. However, the companies that build and repair Navy ships could easily transition to building the large offshore barges and jack-up rigs necessary to install an offshore wind farm. Some of the companies in the industry include BAE Systems in Norfolk and Newport News Shipbuilding in Newport News.

Rotor pieces can be provided by three Virginia companies, including Cobham Advanced Composites in Suffolk, BGB Technologies, Inc. in Colonial Heights, and Defense Holdings, Inc. in Manassas Park. Cobham Advanced Composites provides composite materials, Defense Holdings provides lighting and deicing systems, and BG Technologies manufactures minor components used in the blade pitch system. Although Virginia lacks a company that can assemble an entire drivetrain, there are five companies that manufacture smaller components in the drivetrain including: Craft Machine Works in Hampton, Precision Machine and Fabrication in Chesapeake, Shenandoah Machine

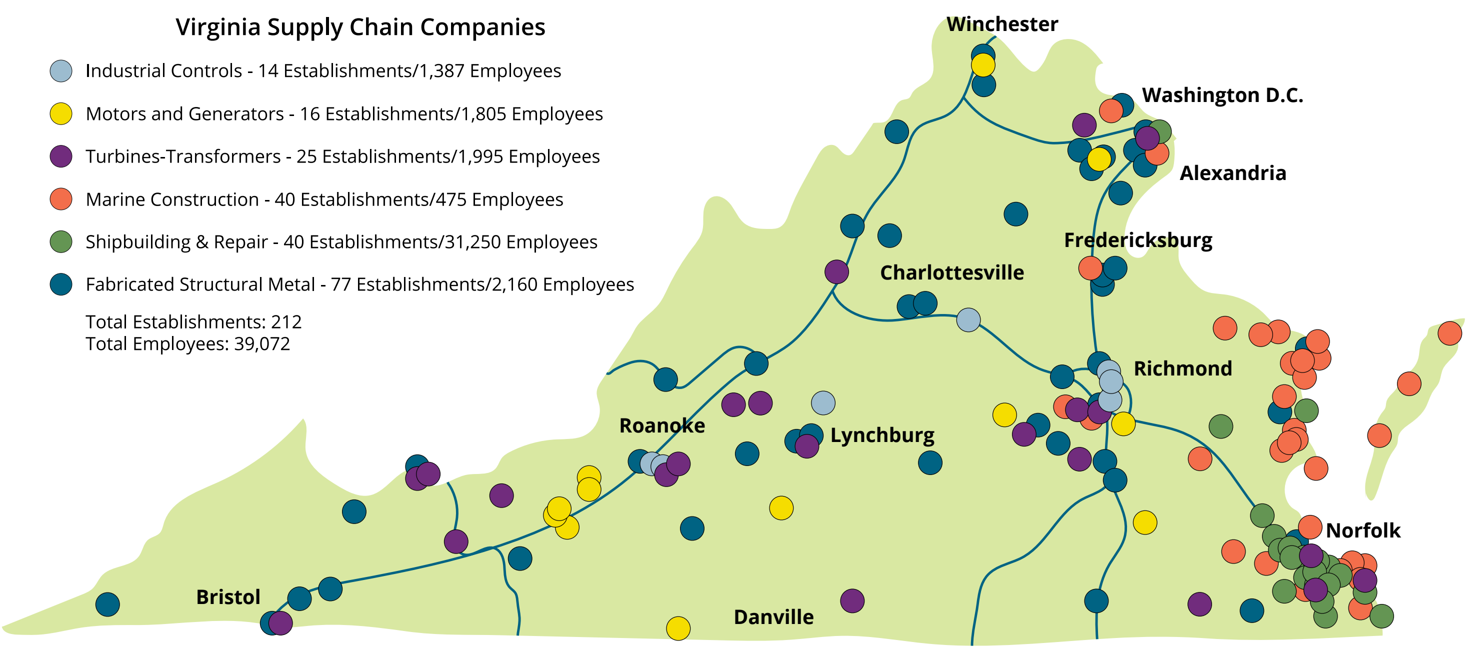


Figure 5. Potential offshore wind supply chain companies (Data source: Virginia Economic Development Partnership)

Offshore energy substation (Credit: Siemens / AG)

Nacelles on a construction site (Credit: Siemens / AG)

Shop, with locations in Shenandoah and Roanoke, and VibraAlign in Richmond. ABB has a generator manufacturing facility in South Boston.

Additionally, while Virginia has a limited number of wind manufacturing facilities to date, there are numerous facilities with *potential* to enter the sector. Motor and generator manufacturers, fabricated structural metal, and marine construction firms all can enter the offshore wind market when demand increases.

Several areas, including the Hampton Roads region, are ideal for an offshore wind energy cluster due to their coastal location and the possibility of existing companies entering the supply chain. Another feature of the Commonwealth that may entice global companies to choose Virginia over neighboring states is the ability to establish manufacturing facilities in vacant buildings near the Norfolk port. This will decrease the logistical challenge of transporting the large components far distances.

Policy Recommendations

Virginia can propel its offshore wind cluster by stimulating demand for offshore wind within the Commonwealth, as well as initiating offshore production to meet the demand of neighboring states. A robust market will attract private investment and strengthen the economy. Virginia can create thousands of high-skill, good-paying jobs by stoking competition, encouraging demand, expanding local control, and streamlining regulatory bureaucracy. Once Virginia makes the decision to grow this sector, a number of policy recommendations will drive offshore wind success:

Policy 1: Target Foreign Direct Investment (FDI) Recruitment Missions to Fill Gaps in Virginia's Offshore Wind Supply Chain

Virginia has a strong anchor in the offshore wind supply chain and a strategic location. Moreover, the offshore wind goals established by east coast states total over 9 GW by 2030,[24] and only 500 MW (half of 1 GW) of production per year for five years (2.5 GW total) is needed for a return on investment in wind turbine manufacturing facilities.[25] An investment of the offshore wind supply chain is worth $500 million and includes a turbine manufacturing facility, blade manufacturing facilities, tower fabrication, a foundry for large castings, and nacelle assembly.[26] The DOE projects the east coast will have over 14 GW of offshore wind by 2030[27]—ample opportunity to export goods and services. Virginia could begin the manufacturing process to supply other states, such as Rhode Island, with turbines needed to produce electricity. Establishing the local supply chain will also lower the cost of the Virginia Offshore Wind Technology Advancement Project (VOWTAP).

However, for Virginia to capitalize on its strengths and demand for export of turbine components, key gaps in the Commonwealth's supply chain must be filled. Many governors lure international companies to their states to create jobs for their citizens, and Virginia is no exception. The Governor can turn gaps in the offshore wind supply chain into international investment missions to bring the following specific turbine component manufacturers to the Commonwealth.

Turbine Component	FDI Target
Large-scale turbine blades	DeWind (Germany) and LM Wind Power (Denmark)
Nacelle shell	Alstom Power (France)
Drivetrain assembly	Romax (UK) and Eickoff (Germamy)
Towers and foundations	AMBAU (Germany), Bladt Indsutries A/S (Denmark), SIF (Netherlands)
Foundry	Global Castings (Germany)
Subsea Cables	JDR Cables (England) and Sudkabel GmbH (Germany)

Policy 2: Revive the Atlantic Offshore Wind Energy Alliance and Facilitate European Exchanges

Other countries have shown that to overcome offshore wind's complicated supply chain and logistics, regional partnerships are a necessity.[28] The lack of coordination in the United States is a key reason that foreign investors do not see Virginia as a stable market for investment.[29] With several neighboring states pursuing offshore wind projects, including Rhode Island, Maine, Massachusetts, New Jersey, Maryland, and Delaware, the potential for strong regional partnerships exists.[30]

The Governor could lead a regional effort similar to the expired Atlantic Offshore Wind Energy Consortium, which could allow states to share resources such as sea vessels and permitting strategies. The Atlantic Offshore Wind Energy Consortium was a Memorandum of Understanding (MOU) signed in June 2010 between the Department of the Interior and the governors of ten Atlantic states including: Virginia, North Carolina, Maine, New Hampshire, Massachusetts, Rhode Island, New York, New Jersey, Delaware, and Maryland. The four-year agreement was intended to coordinate permitting and regulatory processes, share technical research findings, and collaboratively address

Renewable Portfolio Standard

Virginia has a voluntary RPS, meaning that the percentage of electricity that comes from renewable sources is at the discretion of the investor owned utilities (IOUs). The voluntary RPS calls for the amount of energy from renewable sources in 2025 to equal 15 percent of 2007 total electric energy sales (Va. Code § 56-585.2 D). To meet these requirements the utility can either: A) Generate their own renewable energy, B) Purchase renewable energy from non-utility generators, or C) Purchase renewable energy certificates (RECs).

What Are RECs?

Renewable Energy Certificates (RECs) are tradable energy credits that represent 1 Megawatt hour (MWh) of renewable electricity. Even while the price of RECs rise and fall, these credits are bought, sold, and traded between states to satisfy renewable goals. RECs are sometimes purchased from decades-old energy sources and can be saved for future use for up to five years.

infrastructure challenges.[31] Unfortunately, states were slow to take further action to promote offshore wind and the potential of the consortium never became a reality.

Virginia's economy could benefit from reviving the Atlantic Offshore Wind Energy Alliance. Private and public sector leaders from each state could coordinate supply chain activities, financing strategies, research activities, infrastructure design, tax incentives, and permitting processes. Seeing regional coordination on supply chain logistics could increase the confidence of foreign investors. Virginia's port, shipbuilding industry and strategic location make it ideal as the epicenter of offshore manufacturing and logistics services. If Virginia initiates a regional supply strategy and promptly starts an offshore wind manufacturing center, it could begin to export turbine components to other states such as Rhode Island, perhaps even before turbines are installed in Virginia.

Facilitate exchanges with worldwide offshore wind leaders

Collaboration is the key to success in an industry as complicated as offshore wind. By having an ongoing exchange of ideas and learning with offshore wind leaders in Europe, Virginia can master offshore best practices and anticipate common challenges.

Virginia—or the Atlantic Offshore Wind Energy Alliance—could facilitate these formal exchanges with leaders in Germany, Denmark, and the United Kingdom. For example, Virginia business and policy leaders from the VOWTAP project could join DONG Energy for a tour of the two 6 MW Gunfleet Sands pilot project located in the United Kingdom. Many project aspects, including turbine size, logistics, and construction, will be comparable between VOWTAP and Gunfleet Sands. Furthermore, project developers from DONG Energy, or other leading offshore developers, could be invited to Virginia for a formal exchange program with business leaders and policy makers.

Policy 3: Reserve 50 percent of REC Purchases From Renewable Energy Connected to an Electric Distribution Grid Serving Virginia

In the Commonwealth, Renewable Energy Certificates (RECs) are purchased to satisfy Virginia's voluntary RPS and Dominion Virginia Power's Green Power Program, an optional program in which customers request to receive renewable energy.[32] RECs are purchased mostly from out-of-state at a high cost to Virginia ratepayers. For example, Dominion Virginia Power purchased

1.5 million renewable energy certificates in 2012,[33] yet all were from old hydroelectric plants built in the 1940s, and 99 percent of those energy certificates came from out-of-state sources.[34] Between 2011 and 2012, Virginians paid $76 million to Dominion to buy renewable energy from out of state.[35]

In addition to importing RECs, the Commonwealth is a net importer of energy, meaning it consumes more energy than it produces. More than half (55 percent) of the Commonwealth's electricity and fuel comes from out of state.[36] With growing demand for electricity—another 14,000 MW will be needed by 2024—Virginia will need to expand its energy supply over the next decade.[37] Unless the Commonwealth diversifies its energy portfolio, Virginia's energy reliability could be vulnerable to potential interstate grid failures, extreme weather threats, commodity price volatility, or homeland security risks.

To increase Virginia's energy reliability, the Commonwealth could strengthen the voluntary RPS by adding a carve-out to encourage in-state production. Under RPS carve-out, 50 percent of RECs could be required to come from renewable sources connected to the electric distribution grid serving Virginia. Out-of-state purchases to satisfy the RPS or Dominion's Green Power Program could be used if a sufficient number of RECs are not offered for sale by Virginia grid-connected sources. Nearby states, including North Carolina and Maryland, have similar policies as a means to promote a reliable, safe and diverse energy supply.[38] By allocating a portion of REC purchases to renewable sources connected to Virginia's grid, Virginia can continue to diversify its fuel mix with sources such as offshore wind power and provide safe, reliable energy to the citizens of the Commonwealth.

Policy 4: From VOWTAP to Commercial Scale - Decrease Permitting Time

To be a national leader in offshore wind, Virginia needs to reduce the regulatory burdens and streamline the permitting process. Under the current rules, VOWTAP will require 12 different studies and authorizations by local, state, and federal agencies, many of which overlap.[39] As Virginia finishes approving VOWTAP, it can decrease permitting time needed for commercial scale implementation by removing unnecessary steps from the permitting process.

Virginia can improve upon the VOWTAP permitting process by looking to the success European countries have had. In the United Kingdom, the streamlined permitting process decreased the permitting time from six years to 16 months.[40] A properly developed plan can increase efficiency while ensuring safety and environmental requirements are met. Advice from private

Permitting Costs Add Up

Long permitting processes are a barrier to businesses that need to begin manufacturing years before the installation of the turbines. Permitting uncertainty can cause businesses to wait to start the manufacturing process until they have all permits approved, delaying projects for years. The Department of Energy recommends streamlining the Environmental Impact Statement to save up to 1.5 years.

Source: Pacific Northwest National Laboratory, "Offshore Wind Energy Permitting," November 2010

Virginia Offshore Wind Development Authority (VOWDA)

The legislature established VOWDA to facilitate, coordinate, and support the development of the offshore wind industry, projects, and supply chain. VOWDA has authority to collect environmental data and identify existing state and federal regulatory barriers. VOWDA serves a critical role in the regulatory process, working in cooperation with relevant local, state, and federal agencies to upgrade ports and other logistical facilities for the manufacturing and assembly of offshore wind energy project components and vessels.

Source: VOWDA

sector experts could help remove excess permitting procedures and lessen time needed for permitting without compromising regulatory requirements.

Virginia's Department of Mines, Minerals, and Energy and the Virginia Offshore Wind Development Authority could remove regulatory barriers to make Virginia more attractive to wind developers. They could bring in advisors from lean manufacturing and use European best practices. This dedicated effort could drastically reduce the permitting time, significantly cutting the costs of offshore wind development. If Virginia achieves the goal of having a streamlined commercial permit approval process, the Commonwealth will send a clear signal to the private sector that Virginia is serious about offshore wind.

Policy 5: Create a Commonwealth Wind Credit (CWC)

Dominion Virginia Power's recent delay of VOWTAP emphasizes the urgent need for policy to lower costs of offshore wind deployment.[41] Although Congress recently extended the federal Production Tax Credit (PTC) for another five years, the high cost of offshore wind is still a barrier to deployment in the United States. To signal to foreign financiers that Virginia is committed to offshore wind development, Virginia must not rely solely on the federal PTC; the Commonwealth could pass its own Commonwealth Wind Credit (CWC). The cost of the CWC can be offset by income from the leasing of state lands for renewable energy development, as New Mexico has successfully done with its economy-boosting Renewable Energy Production Tax Credit. The CWC can be modeled after similar credits in New Mexico, Kentucky, or the U.S. ITC or PTC.

Virginia could follow New Mexico's example and lease some of its state lands, such as land under control of the Virginia Department of Transportation, to pay for a Commonwealth Wind Credit. Virginia owns a total of 346,900 acres,[42] and would only need to lease a small fraction of that to generators of onshore wind and solar. Recent legislation declaring that 500 MW of solar-generated electricity is in the public interest will drive demand for land for solar energy generation.[43] Leasing state lands and rooftops could be a significant source of revenue that could be used to pay for a wind tax credit. Offering a Commonwealth Wind Credit would send a clear signal to investors that Virginia is serious about offshore wind development and attracting middle class jobs to the state.

New Mexico's Renewable Energy Production Tax Credit

In 2002, New Mexico instituted a state Renewable Energy Production Tax Credit (REPTC) to stoke clean energy investment. The program was so successful that the annual production tax credits for solar are maxed out until 2022. The tax liability is capped at a maximum of $33.5 million per year for 10 years, a fraction of the money the state will earn by leasing land for renewable energy uses. Those land leases are expected to bring in $574 million to the state, far exceeding the cost of the tax credits. Neighboring states, including Arizona, followed New Mexico's lead and instituted similar policies.

