The Arizona Jobs Project

A Guide to Creating Jobs in Advanced Materials

MARCH 2017

AMERICAN JOBS PROJECT

A Letter from the American Jobs Project

It is 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. Of the millions of jobs lost during the recession, most were good-paying, middle-class jobs. Unfortunately, many of the jobs created during the recovery have been in low-skill, low-paying occupations. 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 then-President of China, Hu Jintao. "What keeps you up at night?" President Bush asked President Hu as an icebreaker. As we can easily guess, what kept President Bush up at night was concern over terrorism. Hu Jintao's response was telling: what kept him up at night was "creating 25 million new jobs a year" for his people.

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 guide to 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 and the associated advanced materials that enable energy generation, conservation, and storage. The world is at the brink of a historic energy transformation and the United States plays a crucial role in accelerating the energy transition. Whether borne out of a need for diverse, reliable, and clean power or to achieve energy independence from unstable regimes, the growing demand for advanced energy and enabling materials technology creates "the mother of all markets" for local U.S. businesses to build and sell those solutions. Strategically minded businesspeople looking at global growth projections in advanced energy demand are

making major investments and reaping large revenues. In 2015, the private sector reported nearly $1.4 trillion in global advanced energy revenues. Advanced energy investments are now bigger than the global apparel sector and nearly twice the size of the global airline industry. And jobs? At least 9.4 million people were employed in the global advanced energy sector in 2015, and doubling the share of renewables could nearly triple employment. The question for the United States is: Where will those new jobs be created?

The American Jobs Project is focused on finding ways to make our states the answer to this question. If countries across the globe, including the United States, are seeking technical products and solutions for 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 the U.S. population with the skills those businesses need to build their advanced energy and advanced materials products?

It is true that the United States will not likely be able to attract the traditional manufacturing jobs of the past; those jobs are gone—either to low-wage countries or to automation. We must accept the fact that they are not coming back. But our research shows that with innovative policies and a smart focus on industrial sectors, states can become global hubs of innovation and job creation in specific advanced manufacturing industries that capitalize on each state's strengths.

The American Jobs Project gives policymakers the tools to spur economic growth and create good-paying jobs in their states. Our analyses chart pathways designed to accelerate and expand a state's economy. We propose innovative solutions built on extensive research and tailored to each state. Many are best practices, some are new, and all are centered on 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.

The American Jobs Project will empower state leaders to build prosperous and equitable advanced energy and advanced materials economies that will transform our nation's energy future. If these recommendations are adopted, the beneficiaries will not only be those hard-working Americans looking for the dignity of a good-paying job, but everyone in this nation who deserves the right to affordable, secure, clean, efficient products and energy.

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About Us

American Jobs Project

The American Jobs Project is a nationally focused, research-based initiative dedicated to U.S. economic growth through advanced industries. The organization is driven by six core team members and has received support from nearly one hundred student researchers with a broad range of expertise, including law, business, engineering, and public policy. The American Jobs Project brings best practice strategies and innovative ideas from around the globe to local and state governments and stakeholders, creating bottom-up strategies that create good-paying jobs in the advanced energy and advanced materials industries.

Nikhilesh Chawla and Zachary Holman, Arizona State University

Nikhilesh Chawla is Director for the Center for 4D Materials Science and is the Fulton Professor of Materials Science and Engineering at Arizona State University. He received his Ph.D. in Materials Science and Engineering from the University of Michigan. Prior to joining Arizona State University, he was a postdoctoral fellow jointly at Ford Motor Company and the University of Michigan, and a senior development engineer at Hoeganaes Corporation. His current research interests encompass the deformation behavior of advanced materials at bulk and small length scales. He is a fellow of ASM International and a past member of The Minerals, Metals, and Materials Society Board of Directors. He has also received numerous awards of distinction in the materials field and is engaged in several academic publications.

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Dozens of hands were involved in the process of researching, writing, designing, and reviewing the report. Tiffany Wong and Laura Hobbs were the lead authors and researchers. Mary Collins and Jackie Kimble served as the lead editors, Henry Love was the lead analyst, and Amariah Baker was the graphic designer. Other contributors include Marlon Gonzalez, Kate Ringness, Andrew Miller, and Wes Adrianson.

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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 and advanced materials sectors—and to do so at the state, not the federal, level. State and local leaders who leverage the unique strategic advantages of their state to grow localized clusters of interconnected companies and institutions are poised to create quality jobs. This report serves as a strategic guide to support those efforts.

Extensive research and more than sixty interviews with stakeholders and experts in Arizona have identified advanced materials—namely, carbon fiber, advanced ceramics, and semiconductor materials—as showing particular promise in the state. Advanced materials are the foundation for many manufacturing industries and can enable technological innovation, creating middle-income jobs for Arizonans and elevating Arizona companies in the marketplace.

Arizona is well positioned to benefit from rising global demand for advanced materials given its base of eighty-nine companies, leading research universities with materials expertise, and advantageous location and climate for manufacturing. Opportunities to leverage this momentum to further serve growing regional, national, and global markets offer real benefits for the state economy and Arizona residents.

However, there are several barriers hindering Arizona's advanced materials industry and preventing it from reaching its full potential. These barriers to growth range from underfunding for STEM education and workforce training to a lack of technical and financial resources for business development. Arizona must address these roadblocks in order to become a competitive hub for advanced materials.

To take full advantage of these opportunities, state leaders can pursue strategies to create a strong foundation for industry growth and to help Arizona businesses grow, innovate, and outcompete regional, national, and global competitors. With forward-thinking policies, Arizona's advanced materials industry can support nearly 66,000 jobs annually through 2030. These direct jobs will spark local job growth and economic development as employees spend their earnings in the local economy.

Summary of Recommendations

The analysis presented in this report culminates in recommendations for Arizona's leaders based on best practices in the United States and abroad. Each recommendation identifies opportunities for barrier removal and future growth in the advanced materials sectors. While the recommendations are intended to be complementary and would be more powerful if adopted as a package, each can also be viewed as a stand-alone option.

Organize an Advanced Materials Consortium to Define Industry Needs and Foster Resources for Growth. An industrial consortium could be organized by Arizona businesses and other stakeholders or be hosted by state universities to encourage public-private collaboration and share resources. Member fees and the universities' Technology and Research Initiative Fund (TRIF) could help fund administration and operation expenses. *Key players: Businesses, universities.*

Provide Materials Testing and Validation Services to Encourage Technical Collaboration between Schools and Industry. University-based resources for industry could enable access to capital equipment and technological expertise. Universities could leverage research revenue to match financial support from industry via user fees and privately owned machinery. *Key players: Businesses, universities.*

Expand Supply Chain Assistance for Small Businesses to Integrate Advanced Materials in Their Product Lines and Manufacturing Processes. Access to capital for factory retooling could allow Arizona's small businesses to tap into the advanced materials market and grow the in-state supply chain. The Arizona Commerce Authority could increase the state funds to RevAZ and dedicate a portion to a retooling loan fund to support small business growth. *Key players: Arizona Commerce Authority, RevAZ, small businesses.*

Establish a State Investment Fund to Stimulate the Venture Capital Environment. A state-initiated investment fund could bolster Arizona's venture capital environment and provide critical capital for early-stage ventures and small businesses in the state's growing high-tech economy. The Arizona Commerce Authority could leverage insurance premium tax credits to engage insurance companies in venture capital. *Key players: Arizona State Legislature, Arizona Commerce Authority, venture capital firms, insurance companies, businesses, entrepreneurs.*

Finance a STEM Immersion Strategic Fund for Targeted K–12 Curriculum Enhancement and Pre-Employment Training. A strategic fund for science, technology, engineering, and math (STEM) education could help prepare Arizona students and educators for Arizona's growing number of STEM jobs. The state could coordinate private foundations to support this initiative. *Key players: Governor's Office of Education, private foundations, businesses, Arizona Department of Education, Science Foundation Arizona, K–12 schools.*

Deploy Mobile Manufacturing Labs to Prepare Regional Workforces for Advanced Manufacturing Jobs. A fleet of mobile training labs could increase regional and local capacity to provide manufacturing education by traveling to schools, worksites, and community learning centers in rural, tribal, and other underserved regions. Funding could come from industry partnerships and federal grants for workforce and community development. *Key players: Economic development organizations, educational institutions, nonprofits, businesses, local communities.*

Encourage Foreign Direct Investment to Bolster Arizona's Advanced Materials Supply Chain. State and local leaders could attract investment from global companies to address supply chain gaps and expand employment opportunities for Arizonans. Foreign direct investment missions could be a natural extension from the activities of the existing state and regional economic development organizations. *Key players: Transportation and Trade Corridor Alliance, economic development organizations, businesses, universities.*

The Arizona Capitol Museum in Phoenix, Arizona

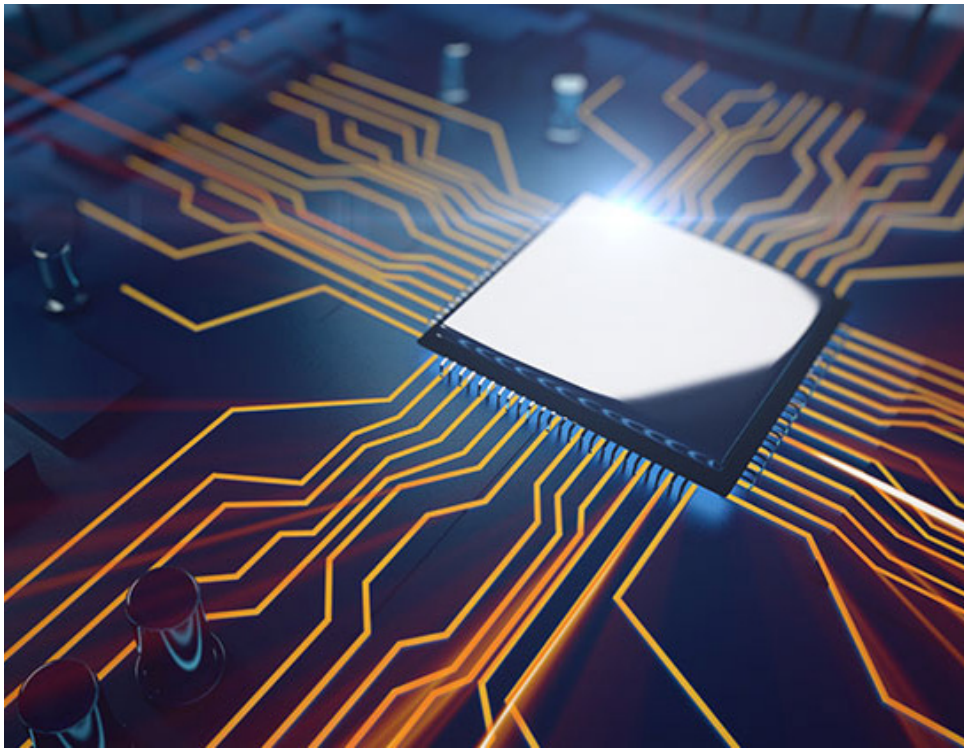
Introduction

The American Jobs Project aims to spur job creation in the advanced energy sector by identifying innovative and state-specific policies and non-legislative solutions. This national initiative takes advantage of the emerging global demand for advanced energy and advanced materials. The American Jobs Project team analyzed these opportunities in Arizona and designed recommendations specifically tailored to the state's strengths. These recommendations are informed by extensive research and over sixty interviews with local stakeholders and experts.

This report identifies opportunities to stimulate growth in an advanced materials economic cluster that leverages the state's legacy industries, current investments, and entrepreneurial business development activities. State and local leaders who seek to capitalize on the state's resources to create skilled, good-paying jobs can use this report as a foundation for action.

What is Advanced Energy?

Advanced energy diversifies energy sources, uses energy more productively, and reduces health and environmental costs. All sources, technologies, products, and services that help meet the need for affordable, secure, and clean energy are advanced energy. For example, advanced energy encompasses renewable energy sources, such as solar, wind, hydro, geothermal, and biofuels. Advanced energy also incorporates technologies and services that improve energy efficiency or make energy available when needed, such as photonics, smart buildings, energy storage, demand response, and smart grids. Other technologies and products that reduce energy consumption include electric vehicles, efficient industrial processes, and airplane bodies made of lightweight composites.



Semiconductor devices are fundamental to many advanced applications

What are Advanced Materials?

Advanced materials are next-generation components that are at the heart of many technological advancements across a variety of industries. Examples of advanced materials include nanomaterials, lightweight metals, and advanced ceramics. Advanced materials are closely tied to advanced energy because they can increase the capacity of energy generation technologies and improve energy efficiency. For example, wide-bandgap semiconductors can enable greater solar energy conversion, and carbon fiber composites can allow for lighter, longer turbine blades for increased wind power output. Furthermore, lightweight materials in aircraft and vehicles can significantly increase fuel economy, reducing consumption of transportation fuels.

Why Advanced Materials?

Advanced materials support large, growing end-use markets, including energy, transportation, health, and information and communication technology. By 2030, these global end-use markets are projected to pass $7 trillion in annual revenues, with the advanced materials market accounting for $400 billion. In the energy sector alone, materials will compose 5.7 percent of the end-use market. In recent years, North America has led the global advanced materials market, and the United States is well positioned to continue to drive this market and supply rising global demand.

Additionally, the advanced materials industry fosters many good-paying, middle-class jobs, most of which are in the manufacturing sector. The average manufacturing worker earns an hourly wage of $26, over three times the federal minimum wage and within the middle-class income bracket. For each U.S. job created in manufacturing, an average of 1.6 new jobs in local goods and services are supported.

There is also an increasing focus on advanced materials at a national level. Launched in 2011, the Materials Genome Initiative is an R&D effort spanning multiple federal agencies to catalyze the discovery, manufacturing, and deployment of advanced materials, while reducing costs across the value chain. National research institutes have sprung up across the country to promote public-private partnerships for materials research, innovation, and exchange of best practices.

The Materials Genome Initiative

To remain a major player in an increasingly competitive global economy, the federal government launched the Materials Genome Initiative (MGI) in June 2011 to accelerate and reduce the cost of materials research and deployment. Multiple agencies worked closely on this effort including the U.S. Departments of Energy (DOE) and Defense (DOD), the National Science Foundation (NSF), the National Institute of Standards and Technology (NIST), and the National Aeronautics and Space Administration (NASA). Under MGI, the federal government has invested over $500 million in new R&D programs and innovation infrastructure. For example, DOE created a materials database that has more than 600,000 materials and engages over 20,000 users. The DOE Energy Materials Network has encouraged industry collaboration through access to national lab capabilities and resources. An NSF-funded program also provided 258 grants to materials development teams across eighty colleges and universities in thirty states. As of May 2012, thirty-one companies and academic institutions pledged to collaborate on MGI's vision for innovation and thirty-three universities committed to train the future materials workforce.

Why Economic Clusters?

"Clusters are geographically close groups of interconnected companies and associated institutions in a particular field, linked by common technologies and skills."

– Michael E. Porter, *Clusters of Innovation*

Economic clusters encompass a variety of linked industries and institutions, including suppliers of specialized services, machinery, and infrastructure, which form a supply chain. Clusters also extend to manufacturers of complementary products and to industries related in skills and technologies. By placing themselves near industry allies, companies can benefit from each other's unique expertise and a trained workforce. Companies in a cluster enjoy access to specialized assets, which helps increase productivity and efficiency.

