Colorado Jobs Project

A Guide to Creating Advanced Energy Jobs

MARCH 2016

AMERICAN JOBS PROJECT

A Letter from the American Jobs Project

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

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

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

Our quest starts with identifying the biggest market opportunity of our era: the global demand for advanced energy solutions. That demand—whether borne out of a need for diverse, reliable, and clean power or to achieve energy independence from unstable regimes—creates "the mother of all markets" for local U.S. businesses to build and sell those solutions.[6] Strategically minded businesspeople looking at global growth projections in advanced energy demand are making major investments and reaping large revenues. In 2014, the private sector reported $1.3

trillion in global advanced energy revenues, the fastest-growing year on record.[7] Advanced energy investments are now bigger than the global apparel sector and almost four times the size of the global semiconductor industry.[8] And jobs? Up to 16.7 million jobs are projected to be in the global advanced energy sector by 2030, almost tripling the 5.7 million people employed in the sector in 2012.[9] The question for the United States is: where will those new jobs be created?

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

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

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

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

Table of Contents

About Us

American Jobs Project

The American Jobs Project is a national, interdisciplinary, research-based initiative. Our team includes nearly 100 student researchers with a broad range of expertise, including law, business, engineering, and public policy. We have ongoing relationships with hundreds of on-the-ground stakeholders and are actively collaborating with university partners and industry allies.

Academic Partner - Tom Plant

Tom Plant served as director of the Governor's Energy Office in the Ritter administration, with principal responsibility for developing and implementing the Governor's policies for a new energy economy. He was Colorado House District 13 representative from 1998 through 2006, including two years as chairman of the House Appropriations Committee and one year as Chairman of the Joint Budget Committee. Among the key pieces of legislation he sponsored were the Colorado Renewable Energy Act, and energy efficiency tax incentive legislation.

Plant was named Legislator of the Year by such organizations as the University of Colorado and the Sierra Club of Colorado. He received the Green Sense Award for Environmental Leadership from the Colorado Conservation Voters, and the Champion of the Family Farmer Award from the Rocky Mountain Farmers' Union. While serving in the legislature, Plant was executive director of the nonprofit Center for ReSource Conservation in Boulder, Colorado.

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Jeff Lyng, *Center for the New Energy Economy*

Executive Summary

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

Colorado is well-positioned to benefit from the growing demand for advanced energy given the state's strengths in advanced manufacturing and engineering, its leading universities and research facilities, and its skilled labor force. Opportunities to leverage this momentum to further serve growing regional, national, and global markets offer real benefits for Colorado's economy and good-paying jobs for the state's residents.

Extensive research and more than 100 interviews with local stakeholders and experts in Colorado have resulted in identifying two economic sectors that show particular promise: solar and wind energy.

There are several barriers hindering Colorado's advanced energy industries and preventing supply chains from reaching their full potential. Colorado must address these roadblocks to grow the state's advanced energy sectors and realize economic gains. To take full advantage of these opportunities, Colorado's policymakers can enact policies to increase demand for solar and wind technology and to help the state's businesses grow, innovate, and outcompete regional, national, and global competitors. Indeed, with the right policies, Colorado's solar and wind energy industries can support up to 13,000 jobs annually in these two clusters.

This project serves as a research-based roadmap for state and local leaders who seek to develop smart policies focused on leveraging the state's resources to create skilled, good-paying jobs. Concerted effort at the state and local levels can create an environment that attracts new companies and grows existing companies headquartered in Colorado. Employees in the advanced energy sector will spend their earnings in the local economy at grocery stores and restaurants, and those local establishments will need to hire more employees to satisfy demand. This creates a multiplier effect throughout Colorado's economy, where a single dollar spent in a community circulates through local businesses and their employees numerous times.

Summary of Policy Recommendations

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

Solar Technology

Create an Energy Storage Mandate: Establishing a market for energy storage technologies to allow for continued integration of renewable energy sources.

Support the Development of Residential PACE Programs: Expanding use of residential PACE by instituting a loan-loss reserve program and a PACE toolkit. PACE financing mitigates the high upfront cost of solar for customers by allowing property owners to finance investments in solar panels with a loan that is repaid through their property tax bill.

Enable Group Solar Purchasing: Increasing access to solar by enabling communities to purchase greater quantities of solar panels at discounted group rates.