Source: Clean Energy Finance Forum, "Get in Line," December 2014

Policy 6: Coordinate the Virginia Offshore Wind Development Authority and Virginia Port Authority to Meet Supply Chain Needs

In the United Kingdom, the Port of Grimsby has been dedicated to wind activities. Via coordination with local officials and business leaders, it acts strategically with other nearby ports to coordinate supply chain activities including: establishing operations and maintenance hubs, allocating terminal space for offshore wind installation vessels, and allotting space for manufacturing wind turbine components.[44] Phase three of offshore wind turbine installation will bring an additional 1,500 jobs to the Port of Grimsby alone,[45] not counting the United Kingdom's 6,800 full time offshore wind jobs.[46]

To create an industrial cluster that leverages the Port of Virginia and the facilities owned by the Virginia Port Authority and the private terminals in the region, the Virginia Offshore Wind Development Authority, along with the Virginia Port Authority, Virginia Maritime Association, and the Virginia Offshore Wind Coalition could work strategically to ensure efficient allocation of waterfront resources to support the offshore wind industry. The Department of Mines, Minerals and Energy could build upon the Port Readiness Study of BVG Associates, a marine energy consultant group.[47] The Port Readiness Study will evaluate the port's ability to locate large manufacturing facilities, stage sizeable numbers of wind turbines and other components, and develop scenarios for building the wind turbines and towers.[48]

Based on the analysis of BVG (released fall 2015), the Department of Mines, Minerals, and Energy, the Virginia Port Authority, Virginia Maritime Association, and the Virginia Offshore Wind Coalition could convene to identify and determine the facilities, public or private, that could benefit the emerging offshore wind market. The willingness to repurpose private container terminals or other private waterfront facilities, as well as the possibility of re-purposing the Newport News Marine Terminal for offshore wind could be discussed. Considering its location near Newport News Shipbuilding and its interest and desire to be fully integrated into the offshore wind industry; this terminal could be ideal.

The Jones Act and Virginia's Opportunity

What is the Jones Act?

Also known as the Merchant Marine Act of 1920, the Jones Act prevents foreign ships from sailing between American ports (U.S.C. 46 § 861-889). Only U.S.-made and manned ships can deliver goods from port to port and install subsea cables.

Cranes on an offshore wind farm support vessel (Credit: Julochka / Blogger / CC BY-NC)

How is the Jones Act an opportunity for Virginia's shipbuilding industry?

There are no U.S.-made specialty sea vessels available for offshore wind installations. Virginia can begin production of specialty vessels to prevent installation bottlenecks along the east coast. Offshore wind requires several types of sea vessels for installation and maintenance: self-propelled jack-up vessels, jack-up barges without propulsion, heavy-lift vessels with working barges, and a specialized subsea cable installation vessel. These ships can be used for offshore wind development all along the eastern seaboard.

How many ships are needed for offshore wind projects and how long does it take to manufacture ships?

The London Array, a 630 MW wind farm, required 60 ships for installation. New vessel manufacturing can take up to 2.5 years from time of investment to time of use,
and conversion of ships takes about 10 months.

Sources:
Navigant Consulting, "U.S. Offshore Wind Manufacturing and Supply Chain Development," February 2013.
REVE, "Offshore wind power," July 2015.

Policy 7: Prepare Virginia's Ports to Meet the Needs of the Offshore Wind Supply Chain With Funds From the Virginia Transportation Infrastructure Bank

Before development of offshore wind turbine farms can begin, the Commonwealth will need to build specialty ships to facilitate the installation process and begin manufacturing wind turbines near the coast. Virginia's ports are not currently prepared to handle this increase in manufacturing activity and shipbuilding infrastructure. Port upgrades are badly needed.

The Commonwealth already has at least one mechanism in place to fund port upgrades: the Virginia Transportation Infrastructure Bank (VTIB). The framework for VTIB was created in 2011 by the legislature to finance transportation projects including ports, airports, toll facilities, mass transit, railways and other transportation facilities.[49] VTIB is a revolving loan fund that comes from private and public funds, the latter of which come from the Transportation Trust Fund—a pool of funds from motor fuel tax, road tax, license fees, and state general sales tax.[50] Without amending the authorizing legislation, the Commonwealth Transportation Board could approve VTIB funding for infrastructure related to the manufacture of sea vessels used for offshore turbine components.[51]

Chapter Summary

With its stated commitment to offshore wind, its strategic ports and its prime location, Virginia has the opportunity to lead the Atlantic states in offshore wind manufacturing and production – but the Commonwealth must act quickly. Offshore wind is projected to grow to 20 GW by 2030, and those products will be supplied by businesses somewhere—the question is whether Virginia will act to capitalize on its natural advantages. Although the Commonwealth has made some progress in its renewable energy policies, its lawmakers have several opportunities to improve the existing policy infrastructure to maximize the economic benefits Virginia receives from its investments.

Chapter 3: Carbon Fiber Composite Materials

Virginia's Carbon Fiber Composites Future

The year is 2035; former Sergeant Geoffrey Wallace puts his truck into drive and hits the gas pedal with his carbon fiber reinforced polymer (CFRP) composite prosthetic leg, a much lighter version than the heavy aluminum kind he used after returning from Afghanistan. Geoffrey drives past the gas station, a place that gets a lot less of his money since he bought his new truck. Because it has a CFRP composite body, he spends half as much on gas bills each month.

Geoffrey pulls into the parking lot of the CFRP composite wind turbine blade manufacturing facility, where he has worked for the past 15 years. The factory floor extends as far as the eye can see and is as spotless as a surgery ward. The space is filled with wind turbine blades, each the size of an 18-story tall building. Today, another 12 blades are ready for transport to the port—a process that used to require twice the time, money, manpower, and equipment when heavy fiberglass blades were used. Thanks to Virginia's CFRP composite and offshore wind manufacturing initiatives, Geoffrey received specialized workforce training, which equipped him to rise to a senior-level operations manager in this burgeoning industry.

Tomorrow, he will board a CFRP composite plane for a vacation to Key West with his wife and daughter—a vacation they're paying for with the money they've been saving on gas. When Geoffrey was his daughter's age, most of the things he used in his daily life were made overseas. It was hard to find anything bearing the label "Made in America." How times have changed. Geoffrey's truck, his leg, and the plane he'll be flying on were made not just in America, but in Virginia!

Identifying Virginia's Strengths, Weaknesses, Opportunities and Threats in the Carbon Fiber Reinforced Polymer (CFRP) Composites Sector

CFRP Composite Manufacturing in Virginia

STRENGTHS	WEAKNESSES
• Strong in-state defense industry • A robust manufacturing industry, with anchor companies such as BGF, DuPont, Dow, and Kevlar • The Institute for Advanced Composites Manufacturing Innovation (IACMI) and its partnership with 24 Virginia-based companies • Strategic location along shipping and logistics pathways for exports	• Lack of collaboration with IACMI by state officials • Barriers to entry include complicated taxes and cumbersome permitting
OPPORTUNITIES	**THREATS**
• Industry growth exceeds GDP growth rates • Foreign companies desire new U.S. manufacturing facilities • Vast end use potential, including wind turbines blades, transportation, construction, medical applications, satellites, and sports equipment[1]	• Competition for investment dollars from other IACMI states, including Tennessee, Ohio, Michigan, Colorado, and Indiana • Foreign competitors, including Japan and Germany, seeking to expand their carbon fiber exports • Lack of large-scale best practice models

What is Carbon Fiber?

Carbon fiber is a long, thin strand of pure carbon that is flexible and strong. It is made from precursor chemicals, such as PAN, which are heat treated and oxidized.

What is a Carbon Fiber Reinforced Polymer (CFRP) Composite?

Carbon fiber reinforced polymer composite is a material that is as much as five times stronger than steel, but weighs 60 percent less than steel. CFRP composites are made by weaving carbon fiber into a cloth, encapsulating the cloth in resin or plastic, and heat-treating it. The U.S. Department of Energy believes that carbon materials have the potential to replace steel in many applications, including vehicles and energy technologies.

Source: IBISWorld, "Carbon Fiber & Graphene Manufacturing in the US," August 2014.

CFRP Composites: A Building Block for Efficiency

CFRP composites' ultra light weight and high strength enable efficiency in many technologies. Automobiles and aircraft will require less fuel due to decreased weight. In wind power generation, lighter, longer blades can increase power output and ease the burden of transporting large blades.

Source: TMS Energy, "Materials," 2012.

Spooling of carbon fibers (Courtesy of BMW Group, Germany)

Demand for CFRP Composites Is on the Rise

Carbon fiber reinforced polymer (CFRP) composites are next-generation materials five times as strong as steel but two-thirds the weight.[2] Demand for carbon fiber is predicted to double from 2014 to 2020,[3] growing to over 100,000 tons by 2020.[4] CFRP composites are currently used in sports equipment like golf clubs and mountain bikes, or high-end vehicles like the BMW i8.[5] Demand for the strong, lightweight material is on the rise in many industries including transportation, infrastructure, energy, and recreation.[6] Market analysts project the CFRP composite materials market will grow to up to $25.2 billion by 2020,[7] increasing at a rate of nearly 12 percent per year.[8] In the automotive carbon fiber market, where lower weight but high strength corresponds to greater fuel efficiency, explosive innovation and growth are expected. Market analysts predict CFRP composites will be the standard for vehicle use by 2025.[9] The U.S. Department of Energy projects that by 2030, CFRP composites will be the status quo for performance and sustainability standards in the automotive industry.[10]

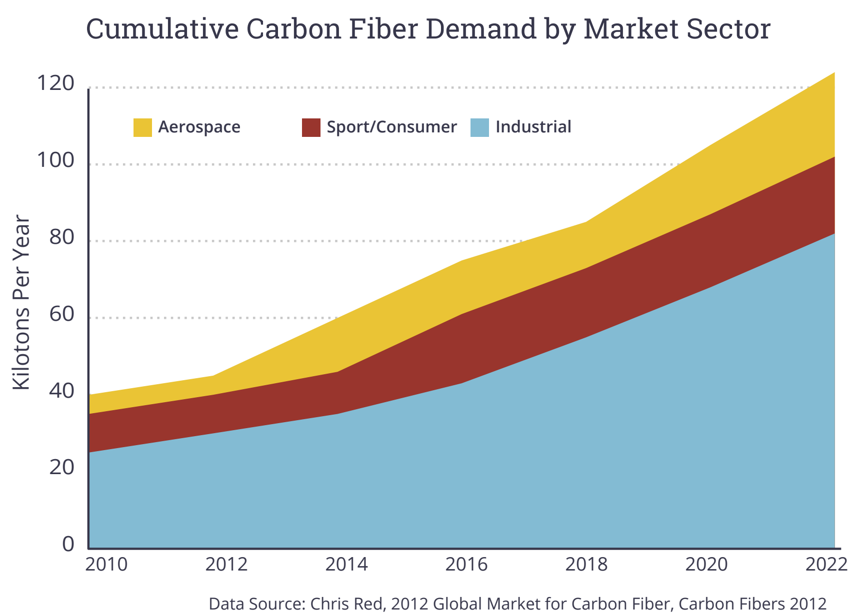


Figure 6. Carbon fiber demand will increase most in the industrial sector

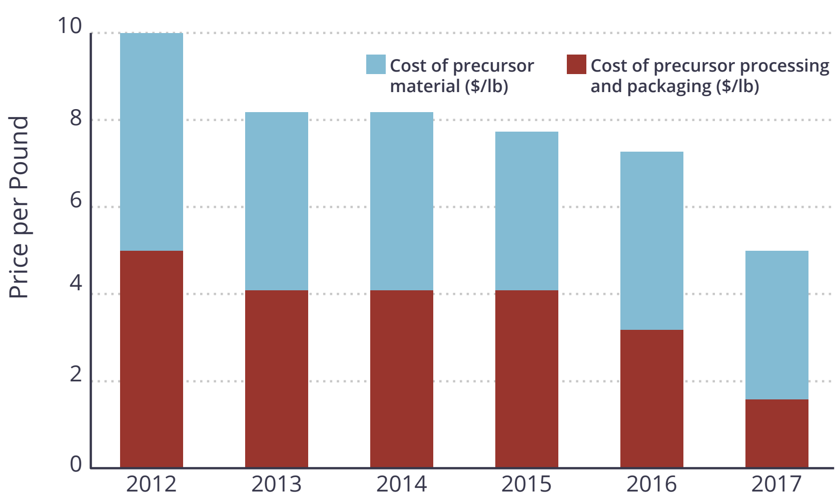
As global demands for carbon fiber increase (Figure 6), the foreign export market is also a significant opportunity for CFRP composite manufacturing. In 2014, the U.S. exported $630 million of carbon fiber and export opportunities continue to rise, with Italy and Canada as the top foreign customers.[11] Virginia's strategic shipping location gives the Commonwealth a competitive advantage to manufacture and export across the globe.

Falling Costs of Carbon Fiber

CFRP composites cost about $15 per pound,[12] which can range from 1.5 to 5 times the cost of steel.[13] While the cost of carbon fiber is more expensive than steel, CFRP composite vehicle owners will save up to $5,000 on fuel costs due to 50 to 70 percent weight reduction.[14,15] Considering the life cycle cost of a good, such as fuel or maintenance, durable goods like vehicles and air transport may have lower life cycle costs when manufactured with CFRP composites, despite a higher upfront purchase price.

Although CFRP composite goods are currently relatively expensive, the cost of the material is projected to dramatically fall—up to 67 percent by 2030—as new research reduces the cost of input materials and manufacturing processes[16] (Figure 7). This projected drop in price to $5 per pound will make carbon fiber cost competitive with steel cars.[17] Due to various fixed and variable costs for steel manufacturing, CFRP composite autos will reach cost parity with steel at $4 per pound.[18]

As Precursor Price Falls, the Cost of Carbon Fiber Drops



Data Source: Lux Research, Stronger, Lighter, Faster...Cheaper? How Innovation Will Affect Carbon Fiber's Cost and Market Impact, September 2012

Figure 7. As the cost of precursor materials drop, the cost of carbon fiber will fall

The high cost of a CFRP composite is due to expensive materials, like chemical precursors, used in the production process (Figure 8). Private and public sector research on new processes and materials for CFRP composite production will lower costs to under $5 per pound in 2017.[19] As of 2012, Dow Chemical is researching new techniques and materials to increase yield of CFRP composites,[20] while Oak Ridge National Laboratory investigates plant-based materials to lower cost.[21] In Colorado, the Rocky Mountain Institute (RMI) emphasizes better supply chains and increased information sharing in business process flows. RMI believes that with streamlined collaboration between

Companies Collaborate to Bring CFRP Composites to Market

In recent times, more companies are uniting to develop solutions to the high price of carbon fiber composites. BMW and Boeing established a partnership to share manufacturing knowledge and jointly research recycling technology. GM and composites producer, Teijin, are collaborating to produce low-cost carbon fiber sheet molding compounds. Ford and DowAska—a Turkish composite producer—recently announced a partnership to reduce the cost of raw materials and improve the CFRP composite production process. DowAska established its U.S. base in Georgia and plans to open a manufacturing facility in the next 3-5 years.

Sources:

CompositesWorld, "DowAska to establish U.S. carbon fiber manufacturing presence," November 2014;

PR Newswire, "BMW Group and Boeing to Collaborate on Carbon Fiber Recycling, December 2012;

William Blair, & Co., "Sector Update," February 2015.