Geographic proximity and repeated exchanges of information help foster an environment of coordination and cooperation among these companies and institutions. Business clusters are shown to increase the productivity of companies, drive innovation in the field, and facilitate the commercialization of this innovation by increasing communication, logistical support, and overall interaction between cluster entities. By having a close network of suppliers and partners, companies can reap the benefits of greater operational efficiency and reduce costs. Clusters also help build a strong foundation for creating and retaining jobs.

Local Demand

Local demand is not essential for cluster development, but it can help to establish a geographic base. Local abundance of natural resources or raw materials can also help grow a local manufacturing cluster. For example, a state with a high solar energy potential or abundance of silicon can be a natural home for a thriving solar manufacturing cluster. However, if local adoption of solar technology is slow, the state can tap into larger regional, national, and global markets to drive cluster development.

Key Cluster Elements

Economic clusters require strong foundations for growth. In today's competitive, globalized economy, businesses are more likely to thrive in cities and states that offer a rich innovation ecosystem, provide fertile grounds for capital investment, and boast a highly skilled workforce. A successful innovation ecosystem bridges the gap between the knowledge economy and the commercial economy, while access-to-capital programs provide the necessary funds to facilitate commercialization and expansion of businesses. Seamless connections between researchers, entrepreneurs, and investors are vital to the success of advanced energy technology businesses—bringing innovative ideas to the marketplace quickly and efficiently. Trained and skilled workers are also fundamental to the success of an economic cluster. A thoughtful, sector-based workforce development approach that engages the public sector, the private sector, and related nonprofits can ensure businesses are equipped to identify employment needs and schools prepare workers with the skills needed to fill available jobs.

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 of Cluster Growth

Clusters can foster a large number of direct, indirect, and induced jobs by stimulating economic activity in a region, and maximizing job creation is highly dependent on local activity. Since manufacturing clusters primarily serve non-local markets, new manufacturing jobs create additional jobs in the trade and service sectors. Workers in manufacturing clusters earn income from sales made throughout the region or nation. These dollars are spent and re-spent in the local economy, creating and maintaining additional jobs in grocery stores, restaurants, medical providers, and other sectors. The result is the multiplier effect where a dollar of earning in a cluster circulates throughout local businesses and their employees, and creates an impact greater than the initial injection. Therefore, promoting an economic cluster by recruiting manufacturers and their suppliers will result in an economic impact many times greater than the initial investment.

Report Structure

The Arizona Jobs Project: A Guide to Creating Jobs in Advanced Materials begins by highlighting Arizona's economic opportunity to build a globally competitive advanced materials cluster. The next sections provide a technical overview of the targeted materials and the cross-cutting technologies that can expand their potential. Then, Arizona's cluster development assets and its advanced materials companies are detailed. The analysis culminates in an assessment of the state's job growth potential and policy recommendations tailored to Arizona. A fully cited version of the report is available on the American Jobs Project website at http://americanjobsproject.us/.

Arizona's Economic Opportunity in Advanced Materials

Post-Recession Job Growth

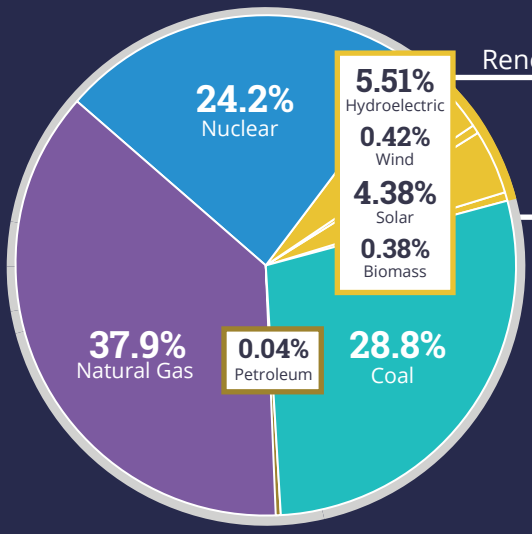
Since the 2008 recession, Arizona has struggled to deliver good-paying jobs across the state. Although the state finally reached pre-recession employment levels in 2016, employment rates are uneven across regions and job growth has largely been in lower-wage sectors. Currently, manufacturing accounts for 8.4 percent of Arizona's GDP and 5.9 percent of its non-farm workforce. Expanding the manufacturing sector in Arizona is an opportunity to galvanize economic development—for each U.S. job created in manufacturing, an average of 1.6 local service jobs are supported. With U.S. manufacturing workers earning an average of 24 percent more than other workers, Arizona's skilled workforce could continue to benefit from traditionally higher manufacturing wages. In fact, the average annual wage of Arizona's 156,100 manufacturing employees is $80,225 compared to $45,500 for the state's nonfarm businesses. Arizonans currently working in low-wage occupations could benefit from the expansion of manufacturing jobs.

Solar array on ASU West Campus in Phoenix, Arizona

Arizona's Energy Profile

Electricity Generation

As of September 2016



Renewables

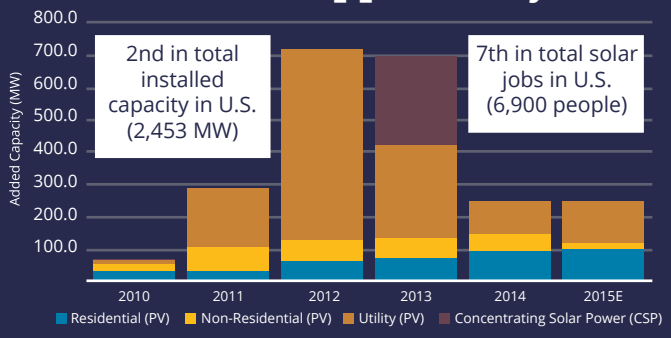
Utility Renewables Goals

Renewable Energy Standard (all regulated utilities): **15% by 2025** with **30%** from customer-side distributed generation

Sustainable Portfolio Principles (Salt River Project): **20% by 2020**

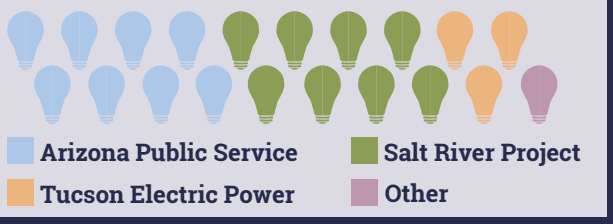
Spent **~$17 billion** on energy imports in 2014

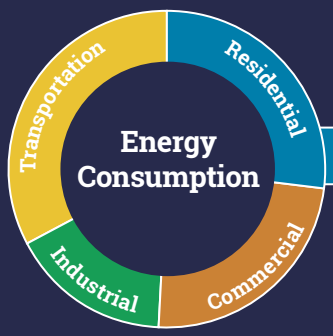
Solar Opportunity



Electricity demand to grow between 1-2% annually, reaching over 20,000 MW in 2021

Utility Share of Customer Base





Air conditioning accounts for **25%**

KEY ACTIONS

1990s

1995: Residential Solar and Wind Energy Systems Tax Credit

1997: Solar and Wind Equipment Sales Tax Exemption

2000s

2006: Commercial/Industrial Solar Energy Tax Credit Program

2007: Updated Renewable Energy Standard and Tariff (REST)

2009: Net Metering for Regulated Utilities

2010

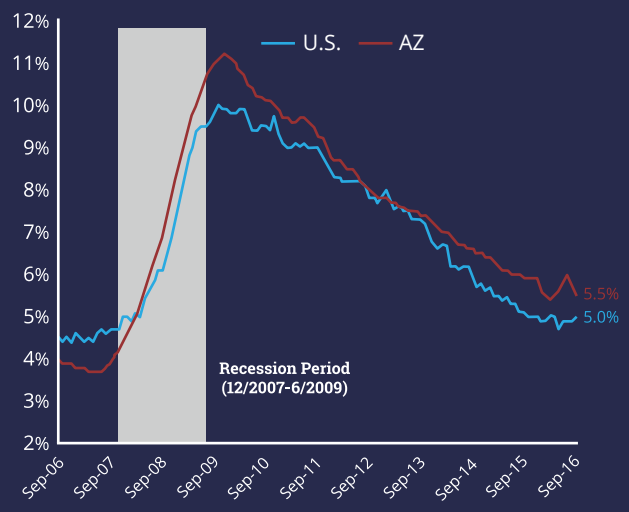
- Energy Efficiency Resource Standard
- Renewable Energy Business Tax Incentives
- Renewable Energy Production Tax Credit, personal and corporate

2011

- SRP Sustainable Portfolio Principles

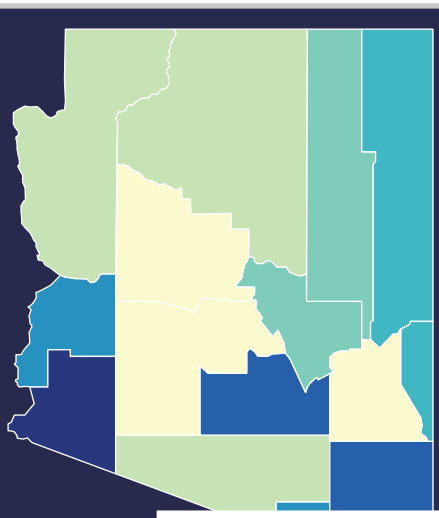
Arizona's Economic Opportunity

Arizona & U.S. Unemployment Rate



Employment is back to pre-recession levels, but joblessness is uneven across the state.

Higher-wage jobs such as manufacturing and construction were lost during recession, but recovery has mostly been in lower-wage, part-time jobs.



Regional Unemployment Rate

5.00 — 18.00

Impact of the Manufacturing Industry

Average salary of $80,225 for manufacturing vs. $45,500 in nonfarm businesses (2014)

	Industry Total	Percent of State Total
Gross Output	$23.77 Billion	8.4%
Workforce	156,100 Employees	5.9% (nonfarm)
Export Goods	$18.27 Billion	81%

2013

- APS imposed fees on solar customers

2014

- EmPower Arizona released, update to 1990 master energy plan

2015

- SRP imposed fees for customer-side generation, including solar
- APS joined California ISO Energy Imbalance Market
- Governor's Office of Energy Policy closed, now the only state without a state office/division dedicated to energy

2016

- ACC opened docket on updating REST
- ACC closed value-of-solar docket, ending net metering

Energy Assets for Manufacturing

Arizona is a prime location for manufacturing firms due to low energy costs. Arizona has among the lowest per capita energy consumption and per capita energy expenditures. Although Arizona is the 14th most populous state, energy consumption is low due to a small industrial sector. Because of limited resources for production, the state relies heavily on petroleum imports to fuel the transportation sector and on natural gas and coal imports for electricity generation. These imports, as well as power from the Palo Verde Nuclear Generating Station, help keep electricity costs below the national average for most end-use sectors and make Arizona a net exporter of electricity.

Arizona also benefits from renewable energy generation that helps to boost energy independence from out-of-state resources. Second to hydroelectric power, solar power accounts for a large portion of renewables. This large solar energy supply is due to the state's sizable solar resource as well as goals and incentives for utility and customer-side solar generation.

Palo Verde Nuclear Generating Station in Tonopah, Arizona

Advanced Materials Support the Growth of the Manufacturing Industry

Arizona could leverage its manufacturing assets by focusing on advanced materials, which would enable product differentiation in Arizona's industries and make in-state businesses competitive in global markets. Aerospace, defense, energy, electronics, transportation, and infrastructure are all emerging markets for advanced materials. Arizona has ranked very poorly in manufacturing sector diversification, and advanced materials could be an area of focus to provide higher-wage opportunities to the existing workforce.

Arizona could specifically invest in an advanced materials cluster that seeks to improve energy efficiency in the production and performance of manufactured products. For example, companies in the cluster could develop solar cells that convert more solar energy into electricity or aircraft with greater fuel economy. These types of innovations have received national recognition and support Arizona's industries. A larger materials focus can effectively strengthen and expand the global reach of the state's manufacturing sector.

Identifying Arizona's Strengths, Weaknesses, Opportunities, and Threats in the Advanced Materials Industry

Arizona's Competitive Advantage

Within the advanced materials industry, Arizona has the opportunity to leverage its strengths in carbon fiber, advanced ceramics, and semiconductor materials. Global demand for each type of material is projected to grow by 10 percent annually until 2024, representing an opportunity for Arizona's manufacturing sector. While this report highlights these three materials, the state houses eighty-nine companies engaged in a wide array of innovative materials. Arizona's entrepreneurial culture has grown out of local innovation hubs and the state's top tier universities. The University of Arizona (UA) and Arizona State University (ASU), in particular, have research thrusts and academic programs dedicated to materials science and engineering, fostering innovative research and highly skilled graduates. Companies have also flocked to Arizona for its favorable tax environment and standard of living, and this business-friendly climate could be leveraged to attract and expand advanced materials companies in the state. By fostering business growth, companies could leverage Arizona's strategic geographical position for export to large economies, such as California, Texas, Mexico, Canada, and Asia-Pacific.

STRENGTHS	WEAKNESSES
1. Home to eighty-nine companies engaged in advanced materials development and application 2. Tier 1 research universities with expertise in materials science and engineering 3. Strategic location for manufacturing and export to large economies such as California, Texas, Mexico, Canada, China, and Japan 4. Relatively low tax environment for businesses 5. Low electricity costs and agreeable climate for manufacturing	1. Lack of targeted state interest in advanced materials 2. Ranked 49th in the nation for state funding for both K–12 and higher education 3. Lack of investment funding for startups and early-stage businesses: captured only 0.2 percent of national venture capital funding in 2015 and 0.4 percent in 2016 4. Reliance on aerospace and defense industries risks a lack of market diversification in manufacturing, resulting in volatility in employment and incomes
OPPORTUNITIES	**THREATS**
1. Synergy with existing large industries, such as aerospace, defense, solar, and electronics 2. Lower cost of living than California and higher incomes for manufacturing jobs can attract workers and businesses 3. Current efforts through Achieve60AZ and the Workforce Arizona Council to enhance the technical education and workforce system 4. Rising global demand of about 10 percent year over year for each targeted advanced material	1. Supply and innovation from out-of-state businesses 2. Policy uncertainty that may impede industry growth 3. High-risk ventures often with costly and long commercialization periods

Barriers to Economic Growth

However, Arizona will need to address significant barriers in education and access to capital before it becomes a major advanced materials hub. In recent years, state support for education has ranked 49th across the nation for both K–12 and higher education, with many community colleges receiving no state funding. In 2015, Arizona captured 0.2 percent of national venture capital funding, and this share grew to only 0.4 percent in 2016. Not only is access to capital important to reinforce the state economy, but also it is particularly critical for advanced materials ventures, which face a high level of risk and uncertainty as well as large R&D and commercialization costs. Arizona should consider providing greater financial support for education and securing risk capital for startups and early-stage businesses to bolster the state economy and its workforce. Through targeted state investment, Arizona could be a major competitor for supply and innovation.