Reduce Barriers to Community Solar: Establishing annual community solar goals, developing public and private sector financing for low-income communities, and extending community solar legislation to municipal utilities and rural electric cooperatives to increase access to community solar.

Create Safe Harbors in Net Energy Metering: Ensuring customers continue to receive equitable and transparent net metering charges. Net metering allows customers to sell excess energy back to the grid.

Offer a Green Source Rider Program: Connecting large, energy-intensive companies with renewable energy without shifting costs to other ratepayers. Fifty-one Fortune 500 companies have signed a declaration demanding access to clean energy, indicating private sector demand for renewable energy.

Wind Technology

Encourage Small Wind Turbine Manufacturing and Deployment: Instituting a small wind tax credit, enabling community wind projects, restoring the anemometer loan program, and creating an export tax credit for qualified small- to medium-sized industries to strengthen the small wind manufacturing

sector by boosting in-state demand for small wind turbines and encouraging exports of small wind turbines.

Create an Anchor Company Tax Credit: Encouraging more wind turbine component suppliers to locate in Colorado by offering a tax credit to companies that recruit them.

Create a Consolidated Balancing Authority: Establishing a unified balancing authority to enable Colorado to efficiently pool energy resources, decrease balancing costs, and allow the state to export electricity.

Modernize Transport Pathways to Improve Wind Turbine Export: Upgrading roadways and encouraging use of rail to transport large goods to allow Colorado to manufacture and export turbines to nearby markets.

Innovation Ecosystem and Access to Capital

Facilitate New Partnerships Within the Energy Innovation Ecosystem and Set Statewide Goals: Proactively aligning university and research partnerships to achieve strategic R&D and funding goals.

Create an Advanced Energy Equity Crowdfunding Hub: Building on Colorado's Crowdfunding Act by streamlining investor access through an online platform.

Workforce Development

Enhance Workforce Training Opportunities Through Dual Enrollment Programs: Establishing industry-specific early colleges and dual enrollment programs to allow high school students to simultaneously earn a high school degree and earn credits for an associate's or bachelor's degree.

Create and Improve Pathways for Veterans to Transition to Advanced Energy Jobs: Establishing programs for veterans that help them transition into the advanced energy workforce by connecting veterans to employers, translating military experience on resumes, and encouraging military recruitment days.

Establish Incentives to Promote Apprenticeships in Advanced Energy Industries: Offering incentives and guidance for businesses to establish apprenticeships to increase the number of statewide apprenticeships, as seen in South Carolina's successful program.

Chapter 1: Introduction

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

This report identifies opportunities to boost growth in two economic clusters in the advanced energy sector that leverage the state's legacy industries and current investment activities. State and local leaders who seek to leverage the state's resources to create skilled, good-paying jobs can use this report as a foundation for action.

Market Opportunity

Demand for advanced energy has soared in recent years and is poised for continued growth. Since 2004, new investment in the advanced energy sector has totaled $2.3 trillion worldwide.[11] In the United States alone, over $386 billion was invested in advanced energy between 2007 and 2014; $51.8 billion was invested in 2014.[12] In nationwide polls, Americans increasingly support renewables over other forms of energy,[13] and demand for renewable energy is likely to continue to grow. By 2030, states will need to significantly reduce power plant pollution.[14] The best way to meet those targets is from a combination of investing in advanced energy technology, utilizing renewable energy sources, and reducing demand through energy efficiency. Projections show that renewable energy will add the vast majority of new generation (69 percent to 74 percent) between now and 2030.[15] These trends point to a clear market signal: demand for advanced energy will continue to grow over the next fifteen years.[16]

Economic Clusters

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

– Michael Porter, *Clusters and the New Economics of Competition*[17]

Economic clusters encompass a variety of linked industries and institutions—including suppliers of specialized services, machinery, and infrastructure—which form a supply chain.[18] Clusters also extend to manufacturers of complementary products and to industries related in skills and technologies. By placing themselves in close proximity to industry allies, companies can benefit from each other's unique expertise and skilled workers.[19] Companies in a cluster enjoy closer access to specialized skills and information, which helps increase productivity and efficiency.[20]

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 in the cluster, drive innovation in the field, and facilitate the commercialization of this innovation by increasing communication, logistical support, and overall interaction between cluster entities.[21] Clusters also help build a strong foundation for creating and retaining employment opportunities.