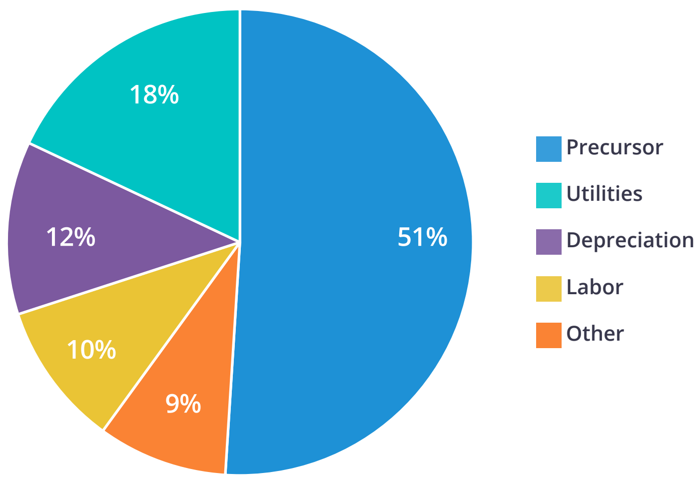
Carbon Fiber: How its Made and Future Uses

The Precursor Is an Expensive Beginning	CFRP composites begin as a rayon or spun polyacrylonitrile strand known as a precursor—a long filament of some basic material that has a high carbon content. The most common precursor is polyacrylonitrile (PAN) which makes up 89 percent of source material for carbon fibers and is expensive.
Precursor Is Processed, Resulting in Spools of Carbon Fiber Thread	The precursor is exposed to extreme heat in an inert gas to activate carbon-to-carbon bonding until the entire strand crystalizes into a single columnar filament. High-carbon filaments (typically 95 percent carbon) are bundled into flat bands made of several thousand filaments and sold for commercial use on 5 - 25 pound spools.
Carbon Fiber Thread Is Woven	Fiber is woven into fabric sheets of varying thickness and weaving patterns. Sometimes fabrics are blended with other high-strength synthetic fibers. Fabric is sold on rolls to component makers.
Epoxy Resin Is Added for Compressive Strength	Manufacturers add epoxy resin to the fabric. The resin binds the material and gives it strength and insulation.
Coated Fabric Is Vacuum Sealed, Molded, and Trimmed	The coated fabric is set in the mold, then vacuum-sealed before curing at high temperatures. Once the curing is complete, the product is removed from the mold before any necessary trimming and drilling.

End Uses and Benefits for CFRP Composites

TRANSPORTATION	ENERGY	MEDICAL
CFRP composites can reduce vehicle weight 50-70 percent, and are predicted to be the standard for vehicle use by 2025.	Wind turbine blades made of CFRP composites can increase efficiency and decrease transportation costs.	CFRP composites prosthetics are increasingly common for good reason—they give strength without the weight of metal.

Breakdown of Carbon Fiber Manufacturing Costs



Data Source: Warren, Dave. 2010. Low Cost Carbon Fiber Overview. Oak Ridge National Laboratory

Figure 8. Precursor materials for carbon fiber make up most of its cost

industry, science, and government, automotive components will be mass produced on a scale of 50,000 or more units by 2018.[22] An increase of CFRP composite adoption at that scale could have big impacts on fuel efficiency nationwide: every 10 percent reduction in vehicle weight will improve vehicle fuel efficiency by up to 8 percent for internal combustion engines and 10 percent for electric vehicles.[23]

CFRP Composite Employment Potential

As demand for CFRP composites rises, Virginia has the opportunity to expand the CFRP composites economy, increase in-state spending, and employ an average of over 5,000 Virginians annually over the next fifteen years. If Virginia's CFRP composites companies are able to increase their national market share to 10 percent and consolidate the supply chain in state, over 75,000 direct, indirect, and induced job-years would be supported. While nearly 35,000 of those would be direct job-years in the state's CFRP composites industry, over 40,000 indirect and induced job-years would also be supported.

These projections for job-years potential in the carbon fiber industry come from national estimates on future demand by McKinsey and industry benchmarks for employment and supply chain expenditures through IBIS World. Based on these national projections, we estimated the direct and induced jobs created using the Jobs and Economic Development Impacts (JEDI) model.

What is a Job-Year?

A job-year is one full-time equivalent job for one year (i.e., forty hours per week for fifty-two weeks, which is 2,080 hours per year). If two people each work a part-time job for twenty hours per week for fifty-two weeks, this is counted as one full-time equivalent job for one year (i.e., one job-year). If one person works forty hours per week for ten years, this is counted as ten job-years.

Why Use Job-Years?

By using job-years, our analysis can take into account the length of a job. In energy projects, many construction and installation jobs are short-term, while manufacturing and maintenance jobs may be long-term. Using job-years allows us to accurately count both types of jobs. For example, if ten full-time technicians are expected to each spend 208 hours on a CFRP composite project, this is measured as one job-year. Alternatively, if one full-time engineer is expected to spend fifteen years working for a CFRP composite company, this is measured as fifteen job-years. In our analysis of Virginia's supply chain, total job-years are aggregated over the 2016 to 2030 period.

Local Share

Local share is the percentage of expenditures that are spent in Virginia. For example, if a CFRP composites company plans to spend $3 million on imported materials and $1 million on additional supplies from companies in Virginia, the local share is 25 percent. In the JEDI model, local share is an independent variable.

Direct, Indirect, and Induced Job-Years

In order to estimate the potential economic impact of Virginia's CFRP composites supply chain, direct, indirect, and induced job-years are measured.

- **Direct job-years:** reflect jobs created in the CFRP composites industry to meet demand
- **Indirect job-years:** reflect jobs created at supply chain companies resulting from increased transactions as supplying industries respond to increased demand from Virginia's CFRP composites industry.
- **Induced job-years:** reflect jobs created throughout the local economy as a result of increased spending by workers and firms in Virginia's CFRP composites industry and in supply chain industries.

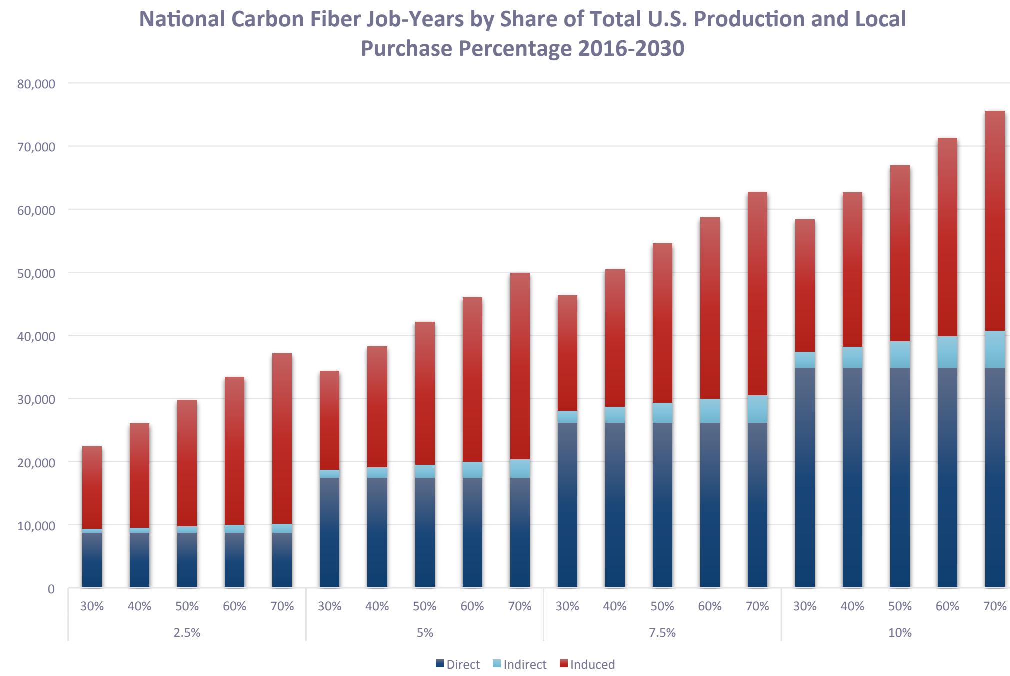


Figure 9. As local supply chain purchases increase more Virginians will work in the CFRP composites sector.

To highlight why growing the CFRP composites industry in Virginia is so important, we have estimated the number of direct, indirect, and induced jobs based on future demand and the percentage of supply chain purchases made within the state. The figure shows the number of direct, indirect, and induced jobs based on local shares of 30 percent, 40 percent, 50 percent, 60 percent, and 70 percent. Since Virginia also has the opportunity to grow its carbon fiber market share, we estimated the number of direct, indirect, and induced jobs based on the market shares that range from 2.5 percent to 10 percent of expected national demand. This range is consistent with market share of other states in the United States. Figure 9 shows how the number of job-years vary as market share and local share change.

Increasing Virginia's share of the national carbon fiber market and consolidating the supply chain locally would create thousands of jobs for Virginians. Over the next fifteen years, increasing Virginia's market share of the CFRP composites industry to 5 percent and increasing the local share to 50 percent would support over 17,000 direct job-years and over 24,000 indirect and induced job-years. With a 7.5 percent market share and a 60 percent local share, Virginia's CFRP composites industry could support over 26,000 direct job-years and over 32,000 indirect and induced job-years between 2016 to 2030.

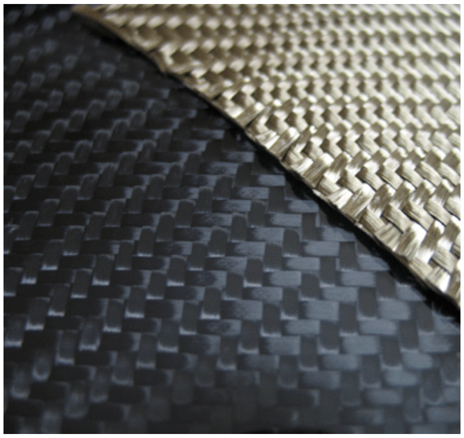
If a concerted effort were made by the state to expand the CFRP composites cluster, Virginia companies could increase their market share and the local share of spending. A 10 percent

Table 2. Companies in the Virginia Materials Supply Chain

COMPANY	LOCATION	CLUSTER ROLE
Honeywell	Richmond	Primary chemical resources and filaments
DuPont	Richmond	Primary chemical resources and filaments
BGF Industries	AltaVista	Fiber weaving
Strongwell Composites	Bristol	Composites structural extrusions
General Dynamics	Marion	Composites structural forming production
Vought Aircraft / Triumph Aerospace	Newport News	Composites structural forming production
Euro-Composites Corp	Elkwood	Maker of honeycomb, and hollow core composite panels
Aurora Flight Sciences Corporation	Manassas	Aircraft manufacturer with expertise in the manufacture of composite vehicles structures
VASCIC	Newport News	Shipbuilding experts

Figure 10. The carbon fiber supply chain is clustered near Suffolk, Hampton Roads, Lynchburg, and Richmond

Heating of precursor materials into carbon fibers (Courtesy of the Oak Ridge National Laboratory, DOE)



Sheets of woven carbon fibers (Credit: Racingjeff / Wikimedia Commons)

Carbon-fiber prosthetics can aid injured soldiers (Source: DVIDS Archive)

market share and a 70 percent local share could support over 75,000 job-years, employing an average of over 5,000 workers per year. Increasing the number of CFRP composites manufacturers, service companies, and supply chain businesses can create thousands of good-paying, skilled jobs and make Virginia a leader in the CFRP composites industry.

Virginia's Lightweight Materials Industry

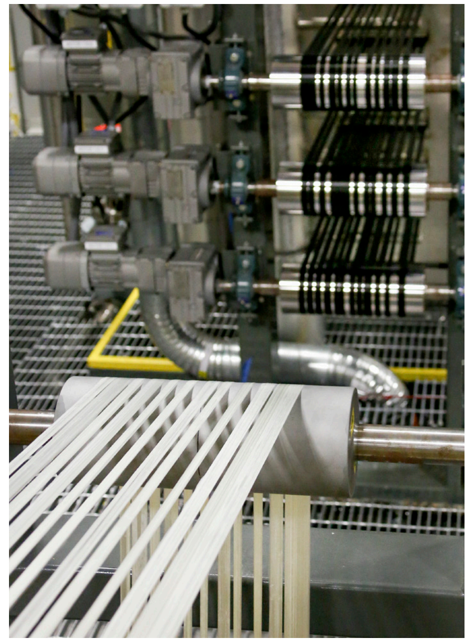
CFRP composite production is a nascent industry, with only a few production facilities in the United States. Virginia has advantages in its CFRP composites supply chain due to its anchor companies, strategic location and diversity of companies involved with carbon fiber (or similar fiber) production. Gaps in the CFRP composite supply chain, like the lack of a carbon fiber filament production facility, represent growth opportunities for the Commonwealth.

Virginia's Supply Chain Strengths: Fabric Weaving and Component Forming

Virginia's advanced materials supply chain is anchored by large firms such as Dow Chemical and DuPont, but firms of all sizes and at all steps of the production process are involved with carbon fiber (or similar fiber) production in Virginia. While large-scale companies produce similar materials, such as Kevlar, at economies of scale, midsized companies weave fibers into fabrics, and smaller companies create automobile bodies from CFRP composites. Firms like BGF, a global manufacturer of high performance materials located in Alta Vista, give Virginia a head start in composite fabric weaving and component forming. The Commonwealth also has a strong demand from end users ranging from small firms such as Feather Carbon in Suffolk, which produces carbon fiber automotive body panels, to larger aerospace firms such as Triumph Aerospace in Newport News and Aurora Flight Sciences in Manassas.

In addition to the variety of businesses working with CFRP (and similar) composites, Virginia has several institutions involved with advanced materials research. DuPont Chemical has research and production operations in plastics at its facility in Richmond. Virginia Tech has several centers working on the next-generation of materials including the Center for High Performance Manufacturing, the Center for Intelligent Materials Systems and Structures, and the Renewable Materials Research Group. University of Virginia also houses materials research in the Commonwealth Center for Advanced Manufacturing. Moreover, Virginia is close to the new Institute for Advanced Composite Manufacturing Innovation, a $250 million public-private collaboration in Tennessee that includes 24 Virginia-based firms.[24]

Although the Commonwealth has advantages in its supply chain like its anchor companies, research and development, and strategic location, Virginia has opportunities to fill gaps in the CFRP composite supply chain. For example, Virginia industries demand large quantities of carbon fiber to make CFRP composites, yet the Commonwealth does not have an in-state carbon fiber plant, forcing it to import carbon fiber from other locations. Having an in-state producer of carbon fiber would strengthen the cluster and allow manufacturing, construction, and supporting industries to profit from this rapidly expanding technology. The Governor's office or local leaders could recruit global companies to establish manufacturing facilities to fill the gaps in the CFRP composite supply chain, including bringing a carbon fiber filament production facility to the Commonwealth.



Precursor materials (Courtesy of Oak Ridge National Laboratory, DOE)

Policy Recommendations

Policy 1: Continue to Expand Virginia's Global Push

Virginia's Foreign Direct Investment (FDI) missions have attracted major international companies to Virginia.[25] One recent FDI success was the commitment by Tranlin, a Chinese paper company, to invest $2 billion, which will bring 2,000 jobs to the Commonwealth.[26] By targeting carbon fiber manufacturers on overseas FDI missions, the Governor, mayors, and business leaders can strengthen the cluster and continue to bring jobs to Virginia.

In an effort to strengthen Virginia's businesses and expand exports, the Virginia Economic Development Partnership launched the Going Global campaign in 2013.[27] Going Global sends defense contractors overseas to pitch their knowledge and expertise to potential customers. The result? New contracts and partnerships in countries such as Australia and Brazil.[28]

FDI TARGETS	HEADQUARTERS
DowAska	Turkey
Toray Composites	Japan
Mitsubishi Rayon Group	Japan
SGL Group	Germany
Quickstep Composites LLC	Australia

Carbon fiber structure of the BMW i3 (Credit: Mario Roberto Duran Ortiz / Wikimedia Commons)

The Going Global Initiative has been successful at connecting firms with opportunities to export their skills, but the initiative could be expanded to also connect defense contractors with promising FDI targets that could fill supply chain gaps. For example, Virginia's Going Global Initiative could connect aerospace contractors that need lightweight materials with foreign carbon fiber manufacturers that would be likely to invest in opening facilities in the United States. By expanding the mission of Going Global, defense companies will continue to benefit from pitching their skills overseas and will be able to connect with FDI targets, potentially bringing billions of dollars of investments and thousands of jobs in the CFRP composites industry to the Commonwealth.