Arizona State University is a top-tier university in Arizona's innovation ecosystem

The Impact and Market Opportunity of Arizona's Targeted Advanced Materials

Arizona has a competitive advantage in three different materials: carbon fiber, advanced ceramics, and semiconductor materials. Not only do Arizona's research universities excel in these areas, but also these materials have synergy with major industries in the state and region, including aerospace and defense, electronics, advanced energy, transportation, and infrastructure. The following section provides an overview of the targeted advanced materials and market trends that Arizona could effectively leverage to become a leader in supply and innovation.

This technology discussion provides a snapshot of each material and does not delve into complementary components and manufacturing equipment that may provide other supply chain opportunities in the state. Refer to page 56 to see the impact of these materials on downstream industries.

Carbon Fiber

Why Carbon Fiber Matters

Carbon fiber is a key lightweighting material for industries ranging from aerospace to automotive and medical. Carbon fibers are thin fibers composed mostly of carbon atoms, bonded as crystals in parallel alignment. This structure produces a strong, stiff, and wear-resistant fiber. Multiple fibers can be bound together as a tow to be used by itself or woven into a tough fabric.

Carbon fiber can also be used in a composite structure, in which reinforcing fibers are embedded in a resin matrix to create unique structural properties. Carbon fiber-reinforced polymers (CFRPs) are five times stronger than steel and one-third the weight of steel, enabling efficiency in many technologies. For example, aircraft and automobiles have greater fuel economy due to decreased weight, and lighter, longer wind turbine blades can increase power output and ease transportation. Increased efficiency results in major cost savings for manufacturers and customers. In the automotive industry, CFRP vehicles can save

owners up to $5,000 on fuel costs over the lifetime of the car due to a 50 percent weight reduction. Accounting for life cycle costs (such as fuel and maintenance) could dramatically increase the long-term benefits of using CFRPs, justifying high upfront material costs.

Cost Benefits of CFRPs in the Aerospace Industry

Aircraft lightweighting offers significant cost savings across the life cycle. Currently, as much as 50 percent of the structural frame of some commercial Boeing and Airbus aircrafts come from CFRPs and other composites. Fuel accounts for the most money spent on aircraft operation, ranging from 28 to 40 percent of total costs. Each pound shaved in a commercial airliner can save 14,000 gallons per year. Incorporating CFRPs in airframes could reduce weight by up to 20 percent. The high corrosion resistance of CFRPs would also reduce the sizable costs associated with maintenance and operation. On the manufacturing side, CFRPs could be easily molded together to cut the number of components and effectively lower the cost of manufacturing and assembly. CFRPs are very moldable compared to other metals. Thus, the development and integration of CFRPs in Arizona's aerospace industry would provide major economic incentives.

CFRPs Are Transforming the Automotive Industry

CFRPs are projected to be widely adopted in automobiles by 2025 and become the standard for meeting performance and sustainability requirements by 2030. Cutting 10 percent of vehicle weight will improve fuel efficiency by up to 8 percent for vehicles with internal combustion engine and increase the range by 10 percent for electric vehicles. CFRP vehicles could reach cost parity with steel-based cars if material costs are driven down to $4 per pound from their current price of up to $16 per pound. With streamlined collaboration between industry, science, and government, CFRP automotive components are expected to reach mass production on a scale of 50,000 or more units by 2018.

Rising Demand for Carbon Fiber

Global demand for carbon fiber and CFRPs is projected to grow at a rapid clip. The global carbon fiber market was valued at $2 billion in 2014 and is projected to grow at 9 to 10 percent per year until 2020. In 2015, the CFRP market was valued at $11.6 billion. Market

Carbon Fiber: How It's Made and Future Uses

The Precursor: A Costly First Step	CFRPs 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 is polyacrylonitrile (PAN) which makes up 89 percent of source material for carbon fibers and is cost-prohibitive.
Precursor Processing Results in Spools of Carbon Fiber Thread	The precursor is exposed to extreme heat in an inert gas to activate the 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- to 25-pound spools.
Carbon Fiber Thread is Woven	The bands of carbon fiber are 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 Added for Compressive Strength	Manufacturers add plastic resin to the fabric. This type of resin addition is called prepregging if done before it is ready to mold. Some fabrics can be coated with resin and directly set in the form mold.
Composite is Vacuum-Sealed 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 and then trimmed and drilled as needed.

End Uses and Benefits for Carbon Fiber	TRANSPORTATION	ENERGY	MEDICAL
	CFRPs can reduce vehicle weight by 50-70 percent and are predicted to be the standard for vehicle use by 2025.	Wind turbine blades made of CFRPs can increase efficiency and decrease transportation costs.	CFRP prosthetics are increasingly common because composites offer strength without the weight of metal.

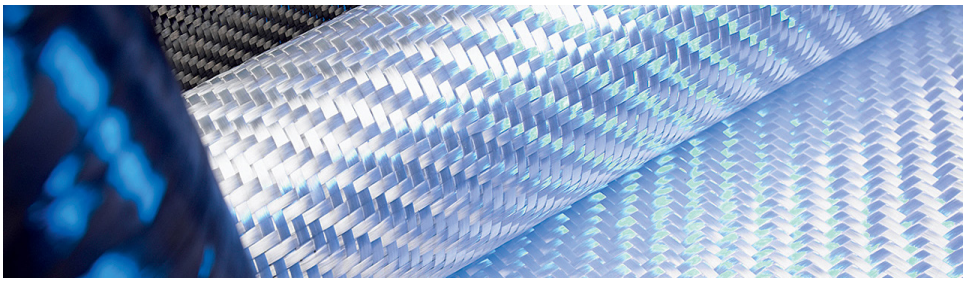
reports estimate an annual growth of 10 to 11 percent between 2015 and 2020. In other words, the global demand for carbon fiber (including CFRPs) will double from 2014 to 2020, growing to over 100,000 tons. North America will remain the largest market due to its growing downstream industries and greater focus on lightweight aircraft and vehicles. In fact, North America was the largest consumer of CFRPs in 2014, accounting for over 35 percent of total volume consumed.

As global demand increases, the foreign export market is a significant opportunity for U.S. CFRP manufacturing. In 2015, U.S. carbon fiber exports totaled about $957 million and export opportunities continue to rise, with Germany and Italy as the top foreign customers. The top applications based on global revenues were aerospace and defense (50 percent), sports/leisure (11 percent), wind turbines (9 percent), molding and compound (8 percent), and automotive (7 percent). Given its strategic location and its industry strengths, Arizona has a competitive advantage for manufacturing and export.

Opportunity for Innovation in Carbon Fiber

The high cost of carbon fiber has been a significant barrier to greater commercial penetration, but targeted R&D could significantly reduce costs and expand market potential. Currently, the cost of CFRPs ranges from 1.5 to 5 times the cost of steel in equivalent applications. The steep cost of CFRPs is due to expensive raw materials, such as chemical precursors, used in the production process. However, raw material and processing costs are likely to drop significantly by 2030. For example, recent projections foresee a 45 to 67 percent decrease in the cost of manufacturing carbon fiber automotive components.

Advances have already been made through public and private sector research. Researchers at Oak Ridge National Laboratory developed a process that could cut costs by 50 percent, and MAI Carbon Cluster Management and BMW are leading an ambitious project to lower costs by 90 percent. Furthermore, innovations to support high-speed production, energy-efficient manufacturing, and material recycling could reduce costs along the supply chain and increase utilization.



Carbon fiber composite reinforcement fabrics

Advanced Ceramics

Why Advanced Ceramics Matter

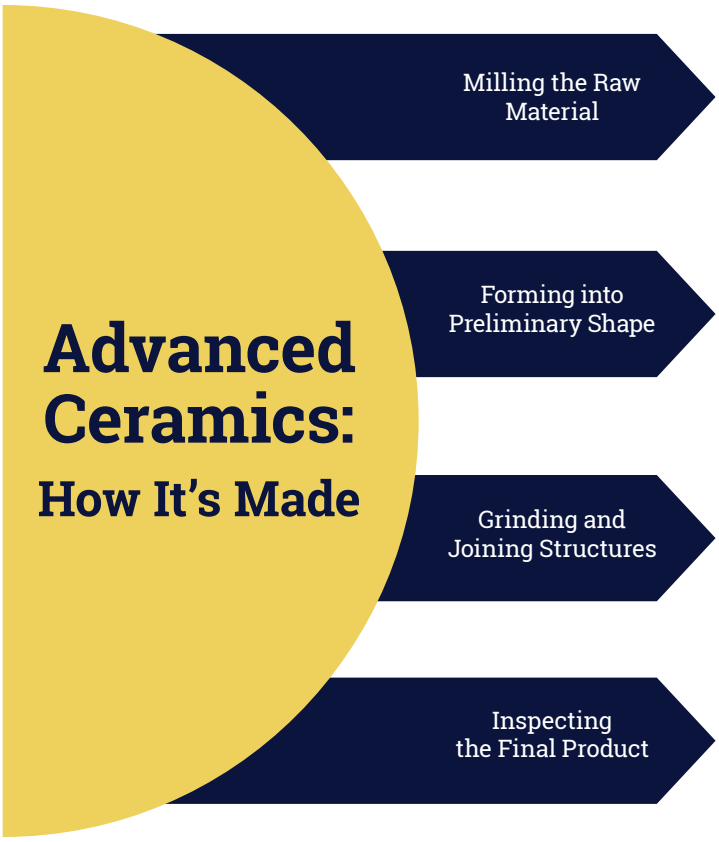
Advanced ceramics are generally lighter than metals, have high corrosion resistance, and remain stable at high temperatures. These material properties make ceramics advantageous for commercial applications in the aerospace, defense, and electronics industries. Ceramics are inorganic, nonmetallic materials that are formed by bonds between metallic and nonmetallic elements. Advanced ceramics are distinguished from traditional clay-based ceramics by their high technical and functional value, created with highly refined materials and controlled processes.

Because of the variety of potential materials and manufacturing processes, advanced ceramics offer a wide array of properties for tailored solutions. For example, alumina is the most widely used material because of its mechanical strength, electrical insulation, and resistance to heat, wear, and corrosion; these properties make it ideal for semiconductor equipment components and insulators. On the other hand, silicon nitride is ideal for engine components because of its toughness and thermal-shock resistance at high temperatures.

The development of ceramic matrix composites (CMCs) expanded the functionality of ceramics. CMCs are refractory fibers (may include carbon fibers) embedded in a ceramic matrix, which creates a light, stiff, and super heat-resistant structure that is primed for high-temperature applications. In fact, CMCs can withstand temperatures up to 2,700°F. In the aerospace industry, use of CMCs in engine cores enable a 6 to 8 percent increase in fuel efficiency through reduced weight, improved durability, and reduced need for cooling. At the commercial level, GE Aviation advanced this technology with their silicon-carbide-based CMCs for jet engines and gas turbines at electricity generating sites.

Testing ceramic materials for use as thermal storage media

Advanced Ceramics:
How It's Made



Raw powder and a solvating material like water are mixed and grinded in a ball mill to produce a fine slurry. Binding agents are added to strengthen the mixture. The slurry is then dried to form a fine powder.

The granulated powder is formed into a preliminary shape close to its final form. Based on the desired shape, forming processes can range from isostatic pressing to dry pressing, extrusion, or injection molding. The shape is then sintered at high temperatures to produce a solid mass.

The resulting structure is grinded and then polished to achieve dimensional accuracy. This process generally uses a diamond wheel because of the ceramic's extreme durability. The ceramic is then bonded with other ceramic, metallic, or resin components for additional capability.

The final product undergoes rigorous testing and inspection to ensure its performance.

Valuable Properties of Advanced Ceramics

DURABILITY

Advanced ceramics are hard and resistant to corrosion and wear.

LIGHTWEIGHT

Advanced ceramics are lighter than most metals.

THERMAL INSULATION

Advanced ceramics are stable at extremely high temperatures.

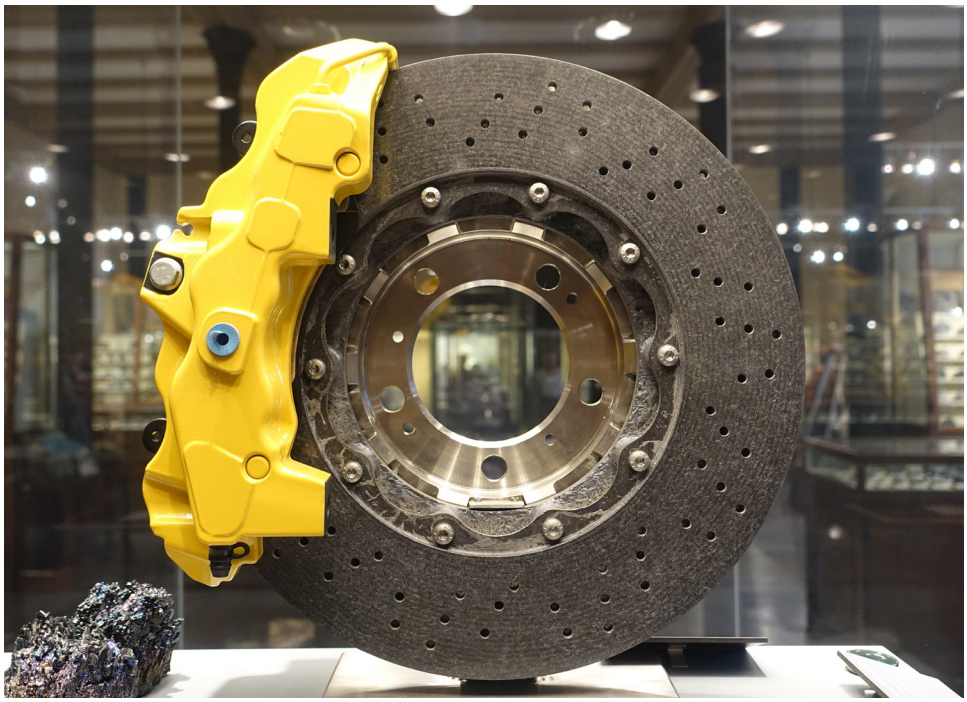
Rising Demand of Advanced Ceramics

The global advanced ceramics market has a projected annual growth of 10.2 percent over the next eight years; the market is expected to grow from $56.7 billion in 2015 to nearly $134.6 billion in 2024. The North American market is the second largest in the world and its revenue is projected to grow by 9.5 percent per year from 2016 to 2024. Across ceramic product segments, CMCs will have the most rapid growth with an annual growth rate of over 13 percent up to 2024, and North America is expected to be the main driver of demand. In 2014, the United States topped global CMC demand, with U.S. demand expected to grow further by 11.5 percent annually until 2019.

Nationally and internationally, the major end-user markets for ceramics are the electronics, medical, and aerospace industries. In fact, electronic devices account for nearly 30 percent of the global advanced ceramics market, the largest application segment in 2015. Additionally, aerospace will continue to play a major role as CMCs grow; this top application segment is projected to grow by 14 percent each year between 2014 and 2019.