Economic Cluster

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

Policy Certainty

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

Workforce Development

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

Innovation Ecosystem

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

Access to Capital

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

Colorado's Energy Profile

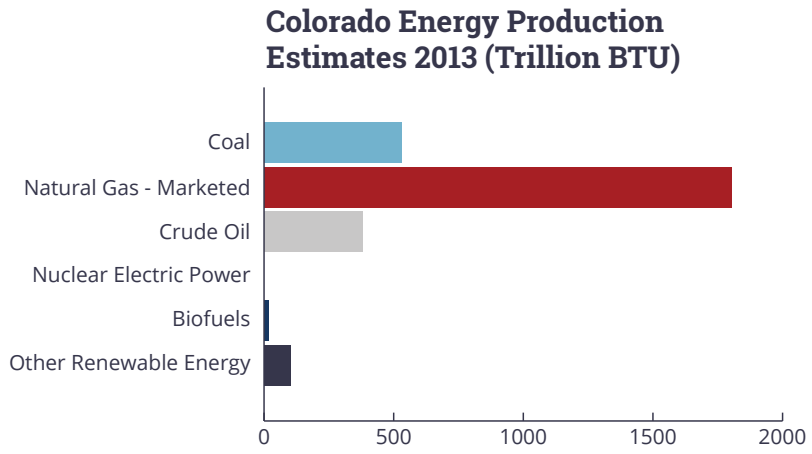


Figure 1. Natural gas dominates energy production in Colorado. (Source: U.S. Energy Information Administration)

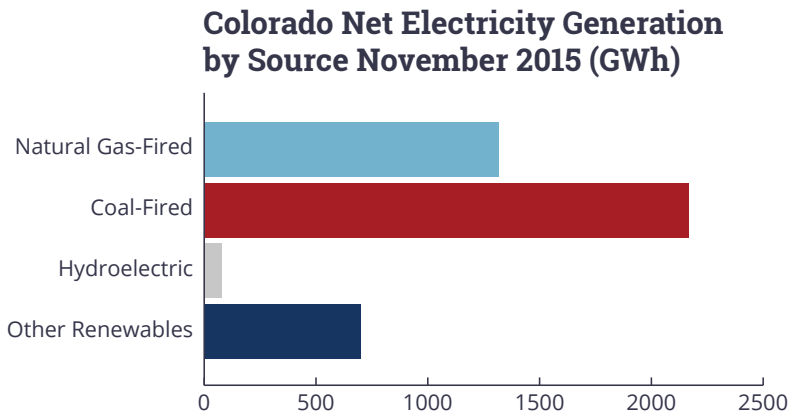


Figure 2. Most of Colorado's electricity is powered by coal. (Source: U.S. Energy Information Administration)

Colorado currently relies on coal and natural gas for over 80 percent of its electricity production, with most of its fossil fuel resources produced in-state.[22] Colorado is home to many rich petroleum reserves such as the Niobrara Shale, which contains up to two billion barrels of oil.[23] Consequently, Colorado is a significant petroleum exporter, contributing to 3 percent of the nation's oil output in 2014.[24] Natural gas is also a significant fossil fuel resource in the state, with Colorado's production doubling since 2001 as natural gas prices have dropped significantly.[25]

Advanced energy sources currently contribute 18 percent of Colorado's total electricity production, and growth in the advanced energy sector is driven largely by the state's ambitious Renewable Energy Standard requiring 30 percent of all electricity

sold by investor-owned electric utilities to come from advanced energy sources by 2020.[26] Colorado has promising renewable resources including biomass, solar, wind, hydropower, and geothermal energy.[27]

Xcel Energy, an investor-owned utility, provides the largest source of power to consumers in Colorado.[28] As of October 2015, Colorado residents paid 11.7 cents per kilowatt-hour, which is below the national average.[29] Industrial activity is responsible for the most energy consumed in the state, with transportation in a close second.[30] Colorado is ranked twenty-fifth in the nation for total energy consumption, with 1,472 trillion British Thermal Units used in 2013.[31]

Advanced Energy Development

The state of Colorado is already well on its way to a robust advanced energy industry. The state ranked eighth in the nation for total solar capacity, tenth for installed wind generation capacity, and third for high-tech employment in 2013.[32] The energy industry currently has more than 122,000 employees in Colorado, a 56.2 percent job growth since 2003.[33]

Colorado's policies have been friendly to advanced energy technologies, and the state's natural resources, educated population, sufficient capital, and strategic location enable the state to further grow its advanced energy industry.