Ultra-light bike using braided carbon fibers (Courtesy of www.pg.de)

Policy 2: Join the Institute for Advanced Composites Manufacturing Innovation (IACMI) and Create a Composites Council

The newly minted Institute for Advanced Composites Manufacturing Innovation (IACMI), a $250 million public-private research institute, presents an opportunity to attract businesses and investment dollars to the Commonwealth.[29] To date, 24 Virginia-based companies are participating in the IACMI,[30] but there has been no participation from the Executive Branch, the Chamber of Commerce, or any other economic development organizations in the Commonwealth. The Virginia Department of Commerce could officially participate in the IACMI, centered just across the border in Tennessee.

What are the benefits of participating in IACMI? Jobs. Participating companies are more likely to partner with other participants. In fact, since the announcement of IACMI in January 2015, major American manufacturers, including Ford, have already announced partnerships with composites companies.[31] Likewise, foreign firms, including DowAska, have announced new operations in the United States.[32] If Virginia fails to engage with IACMI's research, advocacy, business, and government stakeholders, the Commonwealth will be at a competitive disadvantage. Participating in IACMI can help Virginia bring in new business and good-paying jobs. Virginia's Department of Commerce, Virginia's Manufacturers Association, and other economic development agencies in the Commonwealth should consider joining the institute, which can be done by simply visiting the IACMI website.

Additionally, the Governor could establish a Composites Council with leaders from the office of the Secretary of Technology, research institutions and industry to guide Virginia toward CFRP composite opportunities. This is a low-cost, straightforward way for Virginia to keep up with current manufacturing trends, develop strategies for bolstering demand, fill supply chain gaps, and meet companies that are seeking to set up new U.S. operations.

Policy 3: Host an Advanced Materials Technology Competition and Hackathon

Virginia could capitalize on its strong innovation ecosystem—or research and business start-up environment—to stimulate Virginia's market for CFRP composites. The Commonwealth could institute an annual Carbon Fiber Composites Competition and Hackathon to ignite the in-state market for carbon fiber.

Governments, businesses, and institutions have used hackathons and competitions to creatively engage citizens to stimulate the economy, create new products, and solve problems in a variety of fields. For example, the Entrepreneur Challenge at UC San Diego offers a $100,000 prize to encourage innovation in the biomedical field.[33] Participants in GE Appliances' 33-hour Mega Hackathon invent the next generation of appliances in a state-of-the-art advanced manufacturing facility.[34] In DOE's annual Cleantech UP Collegiate Competition, student teams compete for prize money, while receiving business and commercialization training from major research universities.[35] In August 2014, Maryland led its first hackathon, DataBay Reclaim the Bay Innovation Challenge.[36] About 80 local entrepreneurs and technology leaders competed to develop and pitch innovative, data-driven solutions to solve the Chesapeake Bay's chicken litter pollution.[37] Virginia could take best practices from existing successful competitions and hackathons to develop its own CFRP composites competition and hackathon.

Virginia's Carbon Fiber Composites Competition and Hackathon could accomplish a variety of goals. The competition could partner existing businesses with university research teams and lightweight materials companies in the Commonwealth's supply chain to improve existing products by integrating CFRP composites. The hackathon could incorporate methods to reduce cost or improve manufacturing software. The Composites Council could create guidelines and choose winners based on the best prototype and pitch. Winners could receive monetary award to produce a prototype as well as gaining connections to potential investors. Virginia could use its newly-appointed Foundation Liaison (see Chapter 4, Innovation Ecosystem and Access to Capital) to fund the competition.

What is a Hackathon?

A hackathon is traditionally an event in which computer programmers, graphic designers, and project managers collaborate on software projects that last anywhere from a day to a week. Hackathons now extend beyond solving software issues and are used by institutions to solve social, environmental, and technical problems.

Streamlined permits boost production (Alexis Powers / NREL)

Policy 4: Create an Online Platform to Streamline Permits and Allow Local Cost Comparisons

Virginia's Business One Stop is a simple, easy to use website to walk business owners through the steps of opening a business in Virginia. The Commonwealth has streamlined most of the steps, but one step is notoriously difficult: obtaining permits and licenses. Calling all of the departments and offices recommended by the website can lead to countless hours on the phone without answers. Getting that far assumes a business owner has been able to determine where to locate her business, a tough decision when taxes can vary greatly from one locality to another. These are just some of the many soft costs, or indirect costs, that include supply chain costs, installation labor, customer acquisition, permitting, inspection, interconnection, subsidy applications and system design costs. For some manufacturing firms, soft costs can total up to 600 percent of the cost of labor,[38] a huge barrier for new businesses.

New York City's Business Express Wizard

New York City has reduced soft costs by developing seamless, hassle free online platforms that combine local, state, and federal permitting requirements for businesses. The NYC Business Express Wizard is a free, online application that combines city, state and federal-level permits, regulations and licenses for specific businesses. Businesses can even track statuses of permits and pay fees.

(Source: NYC Business Express)

Reducing red tape and streamlining services has been identified as a top priority from states across the nation.[39] Soft costs in Virginia could be reduced by developing a similar, streamlined permitting website. Virginia can expand on the NYC Business Express Wizard model by creating an innovative platform to help businesses owners decide which Virginia location is right for their company. The Business One Stop website could link to a Turbo Tax-like portal that walks business owners through permitting and regulatory requirements, allows owners to compare local tax rates and key statistics, and lets business owners explore local incentives and programs. If it is easy to compare local business environments side by side, cities could compete to be the best place to do business in Virginia. Statewide leaders could appeal to foundations in the state to fund the development of such a site.

Policy 5: Expand Local Implementation of “Defense Production Zones” to Cluster Companies

In 2011, the Virginia Legislature passed SB 99, which created local Defense Production Zones.[40] Local towns, cities and counties have the authority to establish, design, and administer a unique defense zone ordinance to attract defense-related businesses. Incentives for companies include reduced permit fees, reduced gross receipts tax, and permit process reform and can last up to 20 years—a major competitive advantage for companies looking to expand in Virginia.[41] To date, only a few municipalities have passed rules to create defense zones. Manassas Park adopted a Defense Zone in 2012[42] and Fauquier County established a Defense Production Zone in 2014.[43] Localities could use defense zones to provide incentives to CFRP composite manufacturers.

Nearly 10 percent of CFRP composite revenues come from defense.[44] Key defense assets, such as the F-22 and F-35 fighter planes are made of CFRP composites.[45] CFRP composites are also used in helicopters, helmets, body armor and other military equipment.[46] For decades, the Department of Defense (DoD) has sought to decrease fuel consumption, an objective that can be achieved through the expanded use of CFRP composites.[47] DoD research facilities, such as the U.S. Army Aviation and Missile Research, Development and Engineering Center’s (AMRDEC) Advanced Composites Lab, are preparing for the wider transition to composite materials.[48]

The Virginia Economic Development Partnership and Composites Council could prepare to meet the growing demand for CFRP composites from the Department of Defense by working with localities to expand the use of Defense Production Zones. Areas with large research institutions could be prioritized to expedite the transfer of cutting-edge ideas and technology to the marketplace. Expanding the use of Defense Production Zones would make Virginia more attractive to composites companies that manufacture lightweight materials used in defense applications and bring skilled, middle class manufacturing jobs to Virginia.

Virginia Beach: A City That Doesn't Collect the Manufacturing and Tools Tax

Local governments could choose to phase out the M&T tax entirely, as was done in Virginia Beach, a region that employs more than 55,000 skilled workers who produce items like medical equipment and power tools. In 2010, the Virginia Beach city council voted to remove the M&T tax, which had brought in less than $1.5 million per year in city revenue—a tiny fraction of the city's $1.9 billion budget. In 2011, the tax was set at one millionth of one cent per $100, a nuisance tax not collected by the city. Localities can choose to phase the M&T tax out to stimulate their local manufacturing economy.

Sources:

City of Virginia Beach, "Tax Rates and Due Dates."

PilotOnline.com, "Va. Beach to phase out machinery and tools tax," October 2010.

Virginia Beach Economic Development, "Advanced Manufacturing."

Policy 6: Update the Machinery and Tools (M&T) Tax to Include a Separate Classification of Equipment Used Directly in Producing Energy Efficient Products or Materials

CFRP composite manufacturing requires heavy machinery and tools, which are taxed at high rates in some localities in the Commonwealth. A statewide legislative action to remove the M&T tax on items that produce efficient materials, including CFRP composites, will incentivize manufacturing firms to move to Virginia.

The Virginia Legislature could update § 58.1-3508.6, the Machinery and Tools (M&T) Tax, to expand the existing exemption on renewable energy production. Specifically, the exemption could be broadened to include equipment used for efficiency purposes, including CFRP composites manufacturing. The M&T tax is paid annually to localities where the machinery and tools are taxed as a percentage of the original cost of the equipment.[49] Assessment rates vary greatly,[50] with some localities having a higher M&T tax rate than the personal property tax rate.[51] In March 2015, the state legislature approved and the Governor signed the removal of the M&T tax on equipment used in renewable energy production.[52] This measure will help drive production of wind energy; however, it will not drive other industries such as efficient materials.

Chapter Summary

Carbon fiber reinforced composite materials will experience rapid market growth and Virginia has the potential to support 5,000 jobs per year through 2030. With Virginia's existing materials industry, it is primed to enter the emerging CFRP composite market. Strategies like streamlining local permitting processes and engaging with nationwide institutes like IACMI, will connect Virginia to this emerging industry, thus facilitating economic growth.

Chapter 4: Innovation Ecosystem and Access to Capital

In today's competitive, globalized economy, businesses are most likely to thrive in cities and states that offer a rich innovative ecosystem and that break down barriers to capital. A successful innovation ecosystem bridges the divide between the knowledge economy and the commercial economy to promote research and development, bring new technologies to market, and incubate early stage businesses.

Allowing ideas to be easily transferred from the lab to the marketplace accelerates further entrepreneurship and job creation. Essential elements of robust innovation ecosystems include efficient intellectual property protection mechanisms, mentoring for entrepreneurs, and engagement of business and venture capital.

Access to capital is critical for the success of advanced energy clusters, especially ones as capital intensive as offshore wind and CFRP composites. New and growing businesses will face severe financial hurdles during expansion unless action is taken by state and local leaders to expand access to capital.

Seamless connections between researchers and entrepreneurs and access to investors are vital for advanced energy clusters. The new energy economy is a race – and the winners will be able to bring innovative ideas to the marketplace as quickly and efficiently as possible.

"One of the reasons the innovation sector still creates plentiful jobs is that it continues to be a labor-intensive sector, since the main production input in scientific research is human capital—in other words, people and their ideas."

–Enrico Moretti, "The New Geography of Jobs"

Innovation Ecosystem

- Promotes research and development
- Facilitates new technology to market
- Incubates early-stage businesses

Access to Capital

- Provides funding for new and growing businesses
- Connects investors with market opportunities
- Attracts entrepreneurs

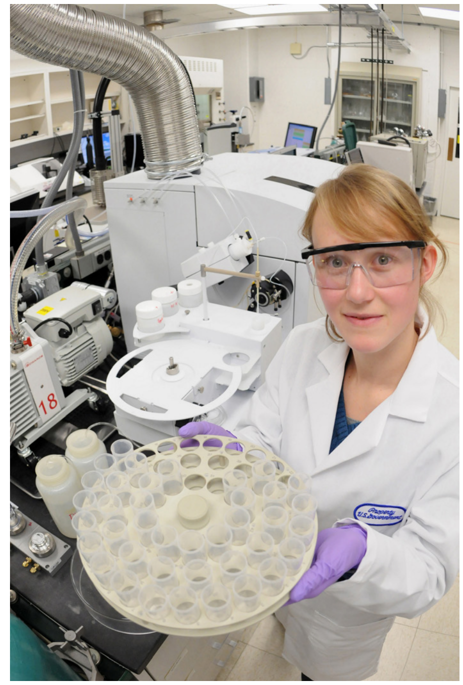
Virginia's Innovation Ecosystem

Virginia's innovation ecosystem is robust, with strong research universities and incentives to assist small businesses. In the 2014 Clean Tech Leadership Index, Virginia was one of the top seven states in the Human and Intellectual Capital category for having a DOE lab, a business school with a top-ranked green MBA program and at least one clean energy incubator.[1]

Research Institutions

Virginia's competitive advantage comes from its many world-class research institutions, including national labs, state research universities, and private research institutions. Virginia Tech ranks consistently in the top decile for research and development expenditures, total federal obligations, full-time graduate students, and doctorates earned.[2] Northern Virginia is home to several federal research institutions that can add value to CFRP composites and offshore wind energy. The Center for Naval Analyses (CNA) in Alexandria works with aviation technology and studies resources, operations, and logistics. The offshore wind industry's complicated logistical needs can learn from CNA's expertise.

The Commonwealth Center for Advanced Manufacturing is a partnership between Rolls Royce and Virginia universities to accelerate product development and technology transfer. The 60,000 square foot facility for research scientists and doctoral students from the University of Virginia, Virginia Tech, and Virginia State University is a center for developing and testing products.[3] Virginia's robust research environment is a major advantage to creating strong CFRP composite and offshore wind innovation clusters.



Research of battery materials (Credit: Argonne National Laboratory / Flickr / CC BY-NC-SA)

Local Programs That Drive Innovation and Entrepreneurship

Virginia has an impressive suite of local programs geared to drive innovation and entrepreneurship, and is often rated as number one in terms of business climate.[4] Virginia is home to 35 business incubators, including both private-public partnerships and government funded incubators.

Existing Networking Partnerships. The Virginia Business Incubation Association (VBIA) is a networking organization that promotes small business development throughout the Commonwealth.[5] VBIA aims to increase public awareness about business incubation and nurture start-ups. The Virginia Innovation Partnership, associated with the University of Virginia and U.S. Chamber of Commerce, was a statewide proof of concept network to fund and prepare young innovators. From 2010 to 2013, entrepreneurs from various Virginia universities received grants and mentoring to bring their ideas to market.[6] The Virginia Small Business Development Center Network also connects entrepreneurs with capital, and small business owners to players in the innovation ecosystem, such as the George Mason Enterprise Center, community colleges, and private and public economic development authorities in 29 centers across the Commonwealth.[7]

Regional Cluster Strategies. Virginia has several established zones to encourage industry clusters that municipalities can build upon.

- The Virginia Enterprise Zone Program is administered by the Department of Housing and Community Development and offers grants for job creation and real estate property. Fifty-seven Enterprise Zones have been developed throughout the Commonwealth.[8]

- Foreign Trade Zones are a partnership with U.S. Customs and provide relief from paying customs on imported goods. Six Foreign Trade Zones are established in Virginia.[9]

- Technology Zones can be established by cities to attract certain industries, and the associated exemption from ordinances, fee waivers, and tax incentives can last up to 10 years.[10]

- Defense Production Zones are another type of local program enacted by cities or counties to attract defense-related business. Incentives, which include tax breaks and a reduction in permit fees, will last up to 20 years. Currently, Manassas Park and Fauquier County are the only regions to have a Defense Production Zone.[11]

Tax Incentives. The Commonwealth Capital Gains Tax Exemption incentivizes investment in early-stage biotechnology, technology, and energy startups within the Commonwealth of Virginia. The tax exemption expires in 2020, and provides exemptions on long-term capital gains throughout the entire life of the investment.[12] Virginia's angel investor tax credit is also designed to encourage investment in technology startups. The credit offers a 50 percent leverage or up to $50,000 an investor puts towards a qualified Virginia technology startup.[13]

Access to Capital

For entrepreneurs, access to capital is essential to grow their businesses and bring their products to market. Unfortunately, many entrepreneurs are not able to find the necessary capital to sustain their companies long enough to reach the commercialization phase. As shown in Figure 11, companies nationwide face funding shortages during the prototyping and commercialization phases. Because 75 percent of venture capital funding goes to companies in California, New York, and Massachusetts, companies in the other 47 states face even more funding difficulties.[14]

Venture Capital. Virginia is home to at least 24 venture capital (VC) firms.[15] In 2014, there were 75 venture capital deals in the state and investments totaled just over $475 million.[16]

Discretionary Funds/Grants. Several discretionary funds, such as the Governor's Opportunity Fund and Clean Energy Manufacturing Incentive Grant, enable the executive branch to incentivize firms that will benefit the economy.