Opportunity for Innovation in Advanced Ceramics

Machining costs remain the biggest barrier to commercial penetration for advanced ceramics. Although the cost of machining advanced ceramics for prototyping are comparable to non-ceramic materials, machining ceramics for production-quality structures can be expensive due to larger material inputs (ceramics cannot be easily prepared to closer tolerances) and the lack of customized grinding processes for different materials. CMCs also require energy-intensive manufacturing given the material's high-temperature resistance. Ceramic fibers can be costly inputs for composite structures. For example, carbon/carbon CMCs are the cheapest compared to oxide and silicon carbide CMCs because of larger production volumes. However, economies of scale will have a significant impact on lowering prices and facilitating market penetration. Greater production and innovations that improve both fiber costs and processing technologies are key to bolstering in-state manufacturing across industries.



Silicon carbide CMC car brake

Semiconductor Materials

Why Semiconductor Materials Matter

Semiconductor materials are integral to the power and electronics industries. By definition, semiconductors are materials that have electrical conductivity intermediate of conductors and insulators. The conductivity of semiconductors can be altered through a process called doping, in which impurities are added to pure base materials. Semiconductors are typically made with group IV materials such as silicon and silicon carbide, group III-V materials such as gallium arsenide and gallium nitride, and group II-VI materials such as cadmium telluride. These semiconductor materials form the foundation of semiconductor devices such as key electronic components and solar cells that control the flow of electrical current and enable power conversion. Semiconductor material innovations have the potential to handle larger loads and increase power conversion efficiency, resulting in cost and energy savings.

Advancements in Semiconductor Technology

Semiconductors with bandgaps wider than traditional silicon have the possibility of enabling greater energy efficiency in large-scale applications. Arizona State University is involved in a national research initiative to make wide-bandgap semiconductors competitive in the global market. This innovative technology allows for better size, speed, reliability, and efficiency than silicon-based components. The advantages include cutting energy losses, handling larger voltages at higher temperatures, and improving power quality. For example, solar inverters that use wide-bandgap semiconductors could reduce the electricity losses of DC-to-AC conversion by 50 percent.

Rising Demand for Semiconductor Materials

Rising demand in semiconductor materials is tied to growth in major end-user industries. As end-user demand grows over the next seven years, compound semiconductors that could replace silicon in material applications are also projected to grow. For example, the gallium nitride semiconductor device market will grow at 17 percent per year between 2016 and 2024, reaching $3.4 billion due to increasing use in the aerospace and defense sector. In 2015, the global market for semiconductor fabrication and packaging materials was valued at $43.4 billion, dropping 1.5 percent from the previous year. Asia Pacific dominates the industry with Taiwan, South Korea, Japan, and China each having

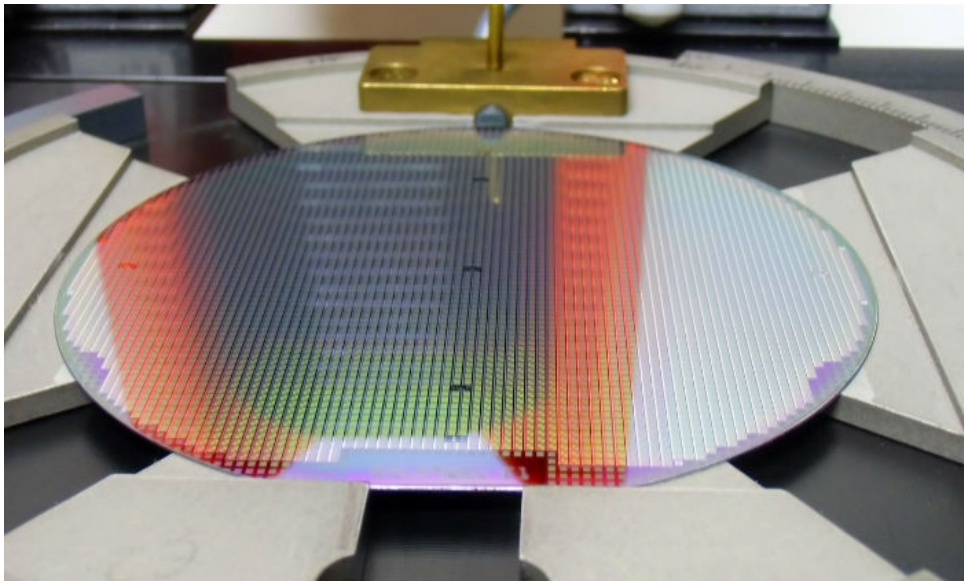
Future Opportunities in the Solar Industry

Solar power is an obvious asset to Arizona's energy economy, providing numerous jobs and a renewable energy supply. Arizona is ranked second in the United States for total installed capacity, and there is substantial opportunity to expand. With an estimated practical potential of 5,200 GW, Arizona could significantly increase its current installed capacity of over 2.4 GW. Advancements in semiconductor materials for solar cells, in conjunction with clear market signals and stakeholder cooperation, could be a boon to the local industry and create a sustainable jobs base for Arizonans.

larger market shares than North America (12 percent). However, the materials market in North America grew by 1 percent over 2014–2015 while contracting in Taiwan and Japan. The market for fabrication materials, in particular, is expected to reach about $30 billion by 2020. The growth of complementary materials, such as wet processing chemicals and thin-film metals, is projected to be the fastest among semiconductor market segments at an annual growth rate of 7.7 percent. While showing more modest growth, the market for fabrication equipment accounts for a significant portion of the industry's revenues.

Opportunity for Innovation in Semiconductor Materials

Materials account for roughly 35 to 40 percent of the cost of manufacturing semiconductor devices. Silicon-based semiconductors have fallen in cost over recent years due to their large-scale adoption. Commercial penetration of innovative alternatives will require economies of scale in manufacturing. Gallium nitride semiconductors, for example, are relatively expensive due to the high cost of the materials input and the fabrication process. Other materials, such as gallium arsenide for energy-efficient solar cells, can be 100 to 200 times more expensive to manufacture, relegating them to niche applications. Thus, efforts at the university and federal levels to make cost-competitive, energy-efficient semiconductors could support the growth and expansion of the industry.



A wafer of semiconductor material used for electrical applications

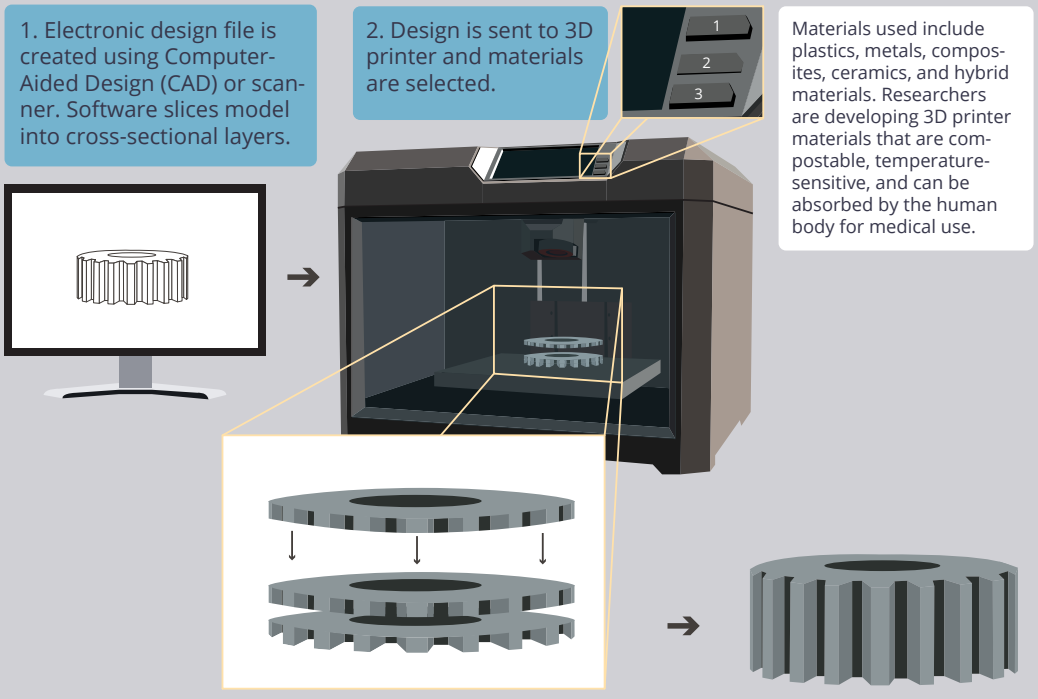
Cross-Cutting Technologies that Expand the Potential of Advanced Materials

Greater analytical and machining capabilities widen the spectrum of materials development and application. Additive manufacturing and nanotechnology are two significant technologies that enable greater functionality of materials for tailored solutions. By leveraging its strengths in these cross-cutting fields, Arizona could distinguish its leadership in advanced materials.

Additive Manufacturing

Additive manufacturing, commonly known as 3D printing, is the process of depositing successive layers of a material over one another to create a solid 3D object. This process differs from traditional subtractive manufacturing where material is removed from a larger piece to produce a final object. Using computer-aided design software, products ranging from jet engine fuel nozzles to medical implants can be modeled and printed, transforming them from virtual to material with the click of a button.

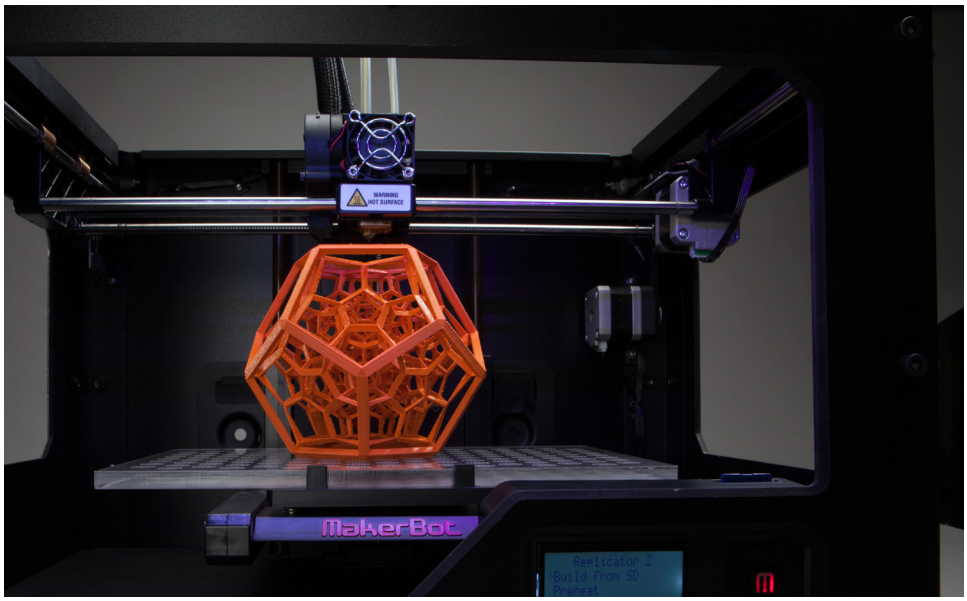
Additive Manufacturing: How It Works



There is growing interest in additive manufacturing in Arizona and across the nation, given the significant advantages it offers to manufacturers and customers. The benefits of additive manufacturing include waste reduction, energy efficiency, faster prototyping, design flexibility, increased customization, space efficiency, and reduced costs.

The adoption of 3D printing has begun to shift the way society designs, manufactures, engineers, and customizes products. Currently, the technology is used widely for rapid prototyping and manufacturing tooling. However, there is greater focus on expanding 3D printing capacity to create functional parts for industry through innovation in material inputs and faster machining processes. Arizona could help usher this trend to its full commercial potential through industry and academic leadership. The Arizona Technology Council's Additive Manufacturing Committee serves as a forum for diverse stakeholders to promote the growth of the technology and industry in the state.

The development of this new processing technology has enabled innovations in how to apply existing materials. Plastics are the predominant inputs for 3D printing; however, there is increased commercial penetration and R&D of metals, composites, and ceramics. For example, Local Motors, headquartered in Chandler, entered the automotive industry with its 3D-printed car technology in 2007. Initial models were made with a mix of 80 percent ABS plastic and 20 percent carbon fiber. More recently, new material designs and applications were explored through public-private partnerships with universities, including Arizona State University. Additionally, Titan Industries in Tempe provides design and fabrication support for 3D-printed titanium components.



3D printers can create complex, 3D structures with minimal material inputs

Nanotechnology

Nanotechnology is another cross-cutting technology that could expand the potential of advanced materials through the science and engineering of matter at a scale of less than 100 nanometers. Specifically, greater structural and functional understanding of materials at ultrafine scales could enable materials innovation, a major asset to both fundamental and applied science. New processes could also allow for materials manufacturing at the nanoscale. Arizona can leverage its advanced capabilities and assets in nanotechnology to expand its materials industry, with support from research universities, legacy semiconductor industry, and organizations such as the Arizona Nanotechnology Cluster.

Carbon nanostructures are one such innovation fostered by nanotechnology. For advanced semiconductor processing, which already takes place well below the 100-nanometer threshold, carbon nanotubes can enable higher efficiencies. These cylindrical carbon-based materials have extremely low electrical resistance, which maximizes power output and speeds up conduction in semiconductors. Because of this property, carbon nanotubes have the potential to outperform silicon transistors in electronic technologies.

Carbon nanostructures can also fortify composite structures. By growing these nanostructures directly on the surface of reinforcing fibers, traditional carbon fiber- or ceramic-based composites can be fine-tuned with certain properties and have expanded applications. However, scalable nanomanufacturing—manufacturing macroscopic products with nanomaterials at a commercial scale—will continue to be a challenge for expanding the market potential of nanotechnology.

Nanometer-scale analysis technologies enable cutting-edge materials research

State Assets to Support Advanced Materials Cluster Development

Having a strong economic foundation is essential to sustaining and growing clusters. Reinforcing the state's strengths in its innovation ecosystem, business access to capital, and workforce development could support the expansion of existing advanced materials companies and attract new businesses to the state. Many of Arizona's business growth and innovation programs grew from the 2011 Arizona Competitiveness Package (HB 2001), which established the Arizona Commerce Authority (ACA) and enhanced tax incentives. The ACA is a private entity that serves as the state's leading economic development organization for business attraction, retention, and expansion. Arizona has since fostered an entrepreneurial climate thanks to ACA's efforts, low business taxes, and the innovative culture of the state's top-tier universities.

Technical manufacturing education in science, technology, engineering, and mathematics (STEM) is also key to creating a skilled workforce for the advanced materials cluster and its downstream manufacturing industries. The Achieve60AZ initiative signals Arizona's recognition of the importance of skill development. Stakeholders identified four key areas for ensuring 60 percent of Arizonans have at least a professional certificate by 2030: improving K–12 pathways, completing credentials, increasing access to higher education, and aligning workforce needs through industry engagement.

These promising efforts have been hampered by a lack of funding for education statewide. Arizona is ranked 49th in the nation in state funding for both K–12 and higher education, with schools in the Maricopa and Pima Community College Districts receiving no money at all. As emphasized by Governor Ducey's 2017 State of the State Address, investments in student learning and teacher development are crucial to keep Arizona's workforce competitive and create thriving communities. The following section outlines Arizona's key assets for maintaining its entrepreneurial culture and reinforcing career pathways for Arizonans.