However, a few policy and technological hurdles stand in the way of Colorado solidifying its leadership in the advanced energy industry. Despite ample wind resources and the presence of Vestas's manufacturing facilities, growth of installed capacity and production of wind turbines has stalled due to a combination of aging transmission systems and a lack of readily available skilled workers. Additionally, although commercial solar energy has pockets of success around the state, the lack of a robust residential PACE program prevents widespread adoption of residential solar in Colorado.

Overall, Colorado is an ideal place for advanced energy technology innovation and development. It is home to a number of top-level research and development facilities, including the National Renewable Energy Laboratory (NREL). Due to its research environment, natural resources, and supportive policies Colorado is strategically positioned to lead the region in wind and solar energy.

Jobs Potential

Maximizing job creation within Colorado is highly dependent on local action. An original equipment manufacturer (OEM) and its local suppliers employ workers from their community. Those employees spend much of their earnings at businesses in the local economy, such as grocery stores and restaurants. Local businesses also hire employees from within the community, who spend their earnings at other local establishments. This results in a multiplier effect, where a single dollar of spending in a community circulates through local businesses and their employees numerous times. Thus, recruiting advanced energy OEMs and their suppliers to a community can result in increases in local spending that are many times greater than the actual expenses of those companies.

With the right policies, Colorado's solar and wind energy industries can support up to 13,000 jobs per year from 2016 to 2030 in the solar and wind industries.

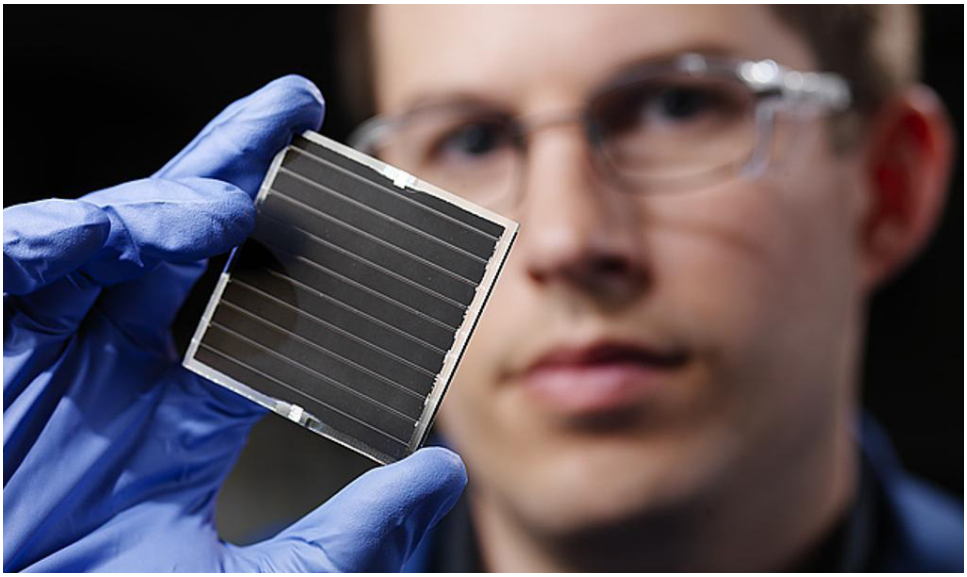
Report Structure

The analysis presented in this report is divided into four complementary chapters, each covering key elements of growing advanced energy economic clusters in solar and wind energies. Chapters 2 and 3 conduct a supply chain analysis for Colorado's emerging solar and wind clusters. This analysis culminates in an assessment of Colorado's potential for advanced energy jobs within each cluster and specific policy recommendations tailored to the state's needs. Chapter 4 analyzes Colorado's innovation ecosystem and access to capital, both crucial elements of sector development, and provides recommendations for further developing the state's innovation pipeline. Chapter 5 provides recommendations for workforce development programs and policies to prepare Coloradans for advanced energy jobs. The conclusion of the report summarizes key themes and the appendix summarizes our jobs modeling methodology.