Regional Revitalization Programs. Virginia has programs to revitalize regions formerly dependent on coal and tobacco. The Virginia Coalfield Economic Development Authority provides low interest loans to new businesses in seven counties of the far southwestern region of the Commonwealth.[17] Likewise, the Tobacco Region Opportunity Fund provides grants to localities in 34 southern Virginia counties of the tobacco producing region.[18] Funding is contingent on performance agreements, with required criteria such as capital investment and job creation.[19]

Small Business Loans and Bonds. A small business is eligible for these programs if they have less than $10 million in annual revenue, fewer than 250 employees, and a net worth of $2 million or less.[20] Programs include the Loan Guaranty Program and Industrial Development Bonds and are financed by the Virginia Small Business Financing Authority.[21]

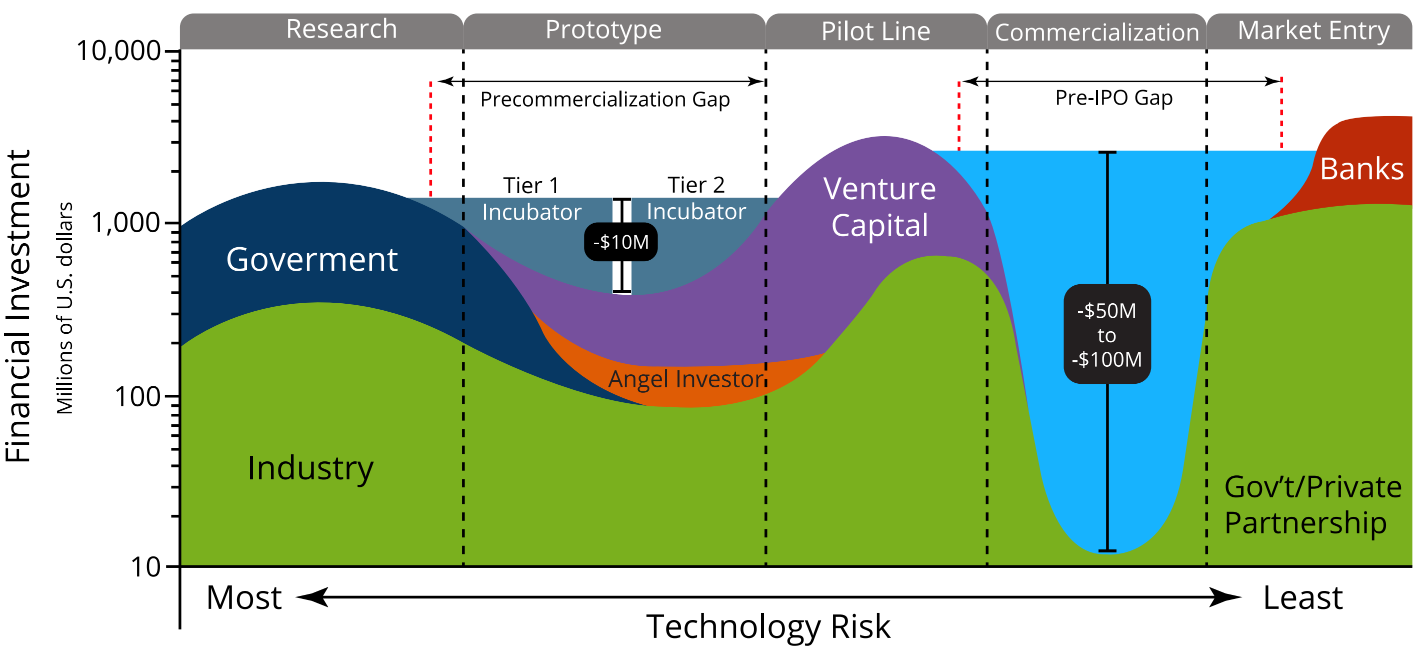


Figure 11. New technologies need help crossing the second "valley of death" during the commercialization process (Source: Department of Energy)

Renaissance Venture Capital Fund (RVCF)

The RVCF in Michigan is a great example of how business leaders, nonprofits, and the public sector can collaborate to boost venture capital and empower entrepreneurs in-state. Born in 2008 out of the nonprofit Business Leaders for Michigan's "Road to Renaissance" initiative, the RVCF aims to invest in the growth of innovative technologies and companies in the state.[24] The privately-run fund was able to raise $45 million to invest in Fund I,[25] which was leveraged to attract total investments of nearly $500 million to 23 Michigan companies.[26] The principal round created hundreds of new jobs with an average salary of $85,000.[27] The fund was so popular with investors that RVCF decided to launch a Fund II, which recently closed with a total of $79 million from private businesses, nonprofits, and state pension funds, all of which will be invested in Michigan.[28]

Policy Recommendations

If Virginia wants to be a national leader in offshore wind and CFRP composites, it needs to further build out its strong innovation ecosystem and expand access to capital. Creative solutions will bring technologies to market faster and jobs to the Commonwealth.

Policy 1: Establish a Fund of Funds

One crucial piece of a state's innovation ecosystem is its venture capital climate.[22] A robust venture capital culture helps entrepreneurs with ground-breaking ideas and new technologies to secure the capital necessary to grow their companies and create good-paying skilled jobs.[23] One strategy to attract top venture capitalists into a state is to establish a state or regionally focused fund of funds, which invests in venture capital funds rather than directly into companies.

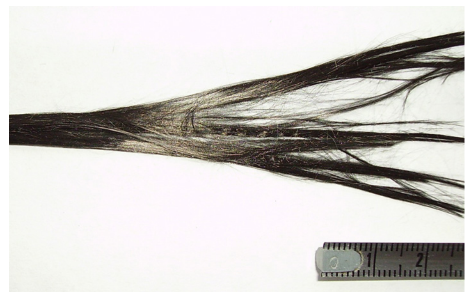
Another model for boosting venture capital is for states to establish a fund of funds seeded with public money and managed by a private venture capitalist. In 2013, Governor Scott Walker signed legislation to approve $25 million to seed the Wisconsin Badger Fund of Funds, which will invest in venture capital funds, which in turn will invest the money into early-stage Wisconsin companies.[29] The Fund has already raised the required additional $5 million in private capital and is currently considering investment options, but Wisconsin's commitment to venture capital has already sent strong signals to entrepreneurs and investors.[30]

While Virginia has funds like CIT (Center for Innovative Technology) GAP funds and the Commonwealth Energy Fund to seed investment in emerging technologies and renewable energy companies, it could do more to bring private investors to the Commonwealth. Virginia can launch its own initiative aimed at bringing investments from top venture capitalists in the country into home-grown technologies and startup companies. A regional or state-focused fund of funds that prioritizes positive returns and engages the business community is a proven, market-driven model for creating jobs and boosting economic growth. By mobilizing stakeholders in the business, nonprofit, and public sectors, Virginia can harness the potential of its ambitious entrepreneurs by attracting the nation's top venture capitalists, who bring knowledge, discipline, and expertise to promising early-stage companies.

Policy 2: Restore Funding for the Center for Innovation Technology (CIT)

Virginia has a strong record of successfully leveraging public dollars to help companies in the Commonwealth grow. The Center for Innovation Technology (CIT) is a public-private funding partnership that invests in technology, energy, and biotechnology startups within Virginia's borders.[31] CIT's four departments include CIT R&D, CIT Entrepreneur, CIT Connect and CIT Broadband. Via these four departments, entrepreneurs can receive funds to help their companies bridge the "valley of death." For example, CIT GAP funds underwrite early-stage financing for technology startup businesses in many sectors, including software and energy. CIT also funds the Commonwealth Research Commercialization Fund that advances science and technology based research and development. Another CIT fund is the Commonwealth Energy Fund for market-ready technologies such as solar, geothermal, wind, and transportation technologies like vehicles and components. Companies that have benefitted from these energy funds include ADI Engineering in Charlottesville, CavitroniX and WireTough in Bristol, Servhawk in Great Falls, and Sunnovations in McLean.[32] Unfortunately, state funding for CIT has dropped from $4.8 million in 2013-2014 to $2.8 million to the fund for 2015-2016.[33]

Spooling of carbon fibers (Courtesy of BMW Group, Germany)



Carbon fiber threads (Credit: Cjp24 / Wikimedia Commons)

Florida has demonstrated that investing retirement funds in early-stage companies yields high profits and creates jobs. State law allows up to 1.5 percent of the Florida Retirement System Trust Fund to be invested in technology and high-growth businesses in Florida.[34] As of 2014, the fund had committed to investing over $380 million in 27 technology and growth companies and 24 private equity funds.[35] Those investments have yielded an internal rate of return of 14.96 percent, distributing an additional $49.6 million to the retirement fund and creating over 11,000 jobs in 12 counties.[36] The investments in technology and growth companies have been especially successful, with an internal rate of return exceeding 20 percent.[37]

Like Florida, Virginia could leverage a small portion of the alternative investments in its $62 billion pension plan to invest in technologies that could bring a positive rate of return and benefit its beneficiaries.[38] The Virginia Retirement System Board of Trustees can work with CIT leadership to "invest the assets of the Retirement System with the care, skill, prudence and diligence" per Virginia Code § 51.1-124.30.[39] Wise investments could make a return and benefit both retirees and new Virginia businesses.

Policy 3: Launch a State Technology Transfer Challenge

As university technology transfer programs become an ever more important piece of a state's innovation ecosystem, many universities are revamping their technology transfer offices.[40] With the pace of innovation moving faster than ever before, having a slow-moving technology transfer office can drive away promising researchers. Providing resources aimed at allowing the best technologies to overcome barriers to commercialization as rapidly as possible makes the Commonwealth more attractive to researchers and businesses. Negotiating licensing on a case-by-case basis, as is done at Virginia Tech's Intellectual Properties Office, can hinder the ability of campus researchers to bring their ideas to the marketplace. In 2012, Virginia Tech only generated 32 license/option agreements and issued 27 patents, bringing in less than $3 million in revenue.[41]

Several state universities have revamped their technology transfer offices and are generating tens of millions of dollars in revenue for the university. Those schools have streamlined the commercialization process to offer a standardized licensing and revenue sharing agreement, instead of negotiating on a case-by-case basis. For example, the University of Michigan offers a standard revenue distribution policy that allocates earnings to inventors, the inventor's department (and school or college), and the central campus administration based on revenue tiers.[42] In 2014 alone, the Technology Transfer Office generated 148 license/option agreements, issued 132 patents, launched 14 startups, and generated $18.5 million in revenue.[43] Since 2001 the Office has brought about $230 million in revenue and helped create over 2,000 jobs.[44]

To attract innovative businesses and top-rated inventors to the state, the Governor could challenge all universities within the state to cut bureaucracy and streamline their technology transfer offices. Providing standardized licensing agreements would allow inventors to bring new technologies to the market as quickly as possible. That market advantage would attract researchers and businesses to the state and create jobs. To encourage public universities to lead the way, Virginia's legislature could launch a competitive grant program to increase public-private partnerships with state research universities that enhance the commercialization of home-grown technologies. Tearing down the barriers to commercialization will send a signal to businesses and researchers that Virginia is committed to cutting-edge research that can create jobs.

Policy 4: Increase Technology Investment Tax Credits

Encouraging investments in early-stage technology startups is essential for states to stay competitive and spur job creation. Many states use a variety of policy tools with this aim in mind. One best practice policy that has seen success in multiple states is a Technology Investment Tax Credit. A properly designed incentive tax credit can influence investment decisions and boost demand for investments in early-stage technology companies. Virginia's Angel Investment Technology Tax Credit is designed to encourage investment in startups, but is smaller than similar credits in other states. The program offers a 50 percent tax credit to investors in qualified Virginia tech startups. The tax credit is capped at $50,000 per investment, and there is a statewide limit of $4.5 million in credits per year.[45]

Virginia could consider increasing its current technology investment tax credit to make it competitive with other states. By creating a significant incentive, Virginia can help to funnel desperately needed investment capital into early-stage technology companies that will innovate and at least partially recoup lost revenue from the credit through increased revenue from new jobs and economic activity. Additionally, Virginia could provide an increased incentive for qualified businesses, as Kentucky does. For example, the Commonwealth could provide a 10 percent higher tax credit for investments in advanced energy companies. A targeted, enhanced tax credit for advanced energy would help spur investment in growing companies and create good-paying jobs for Virginians.

Policy 5: Appoint a Foundation Liaison

Virginia is home to numerous foundations that could be enlisted in the Commonwealth's efforts to create a robust innovation ecosystem and expand access to capital. Every year, foundations in Virginia award hundreds of millions of dollars in grants. Virginia foundations currently fund projects ranging from youth development to emerging energy technologies.

In Michigan, the Governor has a Foundation Liaison, a cabinet-level, non-partisan position. The Foundation Liaison works with the Governor, state legislators, federal officials, the business community, and foundations to build funding partnerships and strategic collaborations. Since 2003, the foundation community has invested over $150 million through partnerships brokered by the Foundation Liaison.[53] Investment priorities include Grades K-16 education, workforce development, and economic development. The Foundation Liaison and the office's staff come to the state on loan from participating foundations.

Ohio's Technology Investment Tax Credit

In 1996, Ohio pioneered a Technology Investment Tax Credit, a temporary tax credit with a $45 million aggregate cap.[46] Ohio's program allowed Ohio taxpayers who invested in early-stage, pre-approved, in-state technology companies to claim a credit worth 25 percent of the investment up to a maximum of $250,000 per company.[47] Over the credit's life of six years, 3,500 Ohioans invested approximately $180 million into more than 665 companies through the program.[48] The program was so popular that venture capitalists are now calling for its return after the cap was hit in 2013.[49]

In 2014, Kentucky followed Ohio's lead and established a similar credit but increased the tax credit to 40 percent of qualified investors in small startups.[50] Kentucky also limits the amount claimed in any year to 50 percent of an individual's total credits and allows a carry over for 15 years.[51] Kentucky's credit increases to 50 percent, from 40 percent, for investments in businesses in "enhanced incentive counties", counties that have been deemed by the state to have exceptionally high unemployment rates or to be among the most distressed counties in the state.[52]

Virginia State Capitol Building (Credit: Skipp Plitt / Wikimedia Commons)

Virginia should consider appointing a Foundation Liaison to connect with and leverage foundation efforts in the Commonwealth. Many of Virginia's foundations share the goals of engaging citizens, spurring business and serving the needs of the Virginia community. The Governor's office could reach out to the leading foundations in the Commonwealth and enlist their help in staffing the foundation liaison office. A key priority for the Foundation Liaison could be stoking cluster development and creating jobs. Via a Foundation Liaison, Virginia and its foundation community could leverage one another's investments and efforts; working together to promote businesses, innovation, and jobs.

Chapter Summary

Virginia has a strong innovation ecosystem: its entrepreneurs, researchers, venture capitalists, universities, and businesses have begun to link steps needed to turn new technologies into market-ready products. However, Virginia can do more to bring new ideas to market. Fiscally responsible policies such as a technology transfer challenge and a private fund of funds will capitalize on Virginia's strong research environment, helping to turn researchers' discoveries into new businesses across the Commonwealth.

Chapter 5: Workforce Development for Offshore Wind and Carbon Fiber Composites

Trained and skilled workers are fundamental to the success of an industrial cluster. Sector-based workforce development goes hand-in-hand with cluster development. If firms in the same cluster are able to coordinate with the government, schools, and related nonprofits on policies and programs to train workers for their sector, they will be better equipped to identify their employment needs and find the workers with needed skills to fill available jobs.