Highlighting Arizona's Cluster Assets

Northern Arizona University

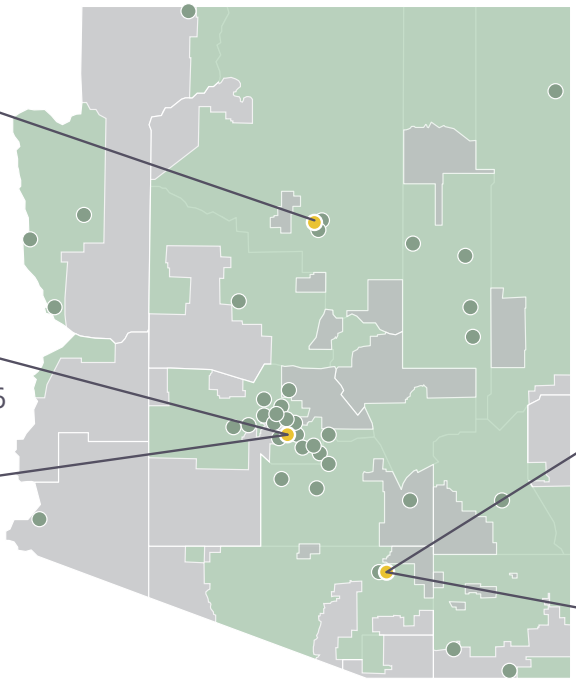
34 Incubators/ Accelerators

Seed Spot

One of the top **20** global startup accelerators in 2016

Arizona State University

Ranked most innovative school in U.S. for two straight years



Color Keys:

Workforce Development

Access to Capital

Innovation Ecosystem

- Community Colleges
- Universities (main campus)
- JTED Coverage

34 Venture Capital/ Angel Funds

Desert Angels

3rd most active angel group in the U.S. in 2014

The University of Arizona

Arizona Commerce Authority Programs

R&D Tax Credit:
Extended **$5 million** total incentives to **45 applicants**

SBIR/STTR Resource Center:
Assisted 84 companies

RevAZ:
Provided **$454,000** of technical assistance in over **100 client projects**

Arizona Fast Grant:
Accelerated **20 companies** in 2013, four of which were in **advanced materials**

Arizona Innovation Challenge:
Awarded **12 companies** a total of **$3 million** in seed funding in 2015

Jobs Training Grant Program:
Awarded over **$27 million** across **102 grants**

Innovation Accelerator Fund:
Issued **$14 million** to 40 companies, creating about **1,500 new jobs**

Angel Investment Tax Credit:
Provided $10.1 million in tax credits from 2007 - 2012, representing investments of **$31.1 million** by more than **450 investors**

Innovation Ecosystem and Access to Capital

Innovation Ecosystem

- Promotes research and development
- Facilitates movement of 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

Research Universities

Arizona is buttressed by three exceptional public universities: The University of Arizona (UA), Arizona State University (ASU), and Northern Arizona University (NAU). Both UA and ASU are Tier 1 research universities with the highest levels of R&D, and NAU is a Tier 2 research university with comparable R&D activity. Total R&D expenditures in each of Arizona's Tier 1 universities rank higher than 90 percent of expenditures in other schools, with federal contracts supporting a large number of these projects.

All three universities conduct research focused on materials science and engineering. UA and ASU have departments dedicated to this study while NAU nests materials understanding under its broader engineering programs. This knowledge base and supporting labs could provide key resources for industry growth within the state.

UA's core competencies include ceramics, carbon fibers, and photovoltaic materials, and this research expertise can successfully move from the lab to the world through public-private partnerships and technology transfer support. In fact, materials-related inventions made up 8 percent (twenty-six patents) of reported inventions in 2015. Materials research projects are supported with about $4–5 million in annual funding, largely from federal grants, with a small portion from state foundation grants and industry. Additionally, the Arizona Materials Laboratory provides extensive facilities and a collaborative space for researchers to advance the technology. Along with ASU, UA is a participating university in the Semiconductor Research Corporation, which aims to streamline and propel semiconductor

The University of Arizona conducts cutting-edge research to stimulate in-state innovation

research. UA also encourages out-of-classroom experiences through its 100% Engagement Initiative, which connects students with mentors and to formal research, community activities, internships, and other projects.

ASU excels at materials processing and characterization, providing fundamental and applied research for materials development. Key areas of research include electronic materials, materials for energy, nanostructured materials, and more nanoscale phenomena. Materials research expenditures across departments totaled approximately $59 million in 2016, and at least 17 percent of available licensing technologies are materials innovations. ASU is also heavily involved in multi-university partnerships, such as PowerAmerica; the U.S. Army-backed Flexible Electronics and Display Center; and the Quantum Energy and Sustainable Solar Technologies, a federally funded engineering research center. For the past two years, ASU was selected as the most innovative school in the United States by U.S. News and World Report.

Resources for Business Growth and Innovation

The Arizona Commerce Authority offers access to capital through numerous loans and competitive grants. The $3 million Arizona Innovation Challenge and Venture Madness provide large-scale opportunities for promising ventures to compete for seed funding. The Innovation Challenge identifies advanced materials and advanced manufacturing as target sectors for growth. The Arizona Fast Grant awarded competitive $5,000 to $20,000 grants to early-stage tech companies.

State resources can enable business development and planning for growth

The Advanced Materials Initiative at Arizona State University

The Advanced Materials Initiative aims to establish a centralized ecosystem for materials research, training, and entrepreneurship at ASU, with impacts at the state and national levels. Faculty expertise, unique facilities, and technology-to-market experience serve as building blocks to create more shared resources, fundamental knowledge, innovative technologies, startups, and skilled graduates. With pilot funding from the university, the initiative will build an identity and culture around advanced materials, engage stakeholders to define broad materials challenges, and provide seed grants to strategic research projects.

The ACA also targets small businesses for growth and innovation resources. Arizona companies can receive loans through the Innovation Accelerator Fund, funded by $18.2 million from the State Small Business Credit Initiative. Loans ranging from $50,000 to $2 million can support business expansion and workforce training, and companies in target industries—such as aerospace and defense, renewable energy, and advanced manufacturing—have priority for these loans. The SBIR/STTR Resource Center, in particular, helps small businesses gain access to training sessions and resources that could make them competitive for these federally funded innovation grants. To expand the global reach of Arizona's materials industry, small businesses can leverage the State Trade and Export Promotion program to enter export markets and increase revenues.

Arizona also promotes private investment in the state economy. Through the R&D Tax Credit, corporations and individuals can receive a 24 percent income tax credit for conducting basic research at universities and in house, which is among the highest R&D credits in the United States. Arizona also offers a refundable tax credit to enable qualified small businesses that may have limited tax liability to take advantage of the incentive. Additionally, the Angel Investment Tax Credit supports economic growth by attracting capital for small businesses. Businesses that invest a minimum of $25,000 can receive a 30 to 35 percent income tax credit and a tax exemption on capital gains derived from that investment. Although the tax credit was extended to 2021, no additional funds were added to raise the $20 million cap, which was quickly fully subscribed. These incentives could be expanded to attract more funding into the state.

Workforce Development

Workforce Development

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

Institutions for Technical Education

UA and ASU each have large undergraduate and graduate programs. In 2014, both universities ranked within the top forty U.S. schools in the number of earned doctorates. ASU ranked sixteenth for full-time graduate students, which demonstrates immense intellectual capital for innovation and the presence of highly skilled candidates to stimulate in-state industries.

Arizona also provides alternative educational pathways through its network of joint technical education districts and community colleges. The joint technical education districts provide career-focused education to high school students based on occupational needs at the state and local levels. They offer STEM programs such as engineering sciences, electronics, and welding. Community colleges also serve as hubs for innovative career

training programs in Arizona. In 2012, five colleges partnered with industry to promote workforce pathways for sustainable energy careers. Through a $13.5 million federal grant, the community colleges redesigned their curricula, hired staff and faculty, and furnished training labs for electric power systems and industrial manufacturing. Over the three-year grant period, the consortium directly served 1,746 students and others that were involved in some capacity. The Arizona Advanced Manufacturing Institute at Mesa Community College also provides customized workforce solutions by developing skills in advanced manufacturing.

Resources for Workforce Education and Training

Science Foundation Arizona (SFAz) is an active nonprofit that provides grant funds for research and education, derived from government, industry, and donor contributions. Since 2007, SFAz has awarded 216 grants, one hundred of which were for STEM education grants that impacted 385,000 students. SFAz also launched the Arizona STEM Network to lead stakeholder collaboration for meaningful opportunities in STEM fields and has developed numerous guides to help educators properly integrate STEM education in classrooms.

Business leaders could also take advantage of the ACA's resources and incentives for workforce development. ACA's Navigator program offers assistance in recruitment, training, and strategic partnerships through "One Stop" service centers across the state. In addition, companies have access to capital through the Job Training Fund and Quality Jobs Tax Credit. The Job Training Fund has awarded 102 grants, totaling $27 million. However, the 2016 fiscal budget reduced wage taxes that funded the program, terminating it earlier than it was scheduled to sunset and eliminating a valuable asset for Arizona's business community. Now, the remaining funds are available on a competitive basis. Companies still have access to income tax credits on investments stoking the creation of good-paying jobs.

Continuous training programs ensure a skilled manufacturing workforce

The Arizona Advanced Manufacturing Institute

Mesa Community College's Arizona Advanced Manufacturing Institute (AzAMI) was established in 2014 to meet the state's manufacturing workforce needs. The core programs include welding, machining, electronics, and additive manufacturing design. AzAMI has increased its training capacity through financial support from the U.S. Department of Labor's Employment and Training Administration and from the Maricopa Community Colleges. AzAMI boasts flexible degree and certificate programs and leverages industry partnerships to provide on-the-job training opportunities. One boot camp for industry certification targets skills for composites technology.

Arizona's Advanced Materials Companies

Business Type	Number in State, By Materials*		Description
Materials provider (includes corporate offices)	21	7 7 11	Mines, manufactures, or distributes advanced materials
Contract research, engineering, and design	21	13 6 6	Provides contract services and independent advanced materials research for industry-specific applications
Processing equipment and service provider	8	2 0 6	Supplies equipment or offers services for testing and machining advanced materials
Component manufacturer	7	3 0 4	Manufactures advanced material components that are used in full systems
System manufacturer (includes corporate offices)	15	9 2 6	Manufactures and assembles full systems with advanced material components for industry-specific applications
Other	17	-	Engages with advanced materials not highlighted in this report and provides other services
Total	**89**	34 15 33	

* Listed in order: carbon fiber, advanced ceramics, and semiconductor materials. Companies that have multiple areas of expertise are counted for each material.

Arizona is home to eighty-nine companies that spans from materials development to end-user-specific industries. Many of these companies are materials providers, full system manufacturers, and contract engineers that assist with system integration. Although most of the companies are engaged with carbon fiber and semiconductor materials due to Arizona's large aerospace and defense (A&D) industry and legacy semiconductor base, advanced ceramics are complementary to many of the same downstream industries (e.g., ceramics in aircraft engines and electronic packaging). Materials providers include copper mining companies, distributors, and manufacturers of processing materials. Arizona could build out its supply chain and foster industry connections by creating an active in-state market and business-friendly climate.

Arizona's materials base is strongest toward industry-specific markets, such as the A&D, electronics, solar, automotive, and infrastructure sectors. The following infographic describes the impact of the target advanced materials on these industries. It also highlights large-scale companies with a presence in Arizona that could benefit from supplying or being supplied by a more robust value chain. These end-user industries tend to generate greater revenues than the materials base, providing more revenue for the

Working on an Airbus composite wing flap

Anchor and Supply Chain Companies

This report distinguishes two types of businesses based on where they are on the industry's value chain. An anchor company manufactures products for end-users and tends to have a large presence in the industry. An anchor company is served by numerous upstream supply chain companies, which can provide materials, manufacture equipment and supplies, and offer contract services. For example, Hexcel is an anchor company in the advanced materials industry that manufactures composite materials, and a business that supplies Hexcel with raw materials for its manufacturing would be considered a supply chain company.

state and supporting businesses further upstream in the supply chain. As seen in the A&D industry, a sizable portion of Arizona's supply chain already serves large anchor companies. Materials providers Hexcel and Cytec and contractors, such as Advanced Ceramics Manufacturing, Advotech, and Osprey Technologies, engage with major A&D companies, including Orbital ATK, Boeing, Honeywell Aerospace, and General Dynamics. A supply chain has similarly grown around Arizona's existing semiconductor manufacturing base, supported by strongholds such as Intel, NXP, ON Semiconductor, and Microchip Technology. Smaller businesses provide complementary processing expertise (e.g., Trion) and materials research (e.g., Lawrence Semiconductor Research Laboratory). Having local, in-state suppliers enables quicker turnover on contracts and increased mobility for collaborative projects.

Arizona could support major industry players in building up their in-state operations and attracting more suppliers. For example, Arizona houses the corporate offices for major advanced energy industry players—First Solar, Kyocera Solar, and TPI Composites—but the state could encourage the development of manufacturing and innovation facilities. Arizona has had recent success in expanding its supply chain through existing relationships. In 2016, Air Products chose to site its spin-off company, Versum Materials, in Tempe, despite not receiving any state incentives. Later that year, Rogers Corporation relocated its global headquarters to Chandler, where its Advanced Connectivity Solutions business unit currently operates. Versum Materials is expected to bring forty new jobs while Rogers could support about seventy new corporate positions. Continuing to foster a business-friendly climate could further attract and retain advanced materials companies.

Arizona could also orchestrate foreign direct investment missions to engage international anchor and supply chain companies.[1] New Arizona-based facilities of established businesses could bring additional capital and know-how to the state, creating job opportunities for Arizonans. These missions could be led by the state as well as its regional economic development organizations. For example, Italian manufacturer Duralar Technologies, a provider of ultra-hard coatings, established its U.S. headquarters in Marana with assistance from Tucson Regional Economic Opportunities, Inc. In 2014, the company planned a $6 million capital investment that would support thirty new jobs in materials science, engineering, and administration. In addition to job-creation incentives, Duralar cited The University of Arizona, the state's low cost of living, and regional support as significant factors in the siting decision.

[1] More information about foreign direct investments can be found on page 74.

Impact of Materials on Downstream Industries

Aerospace and Defense

Key Materials

- Carbon fiber: Incorporated in aircraft for structural applications, such as the fuselage and wings, to increase fuel efficiency and reduce maintenance needs.
- Advanced ceramics: Used as thermal barrier coatings for hot engine sections and as high-temperature insulators for jet engine turbines. Also integrated into body armor.

Notable Geographic Markets

- State and national: Arizona has a robust A&D industry with over 1,200 companies, making the state the third-largest supply chain contributor. PwC ranked it the best state in aerospace manufacturing attractiveness. There is also national interest in lightweight materials for aerospace applications as indicated by the Lightweight Innovations for Tomorrow consortium.

Arizona's Major Companies:

- Boeing
- General Dynamics
- Honeywell Aerospace
- L-3 Communications
- Northrop Grumman
- Orbital ATK
- Raytheon

Electronics

Key Materials

- Semiconductor materials: Fundamental to many different electronic devices that comprise a functioning electronic system, such as controllable switches. Can increase efficiency in power electronics through improved switching frequencies.
- Advanced ceramics: Used in insulators and magnets of electronic parts and equipment.