Chapter 2: Solar Technology

Colorado's policymakers will play a decisive role in the future of solar energy in the state. Over the last decade, solar energy deployment has grown rapidly in the United States due to falling solar photovoltaic (PV) prices, technological advancements, favorable government policies, available financing, and increased consumer demand for clean and renewable sources of energy. States have leveraged solar energy demand through large-scale, utility-owned projects, as well as residential and commercial rooftop installations and community shared solar gardens. By targeting the state's emerging solar cluster with smart and strategic policy choices, Colorado's leaders can attract good-paying solar jobs while producing energy savings. With policies that encourage growth and technological innovation, Colorado can meet the demand for solar products from a strong in-state market and capitalize on export opportunities in regional, national, and international markets.

This chapter provides a guide to further strengthening and developing Colorado's solar economy. After analyzing Colorado's existing solar supply chain and discussing the state's potential for creating good-paying solar jobs, the chapter culminates in policy recommendations for future growth. These recommendations chart a course for Colorado policymakers to enhance the solar sector.



Solar cells are the basic unit of a solar panel.
Photo Credit. Pacific Northwest National Laboratory / Foter / CC BY-NC-SA

Strengths, Weaknesses, Opportunities, and Threats for Solar Technology in Colorado

STRENGTHS	WEAKNESSES
• Solar supply chain of approximately 400 companies employing 4,200 workers[1] • Ranked ninth in the country for total installed solar capacity[2] • High solar energy potential[3] • Robust higher education and research and development initiatives[4] • Aggressive Renewable Portfolio Standard (RPS) and other demand-creating policies[5] • Legislation enabling community solar gardens[6] • Both aggregate and community net metering allowed[7] • Third-party financing allowed[8]	• Limited market due to focus on utility-scale solar[9] • Insufficient electrical power transmission, especially near renewable energy generation development areas[10] • Inconsistent regulatory environment among investor-owned utilities, municipal utilities, and rural electric cooperatives[11]
OPPORTUNITIES	**THREATS**
• RPS includes distributed generation carve-out, applicable to both solar and wind[12] • Potential for strong solar cluster in the Denver area[13] • Four federal Solar Energy Zones in the state for utility-scale solar development[14]	• Utility pushback on rooftop solar[15] • Sustained efforts to add standby charge for net metering[16] • Market uncertainty due to policy threats • Growth of advanced energy sectors in other states may edge out Colorado from leading position[17]

Colorado is located in America's prime solar energy region and has significant solar energy potential.[18] To take advantage of this resource, the state has enacted several enabling policies including net metering, third-party financing, community shared solar, and an RPS with a distributed generation carve-out.

The solar industry is also supported by collaborative research and coordinated workforce training. For example, the Center for Revolutionary Solar Photoconversion (CRSP) is dedicated

to increasing the efficiency and cost-competitiveness of solar electricity generation.[19] The CRSP stems from a research partnership between the National Renewable Energy Laboratory (NREL), Colorado School of Mines (CSM), Colorado State University (CSU), and University of Colorado Boulder (CU).[20] These universities also have many other solar-related research initiatives.[21] Additionally, the state recently worked with the Colorado Community College System to create a utility-approved energy technician specialist degree and certificate program, which includes solar installation maintenance training.[22] Colorado's solar sector is also supported by city-level initiatives: Boulder and Denver have established renewable energy goals, and in 2013, Denver ranked tenth in the nation for installed solar capacity.[23,24]

Colorado's policymakers could position the state as a leader in the advanced energy economy by supporting growth and innovation in the solar sector. To fuel this growth, state leaders could enact smart, strategic policies that spur solar demand and create good-paying jobs for residents. Currently, Colorado's utilities are focused on large-scale solar projects, which leaves significant room for growth in distributed generation. A large part of the national solar market is dedicated to small-scale, distributed solar, but utility pushback on these projects hinders widespread residential and commercial adoption and economic development in Colorado. Through policy leadership aimed at overcoming these barriers, Colorado could stimulate solar deployment, bolster the state's solar cluster, and create thousands of good-paying jobs for residents.

Solar Market Trends

Rising Demand

The past several years have been characterized by a surge of innovation and growth in the solar industry. For example, global PV solar installed capacity has increased by a factor of nearly seventy over the last decade, from 2.6 GW in 2004 to 177 GW in 2014.[25] As a result of this growth, investment dollars are flooding the market, prices are falling, and the industry is undergoing a period of rapid innovation.