Workforce development can include everything from career counseling to training and educational services. A thoughtful sector-based workforce development approach should include: industry best practices for recruiting, hiring, training, promotion, and compensation; education and training infrastructure (including community colleges, project-based learning experiences, and apprenticeship programs); and public policy, specifically rules, regulations, and funding streams related to workforce and education.[1]

With high unemployment or underemployment rates across the country and firms reporting being unable to find workers with the right skills, a focus on workforce development is essential for any emerging or established industry. With more than 20 percent of Virginia's economy linked to federal spending, federal budget cuts from sequestration hit Virginia's economy hard, resulting in state budget cuts, underemployment, and the loss of middle class jobs.[2] Particular regions and socioeconomic groups throughout the Commonwealth encounter distinct challenges in the wake of the recovery: the South and Southwest regions have unemployment rates twice the national average, rates of workers at or below minimum wage are among the worst in the nation, and groups such as veterans and women are often underemployed or underrepresented. Rural areas like Buchanan and Dickenson County have unemployment rates of 11.6 percent and 10.6 percent respectively, almost twice the national average.[3] The South and Southwest regions represent an opportunity to retrain workers to pursue higher-skilled, stable employment in fields like composite materials manufacturing.[4]

Essential manufacturing skills include welding (Credit: William M. Plate / Wikimedia Commons)

Workforce Development Strengths

Virginia's considerable strengths in its workforce development system can continue to prepare workers in fields like Science, Technology, Engineering, and Math (STEM) and advanced manufacturing. Virginia has the 11th largest higher education system in the nation, with 80,000 graduates receiving advanced degrees annually.[5] The Commonwealth ranks second in the nation for college graduation rate, with 70 percent of students completing college in six years.[6] Additionally, Virginia has 23 community colleges on 40 campuses that allow open enrollment—or classes available to the general public—enabling employees to upgrade skill sets via programs at their local campus.[7] Customized training, offered at the community college or business, is designed to address specific skills ranging from Microsoft Office to welding.[8]

Furthermore, Virginia has apprenticeships in almost 200 fields[9]—enabling on-the-job training for more than 13,000 workers in non-traditional fields.[10] From 2013 to 2015, an additional 30,000 high school students—more than ever before—gained industry certifications.[11] Overall industry certifications, state licensures, apprenticeship credentials, certificates, and Associates of Applied Sciences degrees increased 29 percent from 2013 to 2015,[12] placing Virginia at a strategic advantage to train workers in STEM-heavy fields like advanced materials and offshore wind manufacturing.

Workforce Investment Act. Enables Virginia to assist dislocated workers, adults, and youth in finding and maintaining jobs. Funds workforce investment activities such as career guidance, employment plans, and training services through statewide and local programs.[13]

The Manufacturing Skills Institute (MSI). Provides training in association with community colleges and offers several advanced manufacturing certificates. In October 2014, nine community colleges established themselves as MSI assessment centers and will expand the Manufacturing Technician 1 Certificate program.[14] This certificate will emphasize skills needed for manufacturing including: measurement, math, mechanics, fluid power and dynamics, electrical systems, chemistry, manufacturing processes and control, quality and lean manufacturing.[15]

Dream It. Do It. Virginia Career Resource Tool. Offers information for job-seekers, educational and training opportunities,

What Jobs Are Needed for Offshore Wind?

Welders, forgers, software designers, manufacturers, logistics managers, data analysts, installation and maintenance technicians, attorneys, engineers, safety specialists, insurance specialists, and many more skilled professionals can all find good-paying jobs in the offshore wind industry.

professional certifications and news updates from the field. Created by Virginia's advanced technology sector, this free tool also provides the option of creating a personalized profile through which participants can track their job search, progress, and resumes.[16]

Career Readiness Certificates (CRCs). Serve as assessment tools based on the ACT. CRCs are available at community colleges and help match candidates and employers to fill employment gaps, and more than 68,000 CRCs have been issued in Virginia.[17]

Miltary2Manufacturing (M2M) Program. Provides training and helps connect military training to new careers. Participants receive a National Career Readiness Certificate and Manufacturing Technician Level 1 Certification.[18]

Workforce Retraining Program. Provides funding and services to upgrade worker skills. Companies can receive assistance if they integrate new technology, make a capital investment of $500,000 and have at least ten full time employees.[19]

Drawing a wind turbine up for placement (Credit: Dennis Schroeder / NREL)

Wind: Jobs, Skills, Current Training and Training Needs

In the U.S. wind-related jobs will increase by 300 percent by 2030.[20]

Types of Jobs

Wind energy deployment will need a wide variety of professions including: project development, component manufacturing, construction, operations, legal services, data analysts, education, training and research.[21] Therefore holistic workforce development and educational programs are needed to ensure all the jobs—from manufacturers to lawyers—are filled.

Skills Needed

With proper planning, hard-working Virginians can be trained for these good-paying jobs. Potential gaps include project management skills and STEM knowledge. Virginia can learn lessons from the challenges faced by other nations that have pioneered offshore wind. For example, companies in the United Kingdom were challenged by shortages of workers with management, engineering, and technical skills.[22] There, the few trained workers were in high demand from competing industries. Virginia can avoid these problems by ensuring that a sufficient number of skilled workers are available in the Commonwealth.

Current Training

Programs across the Commonwealth are beginning to offer wind technology training. Blue Ridge Community College offers a Wind Power Generation course, while New River Valley Community College and Dabney S. Lancaster Community College offer Wind Turbine Technology courses.[23]

Carbon Fiber Composites: Jobs, Skills, Current Training and Training Needs

The number of jobs in the carbon fiber composites industry will increase 12 percent per year.[24]

Types of Jobs

Carbon fiber composite jobs will be in companies large and small, with demand for workers designing new end uses for materials, engineering more efficient manufacturing techniques, or manufacturing the composite material.

Skills Needed

Carbon fiber composites manufacturing is a sophisticated process, mostly done by technicians. Techniques to master include wet layup, resin infusion, laminating, curing, trimming, and drilling.[25] Knowledge in areas such as measurement, math, mechanics, fluid power and dynamics, electrical systems, chemistry, manufacturing processes and control, and lean manufacturing are key for industry professionals.[26]

Current Training

Virginia Tech's Macromolecules and Interfaces Institute trains engineers in next generation materials engineering, while its Center for High Performance Manufacturing works with firms to ensure the best technology is used.[27] Danville Community College houses equipment for hands-on training in plastics processing technology and Dabney S. Lancaster Community College has advanced manufacturing technology curriculum.[28]

Assembly of a wind turbine drivetrain
(Credit: Jonathan Keller / NREL)

Workforce Development Recommendations

Once Virginia has made a commitment to establish an offshore wind cluster and has taken steps to grow or recruit offshore wind businesses, it needs to develop a training program to provide the talent to ensure the cluster's success.

Policy 1: Establish the North American Offshore Wind Training Academy

Workers must know how to safely weld or repair turbines, all while strapped into a harness hundreds of feet in the air. In addition to the challenges of working at the height of an 18-story tall building, workers must be prepared for heavy winds, rain, and large, moving equipment. Therefore, a training facility with lifelike replicas of towers is essential to prepare workers for a variety of situations and minimize risks.

In Europe, project developers rely on third party firms to prepare workers for the risks they could encounter in the field. Maersk operates training facilities in Denmark and the United Kingdom to give lifelike facilities that provide hands-on training.[29] Their training centers have been approved by the Global Wind Organization (GWO) and hold accreditations from wind industry leaders, including Siemens Wind Power and Vestas.[30]

To fill the need for a lifelike training facility, Virginia could recruit an experienced firm such as Maersk to build a privately-owned training facility or the Commonwealth could establish a public-private partnership. Through a partnership, Virginia could create the North American Offshore Wind Training Academy—a one-stop training facility that offers hands-on training in life-like settings. The academy could focus on key areas, such as safety. The training could cover the GWO's Basic Safety Training Standard's five modules: first aid, manual handling, fire awareness, working at heights, and sea survival.[31] The facility can also serve as the center for hands-on training for wind energy technicians, wind tunnel technicians, wind turbine technicians, wind turbine erectors, and wind turbine mechanics. Full-scale training facilities could make Virginia a global leader in offshore wind training.

Policy 2: Convene Leaders to Determine Regional Strategy, Allocate Training Specialties Among Community Colleges, and Encourage Participation From All Eastern Colleges

The Commonwealth has a number of resources that can be allocated for training in classrooms or labs. Wind training currently exists at nine community colleges.[32] Community colleges in the Hampton Roads area could offer complementary wind training programs, allowing each facility to dive deeper into a specific area, such as blade repairs. Community colleges along the Eastern shore that currently do not offer training in wind technologies could begin to specialize in complementary skill sets, such as offshore wind logistics or management. Collaboration on a statewide strategy could allow for the community college system to minimize costs by efficiently allocating training resources.

The Department of Mines, Minerals, and Energy could compile an offshore wind energy workforce development council to assess regional needs and training goals. The assessment could include technical skills like turbine blade inspection and managerial skills such as logistics. The council could include training experts from the Global Wind Organization, The United Kingdom's National College for Wind Energy,[33] Department of Energy, the American Wind Energy Association, the U.S. Department of Labor, the National Science Foundation, the Virginia Manufacturer's Association, leaders from the Virginia Coastal Energy Research Consortium, the James Madison University Wind Center, the Chesapeake Bay Foundation, and leaders from community colleges. This wind training needs assessment could guide a statewide strategy to build upon the unique strengths of each community college and ensure that all needs are met. Virginia can send a market signal that the Commonwealth is ready for offshore wind development by training workers for these critical jobs.

Policy 3: Establish Mobile Welding Labs

Even with large-scale facilities and efficiently allocated classroom training, Virginia may experience offshore wind workforce development gaps. Welding, in particular, is a skill that must be refined for offshore wind because as wind turbines become larger, welders need to be more precise with measurements. For example, while a shipyard fabricates to the centimeter, welders of wind turbines fabricate to the millimeter.[34] A large portion of welders in the U.S. are not certified for those tighter welding tolerances.[35] A mobile training facility could bring expensive

Virginia Community Colleges That Offer Wind Training

- Blue Ridge
- Dabney S. Lancaster
- Mountain Empire
- New River
- Patrick Henry
- Piedmont Virginia
- Thomas Nelson
- Tidewater
- Virginia Western

Source: Center for Wind Energy, "Virginia Community College Renewable Energy Training Opportunities," http://wind.jmu.edu/eduandwork/documents/community%20colleges%20with%20renewable%20energy%20training.pdf.

Mobile manufacturing training lab used by a North Carolina community college (Credit: trailersoftheeastcoast / Flickr / CC BY) equipment to sites along the coast, training more people for less cost.

Oregon has maximized the use of expensive welding lab equipment by creating a mobile lab. The Southwest Oregon Community College Mobile Welding Lab is a 36-foot lab with computers, SMART boards, welding stations, and a virtual welding simulator.[36] Oregon spent $400,000 to create the lab, but was able to offset the price using funds from the Department of Labor and by charging fees to industry and high schools for training.[37] With this lab, Oregon not only has been able to train welders, but also has expanded the reach of welding programs to underrepresented groups, including women through its "Women in Welding Project."[38]

Virginia could follow Oregon's lead by creating its own mobile welding lab. The lab could travel to community colleges, shipyards, military bases, and other worksites in Virginia to train welders for offshore wind jobs and recruit women and veterans into the offshore wind industry. Since time needed to train welders varies widely—anywhere from a few weeks for workers upgrading their skills to several years of class and on the job training for novices seeking highly skilled work—a focused effort to train welders is urgently needed. Creating a mobile welding lab could meet the diverse training needs of all regions of the Commonwealth.

Policy 4: Offer High School Composites Training to Make Students Employable Upon Graduation in the South and Southwest Regions

The South and Southwest regions suffer from the highest unemployment rates and the lowest wages in the Commonwealth. The workers in these regions would benefit greatly from the creation of new advanced composite manufacturing plants. Advanced composite manufacturing is an industry with high projected growth that pays middle-class wages. The average manufacturing worker earns $5,000 per year more than the average worker in the South and Southwest regions of the Commonwealth.[39] Manufacturers would be more likely to move to those regions if workers were highly skilled. Offering composites training courses in high school could make students in the South and Southwest regions employable in composites manufacturing upon graduation.

An example of how to incorporate training into high schools can be seen in the work of the Advanced Composites Education Services (ACES). ACES has partnered with 20 schools in Washington, Oregon, and Alabama to give high school students the skills needed to fabricate an advanced composite.[40] For example, students at Todd Beamer High School built a carbon fiber composite clipboard, demonstrating their mastery of design and assembly skills.[41] The program allows students to earn high-demand certificates by completing three years of composites training or a rigorous one year program.[42]

Virginia could partner with the Advanced Composites Education Services to bring this training to Virginia's high schools. Incorporating this hands-on training into the high school curriculum would ensure that today's students are prepared to enter the workforce after graduation. Having a workforce skilled and trained in advanced composites could make Virginia irresistible to global manufactures that need to build new factories to meet growing demand. Placing a focus on training in the South and Southwest regions of Virginia would attract manufacturers to the regions of the Commonwealth where the workers are most in need of middle-class jobs.

Policy 5: Create a Part-Time Advanced Manufacturing Training Program in South and Southwestern Community Colleges

To gain an advanced manufacturing job, many Virginians will need to upgrade their skills. Most of those workers cannot afford to quit their current jobs to go back to school full-time. Instead, part-time programs are needed, so that workers can build upon their current skills while still bringing home a paycheck. Existing programs, such as an Associates in Advanced Manufacturing Engineering Technology, take years to complete on a part-time schedule.[43]

Oak Ridge Associated Universities[i] offers a one-year, 25-hour-per-week Advanced Manufacturing Workforce Development Certificate.[44] The training program is run by the Oak Ridge Institute for Science and Education (ORISE), a U.S. Department of Energy-sponsored education and research program.[45] Pellissippi State, a local Tennessee community college, administers the training program at its facility.[46]

Through a collaboration with the Oak Ridge Associated Universities, Virginia community colleges could align their curriculums with national best practices in advanced manufacturing. Creating a similar part-time, one-year certificate for Virginians could open the middle-class job opportunities in advanced manufacturing to workers who currently have

i Oak Ridge Associated Universities (ORAU) is a consortium of 115 universities and Oak Ridge National Laboratory. ORAU seeks to enhance U.S. global competitiveness through collaborative research and education.

low-wage jobs. Focusing resources on community colleges in the South and Southwest regions, such as Mountain Empire, Southwest Virginia, Virginia Highlands, Wytheville, Patrick Henry, and New River, would ensure that low-wage workers have the opportunity to gain new skill sets. Additionally, the Virginia Manufacturing Skills Institute and their participating community colleges, such as Danville and Dabney S. Lancaster Community Colleges, could begin to offer similar part-time training programs that allow workers across the Commonwealth to prepare for an advanced manufacturing certificate while remaining employed. Creating part-time programs would allow hard-working Virginians to upgrade their skills and move into the middle class.

Continuous training and development programs ensure a skilled workforce (Credit: PSNS & IMF / Flickr / CC BY-NC-SA)

Policy 6: Expand Military2Manufacturing to Train Veterans for Advanced Manufacturing Careers

Many of Virginia's veterans learned skills in the armed forces that make them prime candidates for manufacturing jobs. As of 2013, 45 percent of enlisted active duty personnel were medium-skilled workers in occupations such as machinery, electrical technicians, or construction.[47] Virginia's large veteran population -- with an estimated 513,061 veterans under the age of 65 who are candidates for good-paying jobs -- represents an opportunity to recruit disciplined, skilled workers to the offshore wind and advanced composites industry.[48,49]

Carbon fiber manufacturing lab (Courtesy of the Oak Ridge National Laboratory, DOE)

Virginia is already a leader in recruiting veterans into advanced manufacturing. Military2Manufacturing is a program through the Manufacturing Skills Institute that offers outreach, training, and placement in the field of advanced manufacturing to veterans. The program is a partnership between the Manufacturing Skills Institute, ECPI University, Blue Ridge Community College, Northern Virginia Community College, Southern Virginia Higher Education Center, Virginia Department of Labor and Industry, and the Virginia Employment Commission.[50]

Military2Manufacturing can be expanded and improved by incorporating national best practices from New Jersey. UpSKILL is a program at the New Jersey Institute of Technology that retrains veterans for new careers.[51] Funded by the Department of Labor, UpSKILL provides job search boot camps, resume translation from military skills to advanced technology skills, and free career consulting services.[52] UpSKILL also connects veterans to employers based on employer needs and worker skill sets. Because UpSKILL does not require veterans to use their G.I. benefits on the program, veterans can utilize their benefits to continue their skills training in other programs.[53]

The UpSKILL model can be incorporated into Virginia's existing Military2Manufacturing programs, starting with on-base education about advanced manufacturing careers before military personnel leave the armed forces. Similar resume building workshops, consulting services, and matching programs could bring highly skilled workers to potential employers in advanced manufacturing fields and help veterans access good-paying careers.