Notable Geographic Markets

- State, regional, and global: Arizona's materials industry could support large semiconductor and circuit manufacturing bases in the state and western region. In 2015, the U.S. held about 50% of the global market in both semiconductor and manufacturing equipment production with the majority of sales happening outside the U.S. Electronics production is the main driver the global industry's growth.

Arizona's Major Companies:

- Honeywell
- Intel
- Microchip Technology
- NXP Semiconductors
- On Semiconductor
- Raytheon

Solar Power

Key Materials

- Semiconductor materials: Critical to solar cells because they enable electrical current with solar radiation and can increase efficiency.
- Advanced ceramics: Could serve as an alternative barrier film to increase energy efficiency and decrease material costs.

Notable Geographic Markets

- State and regional: Arizona boasts one of the best solar resources in the nation and its total solar workforce could be reenergized by more investment in large-scale projects and distributed generation. Arizona's materials supply chain could also support the large regional market of manufacturers and installers in the western U.S.

Arizona's Major Companies

- CentroSolar
- First Solar
- Global Solar
- Kyocera Solar

Automotive

Key Materials

- Carbon fiber: Used as a lightweighting material for vehicles and in compressed gas storage tanks.
- Semiconductor materials: Used in numerous automotive devices, including microcontroller units and sensors.

Notable Geographic Markets

- National: National R&D assets are dedicated to advancing carbon fiber composites in vehicles. The growing demand for electric vehicles and required charging stations—with the U.S. being a top market in 2015—will continue to stimulate the market for automotive semiconductors.

Arizona's Major Companies

- ChargePoint
- Local Motors
- Swift Transportation

Construction and Infrastructure

Key Materials

- Carbon fiber: Can repair and restore degraded structure as a flexible fabric. When chopped or milled, can be mixed into concrete to improve load-bearing capacity and durability. Can also be used as internal and external reinforcements as pultruded rods and plates.

Notable Geographic Markets

- National and global: Infrastructure needs and investments are increasing in many countries with growing interest in carbon fiber-reinforced applications. Additionally, Arizona companies already have a portfolio of projects in the U.S. and worldwide.

Arizona's Major Companies

- DowAksa CarbonWrap
- HJ3 Technologies
- Quakewrap

In addition to tapping into major downstream industries, Arizona could accelerate business development through its universities and national networks. The university environment not only facilitates collaborative industry research but also fosters new companies. HJ3 Composite Technologies spun out from innovative work at UA, and Material-Wave Interactions Laboratories operated within ASU before becoming an independent business. Arizona is also home to several companies connected to national industry networks. For example, Local Motors and Cytec Engineered Materials are both premium members of the Institute for Advanced Composites Manufacturing Innovation while Quakewrap and many fiberglass composite businesses are members of the American Composites Manufacturers Association. Arizona could leverage its industry involvement to access and support the development of research initiatives and business resources.

Arizona's base of advanced materials companies extends further than the three target materials sectors in this report. The state is also home to Arconic and Gore facilities, which boast advanced materials expertise in lightweight metals and synthetic polymers, respectively. The diverse array of advanced materials in Arizona could be further supported through more fundamental knowledge in materials characterization, processing, and analysis at both the industry and university levels.

Jobs Potential of Arizona's Advanced Materials Cluster

Snapshot: Job Opportunities in Advanced Materials

The following table gives a snapshot of the types of jobs available in the advanced materials industry. Arizona has over 60 percent more materials engineers as a share of state employment than the national average. Materials engineers and scientists work closely with professionals across disciplines, such as mechanical and electrical engineering. Advanced materials also serve as the foundation for many manufacturing industries and their associated jobs, so those job opportunities are included as well.

	Number of Employees in Arizona*	Mean Hourly Wage in Arizona*	Entry-level Education/ Work Experience	Job Description
Materials Scientist	70	$47.01	Bachelor's degree	Study materials and their interactions at microscopic levels to develop and test products
Materials Engineer	820	$50.79	Bachelor's degree	Develop and analyze materials used to create products
Mechanical Engineer	3,890	$43.20	Bachelor's degree	Design and develop mechanical tools, engines, and machines
Electrical Engineer	3,650	$48.24	Bachelor's degree	Design and develop electrical equipment
Engineering Technician (Mechanical & Electrical)	400	$25.21	Associate's degree (in specific branch of engineering)	Assist head engineers with design, production, and testing
	3,280	$28.56		
Assemblers & Fabricators	22,190	$16.71	High school diploma or equivalent with on-the-job training	Assembles manufactured components to create finished products
Metal & Plastic Machine Workers	8,550	$17.80	High school diploma or equivalent with on-the-job training	Prepare and operate machines that process metals and plastics
Industrial Production Manager	2,460	$48.81	Bachelor's degree with 5+ years of work experience	Oversee daily operations of manufacturing

* Number of employees and mean hourly wage in Arizona are based on U.S. Bureau of Labor Statistic's May 2015 State Occupational Employment and Wage Estimates.

Snapshot: Job Impacts of Arizona Companies

Arizona's advanced materials industry benefits from a diverse group of businesses, ranging from small supply chain businesses to large anchor companies. The following vignettes showcase three Arizona companies and their impact on jobs in the state.

Hexcel Corporation, Casa Grande: *500+ Employees*

- Multinational company involved in carbon fiber industry for nearly 70 years
- Established its Casa Grande facility in 1965 with major expansions in 1966, 1973, 1994, and 2012
- Manufactures lightweight honeycomb materials for the A&D industry
- Large customer base includes Airbus, Boeing, Bombardier, and Lockheed Martin
- Why Arizona: National A&D hub, readily available workforce, and agreeable climate for manufacturing

Desert Silicon Inc., Tempe: *10 Employees*

- Homegrown small business and established supplier providing specialized electronic materials
- Founded in 2013 and housed within the MAC6 Conscious Manufacturing Facility, a local incubator and co-working industrial space
- Customizes and manufactures spin-on glass for silicon wafers used in semiconductor production
- Semifinalist at Cleantech Open 2014
- Almost 200 customers across businesses and labs
- Plans to expand facility, increase revenues, and grow workforce
- Why Arizona: Readily available workforce, proximity to customer and supplier base, and access to incubator services

Materion Ceramics Inc., Tucson: *~50 Employees*

- Subsidiary of Materion Corporation with over 45 years of production experience in metal oxide ceramics
- Relocated its headquarters from Ohio to Arizona in 1987
- Manufactures beryllium oxide ceramics and other high-performance materials for applications in A&D, energy, and electronics
- Plans to expand workforce to support diverse materials base and production line
- Why Arizona: Proximity to customer base and agreeable climate for manufacturing

Direct, Indirect, and Induced Jobs

To estimate the potential economic impact of Arizona's advanced materials supply chain, we distinguish direct, indirect, and induced jobs.

- **Direct jobs:** reflect jobs resulting from initial changes in demand in Arizona's advanced materials industry.
- **Indirect jobs:** reflect jobs resulting from changes in transactions between industries as supplying industries respond to increased demand from Arizona's advanced materials industry.
- **Induced jobs:** reflect jobs resulting from changes in local spending as a result of increased demand in Arizona's advanced materials and indirect industries.

Potential Job Growth from Advanced Materials Cluster Development in Arizona

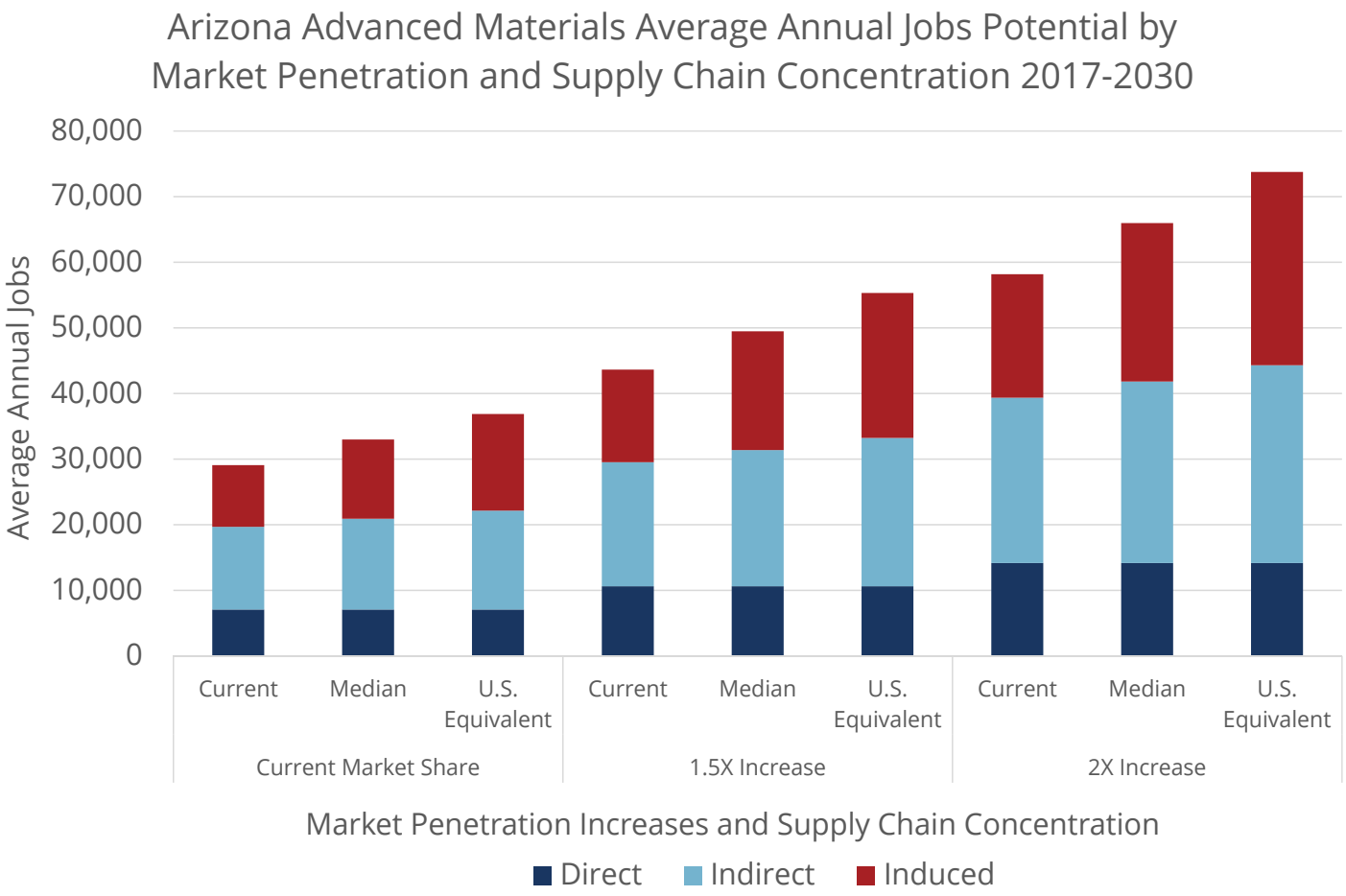
To estimate jobs potential for the Arizona advanced materials industry, we combine existing tools, analyses, and projections from several reputable sources to estimate job potential. Rather than provide a specific estimate, we examine multiple industry growth scenarios that show the average number of jobs that the in-state industry could support annually each year from 2017 through 2030, a fourteen-year timeframe. To generate these estimates, the advanced materials analysis utilized IMPLAN, a highly respected regional economic analysis model maintained by the Minnesota IMPLAN Group. IMPLAN models inter-industry interactions and the resulting regional economic impacts, including employment. We present scenarios across two dimensions: national market penetration and supply chain concentration. A more detailed description of our modeling approach and resources used is provided in the appendix.

As global demand for advanced materials increases, Arizona's advanced materials cluster could grow to serve a larger portion of national demand than it does currently. By fostering industry growth, Arizona could reasonably support nearly 66,000 direct, indirect, and induced jobs each year from 2017 through 2030.

Our projections for jobs potential in the advanced materials industry come from global estimates of future demand, current employment in Arizona's advanced materials cluster, and industry benchmarks for wages and profits. We utilized these inputs to create a variety of scenarios based on two industry growth factors.

Market Penetration: Market penetration refers to the amount of sales of a product in Arizona as a percentage of the total national sales volume for that product. For each material, we created job estimates based on Arizona's current market penetration. We then created two additional scenarios in which the market penetration is increased by 50 percent or doubles.

Supply Chain Concentration: Supply chain concentration refers to the level at which Arizona is able to fill its supply chain needs from in-state companies and attract new companies to its current advanced materials supply chain. The "Current" scenario is based on the existing in-state supply chain. The "Median" scenario represents the mid-point between the "Current" and "U.S.



Equivalent" scenarios. The "U.S. Equivalent" scenario is based on the supply chain concentration that is equivalent to what is currently available in the U.S. economy per IMPLAN's model.

The chart shows the jobs potential of Arizona's advanced materials industry under different scenarios, aggregating employment from carbon fiber, advanced ceramics, and semiconductor materials.[2]

We suggest that the doubled market penetration and the median supply chain concentration are realistic goals for Arizona. If Arizona is able to grow its market share by twofold and expand its supply chain to match half of what is available nationally, the advanced materials industry could support an annual average of nearly 66,000 direct, indirect, and induced jobs from 2017 through 2030. Thus, Arizona's advanced materials industry could serve as a major vehicle for future state economic growth, while creating quality jobs for Arizonans.

[2] A full breakdown of the jobs potential for the three targeted materials is available in the appendix.

Recommended Actions

Arizona has the opportunity to leverage its strengths and potential to build a productive hub around advanced materials. The state can pave a different path from past cluster efforts by fostering sustainable foundations for business and industry growth, and by engaging new and existing resources for their support. In particular, state leaders could facilitate in-state collaborations and foreign investments, increase access to technical and financial resources for businesses, and bolster STEM education and manufacturing training. These efforts would not only fortify the advanced materials cluster, but also grow Arizona's case for being the best place to live, learn, and work. Whether taken as a whole or as piecemeal solutions, the following policy recommendations can attract private investment, stimulate the state's economy, and create good-paying jobs for Arizonans.

Policy 1: Organize an Advanced Materials Consortium to Define Industry Needs and Foster Resources for Growth

Advanced materials are critical to many of Arizona's manufacturing industries. An organized consortium could effectively identify industry needs and opportunities to grow. The objectives of the consortium could fall along a continuum of collaborative activity, ranging from raising awareness of the industry to promoting the industry's products locally and abroad. The Arizona Optics Industry Association (AOIA) demonstrates the success that such an organization can bring to an in-state industry. AOIA grew out of Arizona's cluster-based economic development initiative in 1992. Despite not receiving direct financial support from the state, AOIA has operated through industry commitment and dedicated leadership, meeting monthly to advance three projects each year.

An advanced materials consortium could similarly be organized by the materials industry and supported by organizations such as the Arizona Technology Council, which hosts the Additive Manufacturing Committee and now hosts an optics committee to advance AOIA's goals. Initial discussions could identify the consortium's end goals and intended outcomes for each group of participants.

Another organizational structure could be a university-embedded industrial consortium that leverages the state's robust university

system and emphasizes academic-industry engagement. For example, the Advanced Materials Industrial Consortium (AMIC) established by University of Wisconsin-Madison offers member companies the opportunity to learn about related research, influence research directions, engage with students who could be future hires, and receive specialized access to supporting facilities and licensing technology. AMIC stemmed from the work of the university's NSF-funded Materials Research Science and Engineering Center, and is largely supported by annual member fees. AMIC has grown from one member to over twenty companies. The success of the program has attracted the involvement of the Wisconsin Economic Development Corporation to expand the AMIC model across the state.

Possible Consortium Activities

- Organizing knowledge-sharing events and workshops
- Hosting research projects and hackathons to solve materials challenges specific to member companies or industries
- Orchestrating technology-transfer missions to local national labs
- Partnering to engage with national industry-led research initiatives
- Influencing industry standards and certification procedures
- Supporting STEM curriculum development
- Maintaining a supply chain database

Arizona universities could engage advanced materials companies to create industry resources and boost capital for research and innovation. Because of this creative structure, the university could utilize the state Technology and Research Initiative Fund (TRIF) to initially fund the consortium and cover administrative costs, then transition to using member fees as a sustainable source of funding. Creating a consortium would signal Arizona's commitment to cultivating the industry, fostering innovative materials research, and supporting good-paying jobs in the state.

Arizona Plastics and Advanced Composites Cluster: Despite Initial Successes, Lack of Sustainable Funding Stalled Momentum

In 1997, Arizona companies established the Arizona Plastics and Advanced Composites Cluster to grow the state's materials industry. Over nine years, the cluster grew to over 130 individual and organizational members from industry, government, academia, economic development organizations, and nonprofits. Successes included a repository of skill sets and supplies as well as partnership opportunities to go after larger contracts. However, the cluster suffered from a lack of permanent economic foundations and from high administrative costs. An advanced materials consortium could avoid these pitfalls by incorporating sustainable funding mechanisms recommended here.

Technology and Research Initiative Fund

In 2001, Proposition 301 increased the state sales tax by 0.6 percent and allocated the increased revenue to educational institutions, specifically K–12, community colleges, and public universities. The Arizona Board of Regents (ABOR) established the Technology Research Initiative Fund (TRIF) to manage and administer the Prop. 301 funds that filter to Arizona's universities. ABOR approves TRIF budgets every five years to ensure these business plans meet the selected criteria: promote university R&D, expand access to education with multiple opportunities for entries and exits, and build curricula to support the state's high-tech industries.

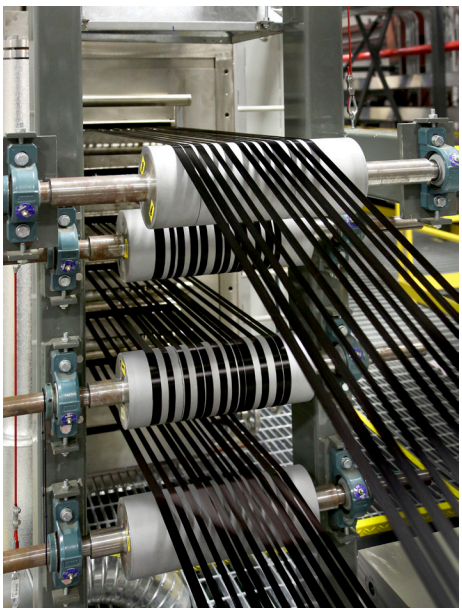
Policy 2: Provide Materials Testing and Validation Services to Encourage Technical Collaboration between Schools and Industry

Advanced materials require intensive testing and standardization to ensure quality technology performance and market confidence. Arizona's colleges and universities serve as a great platform for public-private collaboration, one area being hosting industry resources that also provide hands-on skills development for students. The development of these resources has been driven by industry at both the local and national levels. ASU's Center for Algae Technology and Innovation hosts a national testbed for algae-based ventures. In 2016, ASU also partnered with in-state industry leaders to develop an additive manufacturing research facility. Additionally, both UA and ASU have large-scale testbeds for solar companies. By hosting industry resources in colleges and universities, students can gain from extensive work-based learning opportunities. Arizona could establish a coordinated network of testbeds for materials applications to distribute the cost burden of capital equipment for early ventures and promote standards in materials processing and application. If Arizona establishes a university-embedded industrial consortium, these services could be a natural extension from that organizational structure.

Arizona could look to the success of school-based resources in the United States and abroad. In the 1980s, composite businesses requested testing assistance from Minnesota's Winona State University, which led to the development of the Composites Materials Technology Center. Students at the center provide

Advanced technologies are required for working with nanocomponents

services ranging from materials characterization to testing and prototyping. In 2011, companies in Maine stimulated the creation of the Composites Engineering Research Laboratory (CERL) at Southern Maine Community College. CERL boasts applied engineering expertise for process optimization as well as testing and analysis skills. CERL is wholly owned by the Maine Composites Alliance and its industry partners with financial support from the Maine Technology Institute, so all the capital equipment is privately bought and managed. Other facilities, such as the University of Illinois's Advanced Materials Testing and Evaluation Laboratory, are also supported by user fees from industry and revenue from research contracts. The Danish Certification Scheme, although supported by a state-subsidized university system, gives an example of ensuring product quality through public-private engagement. In partnership with the Technical University of Denmark, manufacturers, owners, and investors require wind turbine certification from the university before installation.


Spooling of carbon fibers

University researchers could work with advanced materials business leaders to develop materials testing and technology certification programs based on industry standards and specific to end-use markets. Standards for measurement, testing, and characterization could be based on research from the Versailles Project on Advanced Materials and Standards, a global collaboration dedicated to promoting world trade through technical standardization; the International Electrochemical Commission, a leading organization for international standards for electrical and electronic technologies; and other similar groups. Depending on industry needs, services could range from testing and validation to product/process certification. For example, export-oriented products could be validated for global standards compliance and additive manufacturing procedures could be evaluated for standardization. However, the offered services should aim to not duplicate resources available from Arizona's small businesses.

Arizona's universities could engage with industry on financing capital equipment—either with user fees or privately owned machinery—and provide matching funds through research revenue. With these large-scale testing and validation capabilities, Arizona's universities would be primed to partner with national research institutes—such as the Institute for Advanced Composite Manufacturing Innovation (composites), Lightweight Innovations for Tomorrow (aircraft lightweighting), and AmericaMakes (3D printing)—and be competitive for national project calls on materials innovation. By leveraging its robust innovation network, Arizona could expand the national and global reach in its advanced materials industry.

RevAZ: Customized Small Business Solutions

RevAZ is an ACA program that serves as the state's dedicated Manufacturing Extension Partnership (MEP) center. The national MEP network is a federal initiative to meet critical needs of small-to-medium-sized manufacturers across the nation. These centers offer tailored business solutions that range from process improvement and supply chain integration to technology transfer and workforce development. To provide these services, MEP centers are able to utilize federal funds to match state investments and private sector fees. RevAZ's specific capabilities in strategic growth assistance and engineering solutions for innovation could be expanded to support business interests in advanced materials for over 4,600 small-to-medium-sized manufacturers in Arizona.

Policy 3: Expand Supply Chain Assistance for Small Businesses to Integrate Advanced Materials in Their Product Lines and Manufacturing Processes

Arizona's advanced materials industry is supported by numerous small businesses providing unique products and services, and it could be bolstered by a stronger local market and expanded supply chain. For example, small businesses could utilize advanced materials to upgrade their operations or provide niche commercial innovations. However, small manufacturers often face barriers to entry in the market, including the cost of materials and machinery. Arizona could leverage existing resources like RevAZ to provide technical and financial resources for business development. The ACA could increase the state funds allocated to RevAZ and dedicate a portion to creating a factory retooling loan fund. Through this program and fund, companies could have access to technical assistance and capital for retooling operations to incorporate advanced materials or transition to high-value industries.

This retooling initiative could be modeled after Wisconsin's successful Clean Energy Manufacturing Revolving Loan Fund (CERLF). Established in 2009, CERLF provides up to $1 million of low-interest financing to businesses investing in clean energy-related projects. For example, Wisconsin-based company Gearbox leveraged CERLF funding to grow its manufacturing operations for wind turbine components. CERLF is jointly managed by the Wisconsin Economic Development Corporation and the Wisconsin Public Service Commission. The program was jumpstarted by funds through the American Recovery and Reinvestment Act and now boasts $38 million in working capital and equipment.

Manufacturers could use loans to purchase machinery and equipment, upgrade or build facilities, or use as initial operating capital. Arizona could pursue federal funding to support the state's investment in supply chain assistance. For example, Energetx Composites tapped into Michigan funds from the U.S. Department of Energy's State Energy Program to shift its fiberglass production line from boat hulls to wind turbines, creating up to 300 new jobs. Loan recipients could also be required to meet metrics for energy efficiency or job creation. This opportunity could help diversify Arizona's manufacturing sector as companies expand to fill niche customer spaces and boost their economic impact.

Policy 4: Establish a State Investment Fund to Stimulate the Venture Capital Environment

Early-stage companies and small businesses typically have limited financial capital for growth and development. These companies tend to lack physical assets that can be leveraged for bank loans. This issue is particularly acute for technology startups that focus on intellectual property rather than building assets. Advanced materials are often high-risk ventures that come with costly and long commercialization periods, yet they can lead to enhanced technologies and disruptive innovations. High-potential bioscience ventures are similarly prone to high costs and long development times, and Arizona's biosciences industry recently identified risk capital as a significant barrier for industry growth. Arizona captured only 0.2 percent of national venture capital funding in 2015 and 0.4 percent in 2016. The state government could create an investment fund to not only foster Arizona's venture capital community, but also increase access to capital for in-state, early-stage and small businesses.

To finance the investment fund, the ACA could engage insurance companies in raising funds for venture capital by selling insurance premium tax credits. Insurers could contribute to the state fund in exchange for a credit against the premium tax liability that can be used in a later year. Once investments are made, Arizona could require reimbursements to the state before investing in businesses.

While this type of mechanism has been used in many states, it has seen recent success in Maryland and Pennsylvania, where tax credits were auctioned off to insurers and then distributed to designated investment partners. Established in 2011, the InvestMaryland program is jointly managed by the Department of Business and Economic Development and the Maryland Venture Fund Authority, a nine-member group of business and investment experts. Maryland employs a hybrid model in which two-thirds of the funds go to selected private venture firms, about one-third filters into the state-run Maryland Venture Fund, and a small portion is directed to the Maryland Small Business Development Financing Authority. InvestMaryland raised $84 million in the auction, exceeding its goal of $70 million. These funds were distributed to about seven venture capital firms and have since supported three InvestMaryland Challenges, an international business competition. Although attributable to multiple factors, the state experienced a 33 percent growth in venture capital from $470 million (fifty-seven deals) in 2012 to $623 million (sixty-two deals) in 2013, over the time of InvestMaryland's initial funding.

Similar to Maryland, Pennsylvania created the Innovate in PA program in 2013 and auctioned $100 million in deferred insurance premium tax credits. Innovate in PA is projected to create at least 1,850 technology jobs, about 3,500 indirect jobs, and a return of $2.37 for every dollar invested. By leveraging this innovative model, the state government could bring these outsized economic impacts to Arizona.

There have been previous efforts to establish a state-run venture capital fund in Arizona, but they were blocked by the legislature. This novel mechanism of auctioning insurance premium tax credits could be the key to stoking interest. Arizona legislators could also look to the success of the state's other government programs to support business development, such as the angel investment and R&D tax credits, and the wide industry demand for greater access to capital in the state. A state venture capital fund could allow Arizona's innovators the opportunity to put their best ideas in the market and build thriving businesses in Arizona.

Policy 5: Finance a STEM Immersion Strategic Fund for Targeted K–12 Curriculum Enhancement and Pre-Employment Training

While Arizona continues to excel in high-tech industries, more attention should be paid to the skills and educational programs needed to support these industries. In Arizona, STEM jobs (including computing, engineering, and advanced manufacturing) are projected to grow by 23 percent compared to 17 percent for non-STEM jobs between 2014 and 2024. However, many students are lost along the STEM pipeline due to limited STEM activities, low graduation rates, and the lack of resources to support educators. Effective STEM education requires high-quality learning opportunities, sustainable programs, and teacher professional development. Adequate funding is crucial to support planning, implementation, and assessment. State leaders should consider establishing a strategic fund for K–12 STEM immersion to support targeted curriculum enhancements and STEM career-focused programs.

Arizona could consider leveraging support from foundations. The managing agency could hire a foundation liaison to connect with and broker support from foundations. Arizona is home to many charitable organizations that could be brought together to support the state's efforts to fortify the STEM pipeline. In 2012, Arizona had over 1,000 private foundations with nearly $5.3 billion in assets and $300 million in charitable contributions. Via a foundation liaison, Arizona and its foundation community could

leverage one another's investments and efforts to support K–12 education.

The Governor's Office of Foundation Liaison

In Michigan, the Governor's Office of Foundation Liaison (OFL) is the first of its kind in the nation. OFL builds funding partnerships and strategic collaborations between the state government and the philanthropic community to support programs that improve education and health for all Michigan residents. Foundations are engaged throughout OFL activities. The Foundation Liaison and OFL staff come to the state on loan from participating foundations, while contributing funders, the Council of Michigan Foundations, and Michigan Nonprofit Association help make up the OFL Advisory Committee. Since 2003, OFL has brokered investments from seventeen foundations, totaling more than $150 million.

The strategic fund for STEM immersion could be managed by the Arizona Department of Education in partnership with SFAz to build off its work on STEM program models and implementation plans. The joint partners could also seek matching funds from private businesses for specific programs and activities. While this strategic fund does not eliminate the need for direct state funding to education, it could help immediately create a robust learning environment for Arizona's youth and foster a workforce-ready population to meet Arizona's projected STEM job growth.

Young women tour a lab to get a first-hand look at careers in science

Policy 6: Deploy Mobile Manufacturing Labs to Prepare Regional Workforces for Advanced Manufacturing Jobs

Joblessness is uneven across the state with some counties severely impacted: unemployment rates in Yuma, Santa Cruz, and Apache counties range from 10 to 18 percent. Over half of all Arizona jobs (53 percent) require middle-level skills, yet only 42 percent of Arizonans have at least a job certification. Broader regional workforce development is important for preparing Arizonans for the manufacturing jobs supported by the advanced materials industry. However, areas located far from the state's metro region may have limited capital to purchase machinery and equipment for hands-on education that is essential for manufacturing training. Arizona could invest in mobile labs to increase access to these resources and highlight STEM career pathways.

Mobile manufacturing training lab used by a North Carolina community college

Schools and industry players in other states have recognized the advantages of mobile training labs. The Southwest Oregon Community College Mobile Welding Lab is outfitted with computers, SMART boards, welding stations, and a virtual welding simulator. Oregon spent $400,000 to create the lab but was able to offset the price using funds from the U.S. Department of Labor and by charging fees to industry and high schools for training. With this lab, Oregon has not only trained welders but expanded the reach of programs to underrepresented groups, including its Women in Welding Project. In Michigan, the Northern Lakes Economic Alliance in partnership with North Central Michigan College and local educational, business, government, and community leaders planned and established a mobile training

lab for digital CNC (computer numerical control) technology. Local company Precision Edge helped fund the project by pledging a $350,000 Community Development Block Grant from the U.S. Department of Housing and Urban Development. The "Fab Lab" now provides training at public schools, colleges, businesses, and Michigan Works! service centers across Northern Michigan counties.