Policy 7: Establish Early Colleges With Work-Based Learning Curriculums

By 2020, two out of three American jobs will require a college credential, many of them in STEM fields.[54] To meet the demand for skilled labor, America will need the majority of high school students to graduate on time, enter college, and earn an associate's degree within three years or a bachelor's degree within six years. Unfortunately, only one in five students meet that goal today.[55] Virginia trails behind states like Arizona, the nation's leader in associate degrees in STEM fields.[56] Similarly, Virginia falls outside the top ten in STEM bachelor's degrees per capita.[57]

Early colleges are an innovative way to engage students in the classroom and better prepare them for the jobs of the 21st century. Through partnerships between high schools and local colleges, students can earn their high school diploma and an associate's degree concurrently in a four- to five-year period.[58] This design enables more students to earn a diploma, particularly low-income and minority students. Students in early college are more likely to graduate from high school (90 percent vs. 78 percent nationally).[59] This is especially impressive because the majority of early college students are from low-income families and will be the first person in their families to attend college.[60]

For example, Ohio has improved upon the early college model by embedding work-based learning in the curriculum of early college classes. As one of 12 states linked to the Pathways to Prosperity Network, Ohio has provided a $14.4 million grant to 15 school districts in Central Ohio to develop six career pathways, including advanced manufacturing.[61] The participating districts that are working with Columbus State Community College span five diverse counties, and engage 22,249 students in 18 high schools.[62] The program is intended to be a pilot that can be expanded throughout the state. In the 2014-2015 school year, the first year of the program, nearly 25 percent of all eligible students enrolled in the program—over 5,400 students.[63]

To better prepare students for STEM careers, Virginia could establish early colleges throughout the state and create a work-based learning curriculum, as Ohio has done. Establishing a

Grades 9-14 career pathway in Virginia can reinvigorate high school education and provide the essential job training that students need to prepare them for skilled, good-paying jobs.

Chapter Summary

Virginia has the potential to expand into the next generation of materials manufacturing and energy production, and has the resources to achieve this goal. Virginia has a skilled workforce, top-notch workforce development programs, community colleges and four-year universities. Its anchor companies could provide a valuable asset for training and capital investments. By thinking holistically about training needs and partnering with other regions who have best practices, Virginia can bring its workforce into the advanced energy economy.

Conclusion

In order to build on Virginia's success in the advanced energy space and position the Commonwealth for continued growth, policymakers will need to make advanced energy a priority. The purpose of *The Virginia Jobs Project: A Guide to Creating Advanced Energy Jobs* has been to analyze the Commonwealth's advanced energy economy in order to create recommendations specifically tailored to the Commonwealth's needs. The policies recommended in this report are complementary and intended to help the state grow demand for advanced energy technologies, manufacture products within the state, enable entrepreneurship for technological advances, fund innovation with accessible capital, and equip workers with the skills required for the state's future economy.

Policy leadership in the advanced energy space can play an important role in promoting Virginia's advanced energy clusters and creating quality jobs for Virginians. Advanced energy clusters focused on offshore wind and composite materials offer a great opportunity for the Commonwealth to grow its economy, create jobs for the Virginia's residents, and become a leader in the production and deployment of advanced energy technology.

If Virginia's policymakers take swift and purposeful action to grow the offshore wind and CFRP composite industries, Virginia can support over 19,000 jobs per year through 2030.

Virginia has the right mix of strengths to leverage this opportunity. With smart, forward-thinking policies, the state can diversify its economy and create thousands of middle class jobs for hard-working Virginians.

For more information about advanced energy technologies and best practice policies, visit http://americanjobsproject.us/.

Extended Learning Section

Appendix A: Virginia's Energy Profile

Virginia's Energy Production and Consumption

Although Virginia is one of the top coal-producing states, most of the Commonwealth's coal is exported and energy is imported from other states. In 2013, Virginia imported more electricity than it produced, amounting to 449 trillion Btus of electricity.[1] Dominion Virginia Power and Appalachian Power are the two investor-owned utilities (IOUs) that provide electricity to the majority of the Commonwealth. As of April 2015, nuclear power is the Commonwealth's biggest contributor to electricity production.

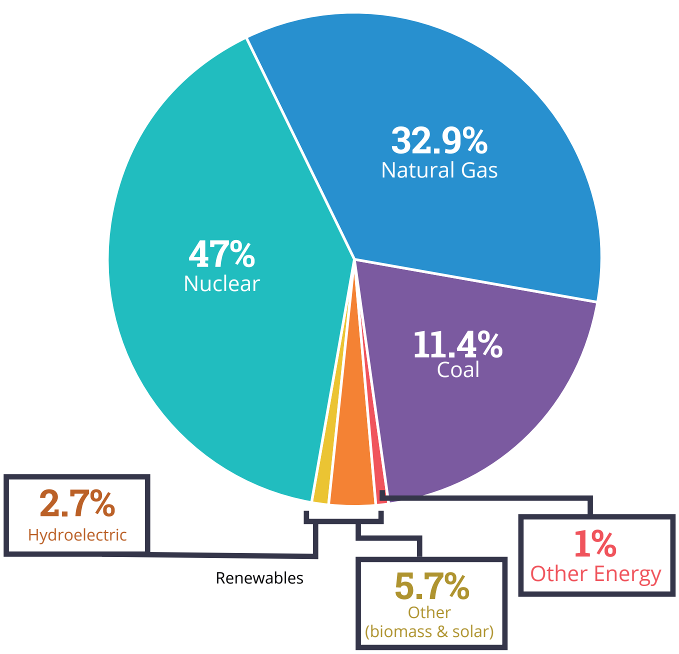


Figure 12. Virginia's 2012 Electricity Generation. Source: U.S. Energy Information Administration

Consumption

In 2015, Virginia's 8.3 million residents paid 11.66 cents per kWh for electricity, placing Virginia below the national average.[2] Due to Virginia's large state-maintained highway network—the third largest in the nation—transportation consumed more energy than the residential, industrial, or commercial sectors.[3] In 2013, total energy consumption by the Commonwealth of Virginia was 2,411 trillion Btus.[4]

Renewable Energy

As noted in Figure 12, Virginia produces less than seven percent of its electricity from renewable sources, most of that being from biomass.[5] Although nominal, that contribution has increased from 2.8 percent in 2008.[6] Virginia has a voluntary (not mandatory) Renewable Portfolio Standard[i], and the IOUs get credit for buying old, out-of-state renewable energy certificates. The chart below details Virginia's renewable energy production as of 2013, which totaled 1,808 MW. Wind energy comes from residential, school, and business wind turbines. Virginia does not have any utility-scale wind.

Installed Renewable Energy Capacity, 2012-2013	
Wind Power (residential, school, and business)	155 MW[7]
Solar Photovoltaic	13 MW[8]
Biomass	808 MW[9]
Hydropower	832 MW [10]

Virginia's Energy Economy

As mentioned, Virginia has greater demand for energy than it can supply itself, meaning it must import energy from neighboring states such as West Virginia and Kentucky. In fact, imports have increased on average 1.4 percent per year from 1998-2008.[11] According to the 2014 Virginia Energy Plan, the Commonwealth will need an additional 14,000 MW of electricity by 2024.[12] This growth can be met in part with in-state energy production from wind—Virginia has about 19,000 MW of offshore wind potential and approximately 2,000 MW of onshore wind energy resources.[13] As Virginia works to secure offshore wind, the Commonwealth can invest in lower-cost technologies like onshore wind, solar photovoltaics, and energy efficiency as long as they are economically

i A summary of the RPS can be found in the Database of State Incentives for Renewables and Efficiency, http://programs.dsireusa.org/system/program/detail/2528.

viable and competitive with existing energy systems.

Virginia is a net importer of energy and consequently the Commonwealth spends large sums of money to import power while it exports coal to other states. In 2009, Virginians spent a net value of $13.7 billion toward out-of-state energy purchases.[14]

While some coal comes from neighboring states, increasing costs of rail transport and high demand for low-sulfur coal have resulted in more international coal imports. In 2008, Virginia paid Colombia $95 million for coal.[15]

Electric Utilities and the State Corporation Commission

Dominion Virginia Power, Old Dominion Power, and Appalachian Power—the three dominant IOUs—control 84 percent of the in-state market for electricity.[16] The remaining 16 percent of the electric utilities comes from 16 municipal utilities (4.4 percent) and 13 electrical cooperatives.[17] The State Corporation Commission regulates utilities by setting electricity rates, terms of service, and rates of return on investments.[18] The revenue model in Virginia varies between gas and electric utilities.[19] In 2008, gas prices were decoupled in the Commonwealth,[20] which means that gas sales and revenues did not necessarily change in lockstep, while electric revenues remain tied to sales. In other words, when rates are decoupled a utility's revenue does not depend on selling as much energy as possible thus they can still earn a profit while also engaging in customer energy efficiency programs.[21]

Grid Connectivity and Oversight

Dominion Virginia Power and Appalachian Power are included in a Regional Transmission Organization (RTO), which administers the wholesale electricity market and ensures grid reliability.[22] The RTO for Virginia is called the PJM Interconnection, which spans the eastern part of the United States (consisting of parts of 13 states and the District of Columbia), and is composed of generators, electricity suppliers, utilities, and transmission owners.[23] The Federal Energy Regulatory Commission oversees PJM to ensure reliable interstate transmission and to approve interstate energy infrastructure.[24] According to an internal study, PJM can reliably operate with up to 30 percent of its generation mix coming from wind and solar resources.[25] As of 2014, Virginia had 15 MW of installed solar capacity[26] and no installed utility-scale wind power capacity.[27] PJM's renewable readiness is an advantage for Virginia as it prepares to bring the offshore wind industry to the east coast. The Commonwealth continues to make grid connections, with several transmission-level 500-kV lines planned to connect high-density areas in Virginia.[28] This increased connectivity will improve grid reliability and prepare for other clean energy additions, such as onshore wind and solar.

Appendix B: The Future of Offshore Wind-Improvements to Current Technology

1. Blade Materials Like Carbon Fiber-Reinforced Polymer (CFRP) Composites Can Increase Turbine Efficiency and Decrease Project Costs

Stronger, lighter materials for wind turbine blades can lead to a large increase in potential power output. The most common material used in today's blades is a glass fiber/thermoset resin composite, which is low-cost but heavy and has a small stiffness-to-weight ratio. However, CFRP composite blades have multiple advantages over fiberglass, which may make it the future status quo. One advantage of a CFRP composite blade is a higher stiffness-to-weight ratio, which results in a larger output of energy per turbine.[29] Also, with CFRP composites the blades can be longer, thinner, and lighter—making them easier and safer to transport to the project site. Companies such as Toray currently produce CFRP composite blades for wind turbines.[30] However, they are not widely adopted due to high cost, but as the size of blades increase, the demand for CFRP composite blades is expected to align with the growth of the wind industry—in 2030, four times the installed capacity of 2011 is expected.[31]

2. Improvements in Blade Aerodynamics Could Allow Tighter Spacing of Turbines—i.e., More Wind Turbines in a Given Area

Improvements in the aerodynamic design of blades continue to offer valuable opportunities. The blade needs to be designed to generate the most lift given the specified operational wind speed range. But it also needs to decrease the wake behind it, one of the most difficult steps in designing the rotor, so as to allow other turbines to be placed nearby. (Wind passing over a blade creates a wake, or turbulence, that occurs in the flow behind the blades. Wind turbines are only able to successfully extract energy from laminar, or smoothly flowing, wind.)[32] Thus, turbines must be placed at certain intervals to ensure that one turbine does not operate in the wake created by others.[33] Decreasing the wake is key to increase the density of wind turbine installations over a given land area—increasing the amount of energy generated from the wind in a given area.

There has been extensive research into redesigning the shape of the wind turbine blade to decrease the amount of wake produced. One design improvement comes in the form of a novel method to actively control both the wake and lift production of a wind turbine blade. It embeds small "pressure actuators," or pressure control systems, into the wind turbine blades themselves, so they can sense the pressure on the blade and blow air through tiny holes in the blade, if necessary.[34] When the latter happens, the blown air mixes with the air passing over the blade, which ensures that the flow remains "attached" to the wind turbine blade. This flow attachment is integral to decreasing both the wake behind the turbine and the vibration experienced by the blades. Overall, extensive research by GE has shown that integration of these actuators can improve the lift up to 60 percent.[35]

Lift: Force caused by the pressure difference between the upwind and downwind sides of the blade. The lift force causes the blade to turn.

Wake: Turbulent region of the wind caused by the wind passing over the rotating solid wings. The wake is slower moving wind that has less extractable power.

3. Smart Turbines Will Detect Defects Before Problems Grow

In future generations of wind turbines, "smart" technologies such as embedded sensors will monitor the health of the machines. Maintenance costs will be reduced and maintenance workers will be safer if a defect is identified prior to devastating failure. New technologies using electro-mechanical actuators can detect energy produced by blade vibrations, which can relay it to accelerometers placed along the structure of the wind turbine. Tests have shown this technique to be extremely effective, with the ability to detect structural defects as little as 20 centimeters long anywhere along a 34-meter blade.[36] Since the maintenance of wind turbines constitutes a potential source of huge expenses, these techniques might find their way into technologies embedded into the structures of wind turbines themselves. Smart turbines could increase demand for software designers to create programs that sort and characterize the data to check for faults, as well as analysts tasked with checking the data to ensure optimal wind turbine performance.

4. Floating Foundations Can Place Turbines in Deeper Water

Currently, offshore wind farms in Europe are situated in shallow waters due to the constraints of the current types of foundations used. However, the near future could see an increasing number of offshore wind turbines being developed on floating foundations for deep waters. Floating foundations, such as the Statoil Hywind test turbine in Norway and the Principle Power WindFloat in Portugal, are in the development and demonstration phase, with commercialization several years away.[37] Floating foundations and their turbines can be fully manufactured onshore and pulled through water to the offshore wind farm, generating significant savings over today's costly expense of barges that bring turbines in pieces to offshore sites.[38] More than 60 percent of the offshore wind resources in the United States are above deep waters greater than 60 meters in depth.[39] These deep-water regions are also ideal for wind farms most likely due to stronger, more consistent winds that can give access to far greater wind resources than shallow-water wind farms.[40]

Appendix C: Future Applications for CFRP Composites

CFRP composites have potentially boundless applications due to their light weight and high strength.[41] Some examples of future end uses include:

1. Lightweight Shipping Containers: Less Energy to Transport Goods

Did your iPad come from China? Most likely it was placed in a steel or aluminum shipping container, and then shipped across the world on a large shipping vessel. Steel and aluminum containers have been used to ship goods for decades, but they are heavy and add to the weight and fuel requirements of air cargo planes and ships. A composite container is 42 percent lighter than aluminum and almost half the weight of steel.[42] If shipping containers were made with CFRP composites, they could save on fuel for energy costs. Although a CFRP composite shipping container is about $5,000 more expensive than steel and aluminum, shipping companies would break even after 75,000 miles due to saved energy costs.[43] TenCate Advanced Armor in Ohio partnered with Air Cargo Containers to produce lightweight air cargo shipping containers.[44] Lighter containers could also mean reduced fuel and faster logistics at container ports and transfer stations.

2. Medical Devices: Stronger, Lighter Prosthetic Limbs and Braces

Prosthetics and orthotics (body part braces) comprise a $2.8 billion global market,[45] with a predicted compound annual growth rate of 6 percent through 2017.[46] Strong but light prosthetic limbs are important for people such as the 1,645 veterans from 2001 to 2015 who had major limb amputations.[47] CFRP composite prosthetics are increasingly common for good reason—they give strength without the weight of metal or ceramics and enable amputees to enjoy an active lifestyle. One company, Intrepid Dynamic Exoskeletal Orthosis (IDEO), recently helped injured veterans become mobile—even enabling them to remain active in sports or outdoors activities.[48] Other U.S. companies like Closed-Mold Composites manufacture next-generation prosthetic feet that are strong and responsive.[49] CFRP composites also have potential for use in safety helmets, wheelchairs, medical implants, and X-ray inspection equipment.[50] Virginia's 781,388 veterans rely on military hospitals to help them regain mobility potentially lost during their service.[51]

3. CFRP Composites for Construction

CFRP composite material is ideal for structural reinforcement because it is strong, stiff, and lightweight. Cement with short CFRP composites has better elasticity and less environmental damage than asbestos-reinforced cement.[52] In Japan, CFRP composites have been used as reinforcement of structures to resist damage from earthquakes.[53] The German SGL group created concrete panels only 26 millimeters in thickness using 3D CFRP composite grids.[54] A similar steel panel would be almost four times as thick, meaning CFRP composites yield more strength in less space.[55] This innovation could revolutionize infrastructure design and construction—an industry with growing potential in the Commonwealth. CFRP composites can reinforce other structures such as bridges and cables.