With a fleet of training labs, Arizona could provide foundational manufacturing education to schools, worksites, and community learning centers across the state and serve rural, tribal, and other underserved regions. Because of their wide geographic reach, mobile labs can enable access to more federal grants for workforce and community development, as shown in Oregon and Michigan. Local economic development organizations, educational institutions, and nonprofits such as SFAz could jointly develop mobile labs and identify funding opportunities through industry partnerships or federal grants. Based on local workforce needs, training labs could also prepare students for a changing manufacturing landscape by featuring 3D printing and digital CNC manufacturing technologies. Mobile manufacturing labs could enrich technical skill training programs and expand access to good-paying jobs for Arizonans, ultimately driving both local and state economic development.

Policy 7: Encourage Foreign Direct Investment to Bolster Arizona's Advanced Materials Supply Chain

What is Foreign Direct Investment?

Foreign direct investment is when a company based in another country makes an investment in the United States by establishing operations or acquiring business assets. FDI increases capital in the economy, encourages transfer of technology and expertise, creates job opportunities for the local workforce, and fills gaps in the local supply chain. Strategies for state leaders include conducting FDI missions in foreign countries, inviting industry leaders to in-state conferences and tours, and providing business incentives.

Foreign direct investment (FDI) is a common strategy to fill business gaps and inject jobs and capital into the state economy. In fact, Arizona-based subsidiaries of global companies support over 84,300 workers, with 28 percent in the manufacturing sector. As described in previous sections, Arizona has key supply chain gaps that could be filled to strengthen its advanced materials

Best Practices for FDI and Exporting Programs

The U.S. Department of Commerce commissioned an extensive study of the most successful FDI and exporting programs around the country and found that state leaders of these programs share several key practices. The report found that they:

- Engage universities in making international connections and economic development;
- Establish strong relationships with economic development agencies and organizations that are active in FDI;
- Collect good data about companies in the cluster;
- Develop contact points at companies overseas;
- Embrace and adapt to cultural differences, e.g., language-specific business cards and marketing materials; and
- Commit to long-term involvement in FDI efforts.

Transportation and Trade Corridor Alliance

Established by the Governor of Arizona, the Transportation and Trade Corridor Alliance is a collaborative effort to (1) strengthen Arizona's position as a key trade partner and unique location for foreign investment; (2) improve the state's physical connectivity to markets; and (3) ensure a cohesive, strategic approach to transportation and trade. This initiative is driven by the Arizona Department of Transportation, the Arizona-Mexico Commission, the Arizona Commerce Authority, and the Arizona Office of Tourism.

industry and expand employment opportunities for Arizonans. Through more strategic stakeholder engagement, state and local leaders could further identify supply chain barriers and conduct targeted missions to attract investment from foreign companies.

The Massachusetts–Israel Innovation Partnership (MIIP) offers an innovative model on how to facilitate global connections. Launched in 2011 following Governor Patrick's trade mission to Israel, MIIP grew from an industry research collaborative to a joint FDI partnership. Major Israeli companies have expanded operations to the state and Massachusetts companies have invested in Israeli intellectual property and R&D operations. As of 2015, more than 200 Israeli-founded companies have made a home in Massachusetts. These businesses accounted for $9 billion in direct revenue, $18 billion in total economic impact, and 4 percent of the state GDP, as well as 9,000 direct jobs and 27,000 indirect and induced jobs.

Arizona could actively seek assistance from SelectUSA, lead generation consultants like WAVTEQ and OCO Global, regional advanced materials consortiums, and local universities to identify and engage with companies that may be interested in locating operations in the state. This strong network of partners could help bolster FDI in Arizona. The following table gives a snapshot of anchor and supply chain companies that could be targeted by the state.

FDI can be pursued across Arizona at the state and local levels, with support from the Transportation and Trade Corridor Alliance, regional economic development organizations, local Arizona businesses, and universities. Having a larger presence of global corporations in Arizona could grow the state's supply chain, enhance the knowledge economy, and create good-paying jobs for Arizonans.

Company	Country	Description
CeramTec Group	Germany	Engineers advanced ceramic components and products for automotive, mechanical, electronic, and medical applications
DowAksa	Turkey	Produces carbon fiber for industrial use in transportation, energy, and infrastructure
Kyocera Corporation	Japan	Manufactures advanced ceramic and semiconductor components, products, and equipment for automotive, electronic, solar, and medical applications
Saint-Gobain S.A.	France	Creates building and high-performance materials for the habitat and construction markets
Toray Industries	Japan	Develops semiconductor and composite materials for electronic, aerospace, automotive, and industrial applications

Call to Action

Arizona's existing advanced materials cluster is a solid foundation upon which the state can grow its economy, create jobs for the state's residents, and become a leader in the production and deployment of advanced energy technology. The policies recommended in this report are complementary and intended to help Arizona manufacture products within the state, enable entrepreneurship for technological advances, fund innovation with accessible capital, equip workers with the skills required for the state's future economy, and grow demand for advanced materials.

Arizona has the opportunity to support nearly 66,000 jobs in the advanced materials industry annually from 2017 through 2030. The state's cluster could supply a significant portion of national demand, especially considering its large supply chain, top-tier research universities, and strategic location for manufacturing.

To capitalize on Arizona's potential in the advanced materials industry and position the state for continued growth, policymakers will need to make a concerted effort to seize the opportunity presented by increasing global demand. Strong leadership plays an important role in promoting Arizona's competitive advantage in the industry and creating quality jobs for Arizonans. State and local economic development depends on the collective work of many partners across government, universities, businesses, and other stakeholders. This report recommends actions that each group can take to support the advanced materials industry. Continued collaboration is necessary to address barriers to cluster growth and demonstrate that the state is ripe for investment.

Arizona's leaders can draw from among dozens of innovative strategies that city, county, and state governments across the country and abroad have implemented to create more job opportunities in the advanced energy sector. Examples of these best practices can be found on the American Jobs Project website at http://americanjobsproject.us/. Furthermore, the American Jobs Project can continue to serve as a partner to Arizona by organizing working groups and conducting deeper analyses, such as identifying supply chain gaps, exploring policy strategies, and evaluating the state's comparative advantage in other advanced industries.

Growing the Advanced Materials Cluster, Growing Jobs

- Organize an Advanced Materials Consortium to Define Industry Needs and Foster Resources for Growth
- Provide Materials Testing and Validation Services to Encourage Technical Collaboration between Schools and Industry
- Expand Supply Chain Assistance for Small Businesses to Integrate Advanced Materials in Their Product Lines and Manufacturing Processes
- Establish a State Investment Fund to Stimulate the Venture Capital Environment
- Finance a STEM Immersion Strategic Fund for Targeted K–12 Curriculum Enhancement and Pre-Employment Training
- Deploy Mobile Manufacturing Labs to Prepare Regional Workforces for Advanced Manufacturing Jobs
- Encourage Foreign Direct Investment to Bolster Arizona's Advanced Materials Supply Chain

When a state succeeds in building an economic cluster, the benefits are felt throughout the state: a more resilient state economy, a skilled twenty-first century workforce that is trained for the jobs of tomorrow, a firm base of young people optimistic about job opportunities close to home, and a rich hub for innovation and collaboration.

A fully cited version of this report is available on our website at http://americanjobsproject.us/.

Sunset over the Grand Canyon

Appendix: Jobs Modeling Methodology

Modeling Approach

The American Jobs Project combines existing tools, analyses, and projections from several reputable sources to estimate job potential. Rather than providing a specific estimate, we show jobs potential across a range of possible outcomes. All jobs are shown as the average annual jobs that could exist during the analysis timeline (2017–2030). The actual number of jobs in any given year could vary significantly from the average, and the annual average is intended to be a target over the analysis timeline.

We believe 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.

Specifically, the advanced materials analysis utilized IMPLAN, a proprietary model maintained by the Minnesota IMPLAN Group. Industry growth estimates and benchmarks from IBISWorld and BCC Research were also used to generate impacts across different levels of U.S. market penetration. Advanced materials make up an industry of industries, with a broad range of technologies and markets. For this analysis, we focused on carbon fiber, advanced ceramics, and semiconductor materials. Products made with these materials have broad-based applications for advanced energy technologies, as well as improving the energy and fuel efficiency of products in many other industries.

Several supply chain scenarios are presented to identify the impacts of growing the Arizona supply chain. The lowest scenario uses the current Arizona economy as the model to represent the impacts of targeting direct advanced materials jobs and not developing the advanced materials supply chain. The highest scenario uses the entire U.S. economy as the model to represent the impacts of Arizona having as complete of an advanced materials supply chain as the entire United States. A “Median” scenario gives the midpoint between the upper and lower bounds presented by the other scenarios, and is used as Arizona’s target jobs potential in this report.

It is important to note that we do not include any impacts associated with the construction of new facilities that may result from an increased number of advanced materials firms locating

in the Arizona economy during the analysis timeline. Additionally, we do not evaluate downstream products and services that are enabled or impacted through the use of advanced materials.

Introduction to IMPLAN

IMPLAN is a proprietary regional economic analysis model, maintained by the Minnesota IMPLAN Group. It uses average expenditure data to estimate how industry spending cascades throughout the economy to suppliers and consumer-facing industries. IMPLAN tracks multiple rounds of indirect and induced spending impacts, until that spending "leaks" out of the selected regional economy. A region is defined by the user, and can be as small as a county or as large as the entire U.S. economy. For this analysis, both the state of Arizona and the entire United States were used.

When a change of spending occurs in an economy, such as increased income for the advanced materials industry, spending also increases for supplying industries and the workforce. This cascading spending, or multiplier effect, can generate an economic impact that is often larger than the initial spending. This multiplier effect is created through multiple rounds of spending by industries paying their suppliers and employees. The supplier industries and employees, in turn, spend their money on other products or services in the economy. As the rounds of spending continue, money "leaks" out of the economy for purchasing products and services that are not available in the region. These leakages are determined by local purchasing coefficients, which are built in to IMPLAN's models. For example, an industry that relies heavily on imported commodity products or foreign labor will have a lower impact on the economy than an industry that can purchase nearly all of its supplies in the regional economy.

The resulting impacts from the spending, including tax revenues, are summed and presented across three impact categories:

- **Direct** – Increased payments to the target industry that support employees of that industry and generate the expenditures that begin to cascade through the economy.
- **Indirect** – Impacts created by industry-to-industry spending, such as supply chain purchases, that are first created by direct spending from the target industry and then through increased spending by suppliers to their supply chain.

- **Induced** – Employees of the target industry and their suppliers consume products and services, as a result of being supported by direct and indirect spending (e.g., workers buy homes, cars, haircuts, and lattes). In turn, the consumer-facing industries can support their employees and those employees spend more of their income on products and services in the economy.

We used the most recent version of IMPLAN for this analysis, which includes 2013 data and improved modeling for regional imports and exports. The IMPLAN model utilizes input-output data from U.S. National Income and Product Accounts at the Bureau of Economic Analysis. The model includes 526 economic sectors that are tied to the North American Industry Classification System codes. Region-specific multipliers follow the flow of spending from where it originates, as it cascades throughout supplier industries and employee spending, and eventually "leaks" out of the regional economy. The sum of the direct and multiple rounds of secondary spending show the total impacts, including jobs created or sustained, tax revenues, proprietor income, and economic output.

Limitations of IMPLAN

It is important to note the limitations of these modeling methods. As mentioned, the estimates shown are only average annual jobs created or sustained and we base this off of the total job-years, or one job sustained for one year, that exist within the timeframe of our analysis. This does not mean that every year will have the same number of jobs over the timeline. Any given year could be above or below the average we present. Job losses in industries that compete with those in our analysis are also not evaluated. Models do not perfectly predict behavior, so indirect and induced job 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.

Model Inputs

The first step to conducting the economic impact modeling was to identify how to characterize the advanced materials industry. Three target industries with significant energy-relevant applications were selected: carbon fiber, advanced ceramics, and semiconductor materials.

Second, a model for estimating the future demand for advanced materials technologies was needed. Estimates of market demand were taken from BCC Research and IBISWorld reports for the targeted materials.

Third, a model for estimating wages and owner income was needed. Estimates of average wages were taken from the IBISWorld. Owner income was derived from IBISWorld's reports and existing industry averages from IMPLAN's databases.

Finally, the current market penetration of Arizona's advanced materials industry was estimated as a function of the current number of firms in the state, based on IBISWorld data. Scenarios were developed by exploring modest increases in the estimated market share. Impacts from improving supply chain concentration utilized both the current Arizona economy, an equivalent to the current U.S. economy, and a median between these two extremes. Using Arizona's current economy for the first supply chain scenario would indicate that Arizona attracts no new businesses to supply their advanced materials industry. Using the U.S. economy as an "U.S. Equivalent" scenario would indicate that Arizona attracts suppliers that could meet the same demand as the current U.S. economy. The "Current" scenario is a lower bound and the "U.S. Equivalent" scenario is an upper bound. Both are equally unlikely extremes, so a "Median" scenario is used to identify a reasonable target number of jobs for Arizona.

Model Outputs

Once the data was prepared for input into IMPLAN, we ran the model for each scenario and generated the outputs. Outputs were reported for direct, indirect, and induced impacts under each scenario in terms of employment, labor income, GDP, total economic output, and state/local and federal tax revenue. Only employment is presented in the report. The additional output data is available by request.

For our analysis, employment data for the three targeted materials were aggregated to represent the jobs potential of the advanced materials industry. The following table gives a breakdown of average annual employment for each material.

Advanced Material	Market Penetration	Supply Chain Concentration	Average Annual Employment			
			Direct	Indirect	Induced	Total
Semiconductors	Current	Current	6,214	11,943	8,782	26,940
		Median	6,214	13,050	11,239	30,503
		U.S. Equivalent	6,214	14,157	13,696	34,067
	1.5x Increase	Current	9,321	17,915	13,174	40,410
		Median	9,321	19,575	16,859	45,755
		U.S. Equivalent	9,321	21,235	20,544	51,100
	2x Increase	Current	12,429	23,886	27,565	53,879
		Median	12,429	26,100	22,478	61,007
		U.S. Equivalent	12,429	28,314	27,392	68,134
Advanced Ceramics	Current	Current	723	548	496	1,768
		Median	723	643	649	2,015
		U.S. Equivalent	723	738	802	2,263
	1.5x Increase	Current	1,085	822	745	2,652
		Median	1,085	964	973	3,023
		U.S. Equivalent	1,085	1,106	1,202	3,394
	2x Increase	Current	1,447	1,096	993	3,536
		Median	1,447	1,286	1,298	4,031
		U.S. Equivalent	1,447	1,475	1,603	4,525
Carbon Fiber	Current	Current	142	107	128	378
		Median	142	142	178	463
		U.S. Equivalent	142	177	228	547
	1.5x Increase	Current	213	161	193	567
		Median	213	213	268	694
		U.S. Equivalent	213	265	342	820
	2x Increase	Current	284	215	257	756
		Median	284	284	357	925
		U.S. Equivalent	284	353	456	1,094

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