4. Multi-functional Materials: Lightweight Car Panels That Serve as a Battery

A car hood that serves as a battery? Volvo is researching multi-functional CFRP composites or materials that store a charge. The Volvo S80 prototype has panels such as the roof, doors, hood, and floor that have all been replaced with CFRP composite and structural supercapacitors.[56] In other words, its CFRP composite frame has a battery built right into the material that can store a charge from energy discharged from pumping brakes or being plugged into the grid.[57] This revolutionary innovation results in a lighter car, which means less energy needed for fuel. The incorporation of charge-storing materials could be used in endless transportation applications from lightweight trains to semi-trucks and sedans that recharge from pumping brakes. Participants on the project include Volvo and Imperial College London, among others.[58]

Appendix D: Highlighted Federally Funded Labs, Research Universities, and Private Research Institutions

Virginia is home to many institutions such as research universities and laboratories that serve as an anchor for the Commonwealth's innovative ethos.

Federally Funded Labs

Virginia is home to several federal laboratories that work under the Department of Defense or the Department of Transportation on subjects related to lightweight materials and offshore wind energy.

Facility	Sponsor[59]
Center for Advanced Aviation System Development, McLean, VA[60]	Department of Transportation, Federal Aviation Administration
Homeland Security Systems Engineering and Development Institute, McLean, VA[61]	Department of Homeland Security
National Security Engineering Center, McLean, VA[62]	Department of Defense
Homeland Security Studies and Analysis Institute, Arlington, VA[63]	Department of Homeland Security
Center for Naval Analyses, Alexandria, VA[64]	Department of Defense, Department of the Navy
Center for Communications and Computing, Alexandria, VA[65]	Department of Defense, National Security Agency
Systems and Analyses Center, Alexandria, VA[66]	Department of Defense, Department of Homeland Security
National Institute of Aerospace, Hampton, VA[67]	National Aeronautics and Space Administration

Federal Research Lease

In March 2015, Virginia won the first federal offshore wind energy research lease in federal waters.[68] The offshore area is for the two 6-MW grid-connected demonstration facilities next to Dominion Power's commercial lease area.[69] Lessons learned from the pilot project will be valuable tools for state and federal officials interested in promoting offshore wind technology, and this award sets Virginia apart from other states interested in offshore wind.

Research Universities

Virginia is home to several world-class research institutes and centers, which are often ranked in the top decile in categories such as R&D expenditures and full-time graduate students.[70]

Collaborative Research Institutions

The Commonwealth Center for Advanced Manufacturing (CCAM) is an interdisciplinary, collaborative research institution that focuses on additive manufacturing, composite materials, machining technologies, and manufacturing systems. CCAM's industry members include Rolls-Royce, Airbus, Siemens, and Newport News Shipbuilding. Universities including University of Virginia, Virginia Tech, Virginia State University, and Virginia Commonwealth University partner with CCAM to accelerate commercialization of technology.[71]

Appendix E: Examples of Local Programs that Drive Innovation

Northern Virginia

The Northern Virginia Technology Council (NVTC) includes 1,000 companies and organizations, making it the biggest technology council in the United States.[93] NVTC advocates for technology policy, provides education and networking, and facilitates community engagement.[94] Prince William County's Innovation Park—a public-private partnership associated with George Mason University—offers opportunities for collaborative research in the Prince William Science Accelerator and a shared space for companies.[95] Investments in Prince William County's Innovation Park total $650 million and are expected to create 2,000 jobs.[96]

Richmond

In Richmond, the Mayor's Opportunity Fund is a discretionary grant that matches the Governor's Opportunity Fund if a busi-

University	Research Institutes & Centers
Virginia Tech, Blacksburg, VA	**Institute for Critical Technology and Applied Science.**[72] *Sustainable energy, renewables, national security, emerging technologies* **Virginia Tech Transportation Institute.**[73] *Transportation technology, policy, product development* **Center for High Performance Manufacturing.**[74] *Innovation-based manufacturing, supply chain management, production and information systems* **Center for Naval Systems.**[75] *National security in maritime systems* **Center for Services Science, Quality, and Innovation.**[76] *Service system design in areas such as security and disaster recovery* **Future Energy Electronics Center.**[77] *Energy-efficient transportation technologies* **Center for Energy and the Global Environment.**[78] *Energy and information systems* **Center for Energy Systems Research.**[79] *Energy systems and applications* **Center for Power and Energy.**[80] *Power grids, alternative power systems, energy storage* **Center for Renewable Energy and Aerodynamic Testing.**[81] *Synergy between aerodynamics and acoustics, as well as engineering and renewables* **Center for Intelligent Material Systems and Structures.**[82] *Structural dynamics, health monitoring, energy harvesting* **Renewable Materials Laboratory.**[83] *High-performance biopolymer structures that mimic natural processes*
James Madison University, Harrisonburg, VA	**Center for Wind Energy.**[84] *Small-scale project siting, workforce development training, ordinance development*
University of Virginia, Charlottesville, VA	**UVA Innovation Initiative.**[85] *Technology acceleration, business mentorships* **Commonwealth Center for Advanced Manufacturing.**[86] *Surface engineering and manufacturing systems* **UVA Applied Research Institute.**[87] *National defense and intelligence* **NSF Industry/University Cooperative Research Center for Lasers and Plasmas.**[88] *Laser and plasma processing of materials, devices, and systems* **Rapid Prototyping Lab.**[89] *3D printing, engineering design and analysis software*
George Mason University, Fairfax, VA	**Center for Energy Science and Policy.**[90] *Energy policy focus* **Center for Air Transportation Systems Research.**[91] *Transportation network optimization, safety analysis* **Center for Innovation and Entrepreneurship.**[92] *Interdisciplinary hub for innovation and early-stage startups*

ness relocates to the state capital.[97] The Enterprise Zone Program promotes clustering of new startups through tax abatements, rebates, and grants to encourage siting in Richmond's designated enterprise zones. For example, the real estate tax abatement lasts 10 years, while the business relocation rebate covers 50 percent of relocation costs up to a maximum of $10,000.[98]

Charlottesville

The University of Virginia Innovation program works with more than 50 startups to facilitate industry partnerships and provides entrepreneurs with mentorship, networking, and other resources to maximize technology transfer.[99] UVA Innovation includes a licensing and venture capital group to provide access to capital and intellectual property assistance.[100]

Hampton Roads

The Hampton Roads region promotes a regional industry cluster approach to business and innovation. Several successful technology incubators exist in the region. As one of the top incubators, the Peninsula Technology Incubator (PTI) has won several awards from institutions like Goldman Sachs and the White House.[101] Housed in the National Institute of Aerospace, PTI connects entrepreneurs, mentors, and investors. The facility is even equipped with drone testing facilities and 3D printers.[102]

Appendix F: Existing Executive Tools to Stimulate Economic Growth

The Commonwealth's Opportunity Fund

The Commonwealth's Opportunity Fund (COF) is a resource to help secure a company location or expansion in Virginia. Given at the discretion of the Governor, a COF grant is awarded to the locality under the expectation that the locality matches the amount and the deal will bring a net positive benefit to the economy.[103]

The Virginia Investment Partnership (VIP) Grant Program

The Virginia Investment Partnership (VIP) Grant Program encourages capital investment by Virginia companies that will promote high-tech economic development in the Commonwealth. VIP grants are discretionary, with an individual project cap of $3 million.[104] The President and CEO of the Virginia Economic Development Partnership determine individual grant amounts.[105]

The Major Eligible Employer (MEE) Grant Program

The Major Eligible Employer (MEE) Grant Program is eligible to companies that invest at least $100 million in capital investments and create over 1,000 jobs.[106] MEE grant values are negotiated on a per project basis and do not exceed $25 million per project. Grants are dispersed in the sixth year after targets are met.[107]

The Virginia Economic Development Incentive Grant (VEDIG) Program

The Virginia Economic Development Incentive Grant (VEDIG) Program is for companies establishing headquarters or large administrative facilities in a major metropolitan area. The company must make a capital investment of $6,500 per job or $5 million (whichever is greater) and 400 full-time jobs.[108] VEDIG funds are dispersed the third year after capital and job creation targets are met, with an annual cap of $6 million per year in aggregate VEDIG payouts.[109]

Industrial Development Bonds

Industrial Development Bonds can be taxable or tax-exempt, with intention of funding land or other capital assets. Tax-exempt bonds are available for projects with expenditures up to $20 million while projects for taxable bonds begin at $750,000.[110] Manufacturing facilities qualify for tax-exempt bonds while eligibility for taxable bonds is limited to job creators.[111]

Green Jobs Tax Credits

Green Jobs Tax Credits amount to an annual $500 credit (for up to five years before January 1, 2018) for each green job with a salary of at least $50,000.[112] Firms can count up to 350 jobs created for the credit.[113]

Major Business Facility Tax Credits

Major Business Facility Tax Credits give qualified businesses locating in Virginia a $1,000 credit for each full-time job created.[114] Companies must qualify by meeting a job creation quota, and credit value is dependent on factors such as hiring schedule and net effect of job creation.[115]

Refundable Research and Development Expenses Tax Credits

Refundable Research and Development Expenses Tax Credits allow businesses to claim a tax credit of up to 20 percent of the first $234,000 of research with a Virginia university.[116] After 2014, the annual credit cap is $6 million.[117]

Appendix G: Jobs Modeling Methodology

Economic Impact Methodology

The American Jobs Project combines existing tools, analysis, and projections from several reputable sources to estimate job creation. Rather than providing a specific estimate, we show jobs potential across a range of possible outcomes. All jobs are shown in job-years that exist during the analysis timeline (2016-2030).

The key to job creation lies in local action. Our estimates are intended to start a conversation about how local stakeholders can work together to set their goals and utilize the same tools and data that we have used to estimate potential impacts.

Tools for Economic Impact Analysis

A number of modeling tools are available for estimating economic impacts from advanced energy industry growth. This report employs two of the most common tools available: Jobs and Economic Development Impact (JEDI) and Impact Analysis for Planning (IMPLAN). Results from the JEDI model only show job gains and do not evaluate losses in other industries. They are based on approximations of industrial input-output relationships, and do not include intangible effects.[118] The JEDI model is widely used because it estimates construction and other project economic impacts at the local (usually state) levels.[119] IMPLAN estimates the economic impact of each dollar invested into a sector and the resulting ripple, or multiplier, effects across the economy.[120] Multipliers are used to generate the economic impacts of the project across three different categories of jobs: direct, indirect, and induced.[121] Not all advanced energy technologies can be modeled with JEDI.

It is important to note the limitations of these modeling methods. As mentioned, the estimates shown are only gross job-year creation. Job losses in industries that compete with those in our analysis are not evaluated. Models do not dictate behavior, so indirect and induced jobs estimates could vary greatly based on the reality of what is actually purchased locally. Also, foreign and domestic competition can play a significant role in limiting the potential for job creation. The estimates presented in this report are highly dependent on sustained local action towards developing and maintaining these industries.

Estimates Used in the Virginia Report

Offshore Wind

JEDI was used to estimate jobs potential for the offshore wind industry in Virginia. We show the jobs potential from several scenarios based on different percentages of local share, i.e., how much of the total industry supply chain and expenditures could occur in the state to serve local and national demand. In the report, we show a range of 30-70 percent of local share. We also assume that if Virginia develops the offshore wind manufacturing base, the Commonwealth would serve the bulk of the Mid-Atlantic Coast of the U.S. with it's products and specialized workforce, including Georgia, South Carolina, North Carolina, Virginia, Maryland, Delaware, and New Jersey. Job-years included in this analysis represent all job-years that could exist during the timeframe of 2016-2030.

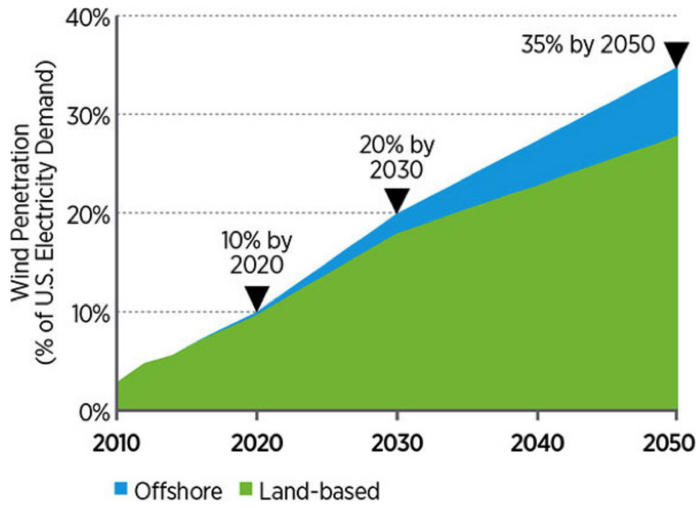


Figure 13. Growing Demand for Offshore Wind

Wind Vision

The Wind Vision Study Scenario is a scenario that extends wind deployment trends, leverages the domestic wind industry manufacturing base, and complements the broader literature.[122] The Study Scenario is represented by wind power penetration levels of 10 percent by 2020, 20 percent by 2030, and 35 percent by 2050 and includes projections for other renewable energy sources.[123] Study Scenario impacts are compared to a Baseline Scenario in which wind capacity is fixed at 2013 levels.[124] This allowed the team to identify and quantify impacts for future wind deployment.[125] The assessment was the work of more than 100 individuals from major stakeholder sectors (government, industry, electric utilities, and nongovernmental organizations), conducted over a two-year period from 2006–2008. The study analyzed wind energy's potential contributions to economic prosperity, environmental sustainability, and energy security.

National Renewable Energy Laboratory: Renewable Electricity Futures

The National Renewable Energy Laboratory's Renewable Electricity Futures Study (RE Futures) examines the extent to which renewable energy supply can meet U.S. electricity demands over the next several decades.[126]

> The study explores electricity grid integration using models with unprecedented geographic and time resolution for the contiguous United States to assess whether the U.S. power system can supply electricity to meet customer demand on an hourly basis with high levels of renewable electricity, including variable wind and solar generation.[127]

The study explores very high renewable electricity generation levels between 30 percent and 90 percent of all U.S. generation in 2050, with a particular focus on 80 percent.[128] The Incremental Technology Improvement scenario was used for our projections.

Scenarios Used in Jobs Analysis

- High Demand Baseline
- High Demand with 80 percent Renewables by 2050
- Baseline Demand with 80 percent Renewables by 2050 and Incremental Technology Improvements

Carbon Fiber Manufacturing

Carbon fiber manufacturing jobs were estimated using McKinsey industry growth estimates[129] and IBIS World industry data for carbon fiber and graphene manufacturing.[130] McKinsey's compound annual growth rate was applied to current industry revenues from 2016-2030. Direct jobs were estimated using IBIS world industry benchmarks for average revenue per employee. Indirect jobs and the induced jobs from direct and indirect employee spending were estimated through IMPLAN. IBIS World's benchmark percentage of revenues used for precursor materials was used to estimate total spending in the organic chemical manufacturing industry, resulting in the total indirect jobs from supply chain spending in that industry and induced jobs from supply chain employee spending. IBIS World benchmarks for average employee wages were applied to the estimated number of direct employees and added to local spending in IMPLAN for an estimate of induced jobs. Some industry benchmark spending from IBIS world was not included in this estimate, such as rent and utilities, marketing, and "other expenses." Jobs potential is shown across a range of U.S. market share that could be served by the state of Virginia. The report graphs focus on Virginia-made carbon fiber meeting 2.5 - 10 percent of national demand, an achievable goal given the Commonwealth's current market share of 1.3 percent.[131]

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