In the United States, solar PV cells are a primary source of new electricity generation. In the first half of 2015, solar represented 40 percent of all new electricity generating capacity, the most out of any energy source.[26] Strong demand has made the United States the world's fifth largest solar market in terms of installed capacity.[27] Forecasts show significant growth continuing through 2030 (Figure 3).[28]

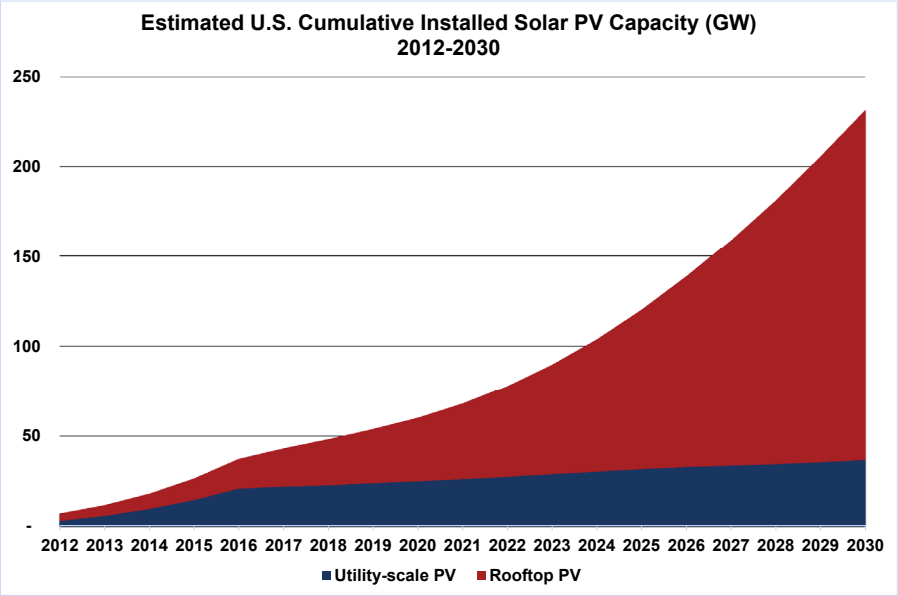


Figure 3. U.S. solar installed capacity could exceed 200 GW by 2030.
(Source: Bloomberg New Energy Finance, 2015 New Energy Outlook - Americas, June 2015)

The extension of the 30 percent federal solar tax credit is projected to inject $38 billion of investment into the market, amounting to an additional 20 GW of solar power.[29] This boost in demand is also aided by the declining cost of solar, making it increasingly competitive with coal and natural gas.[30]

Falling Costs and Increasing Efficiency

In 1961, President Kennedy challenged the United States to land a man on the moon and bring him safely back home by the end of the decade. Driven by competition against the Soviet Union and the mystery of space, the United States achieved one of the most remarkable accomplishments in human history. In the same spirit, the Department of Energy's SunShot program has challenged the nation once again. This time the challenge is not about space, but energy.

The SunShot program uses the levelized cost of electricity (LCOE) as a way to compare the cost of installing a solar system to the rate utilities charge for electricity. The program has set the goal of reducing the LCOE for utility-scale solar energy to $0.06 per kilowatt-hour (kWh) by the end of this decade.[31] Technology-driven innovation will make solar energy cost-competitive with traditional energy sources by 2020. So far, the United States has achieved more than 60 percent of SunShot's goal and is on pace to meet this challenge well before 2020.[32] The cost of solar per kilowatt-hour is forecast to be cheaper than coal and natural gas in the coming years[33] and solar is now cost-competitive in fourteen states where the solar LCOE ranges from $0.10 to $0.15

per kWh and retail electricity price comes in at $0.12 to $0.38 per kWh.[34]

What is Levelized Cost of Electricity?
The levelized cost of electricity (LCOE) is a summary measure of the cost of energy-generating technologies. The LCOE considers an assumed lifespan and utilization level in order to quantify the per-kilowatt-hour building and operating costs of a generating plant.[35] To calculate the LCOE, a variety of factors and inputs are assessed including capital costs, fuel costs, operation and maintenance costs, and financing costs.[36] The LCOE provides a way to compare the cost of installing a solar system to the rate for electricity charged by utilities. Due to nonexistent fuel costs for generation and very low variable operation and maintenance costs, LCOE for solar technology is mostly determined by capital and financing costs.[37]

While the cost of solar energy has declined, the efficiency of solar technology has simultaneously increased. In 2014, the average capacity factor of solar projects built in 2013 was 29.4 percent, compared to 24.5 percent for 2011 projects.[38] This means that the same sized system can produce 20 percent more electricity.

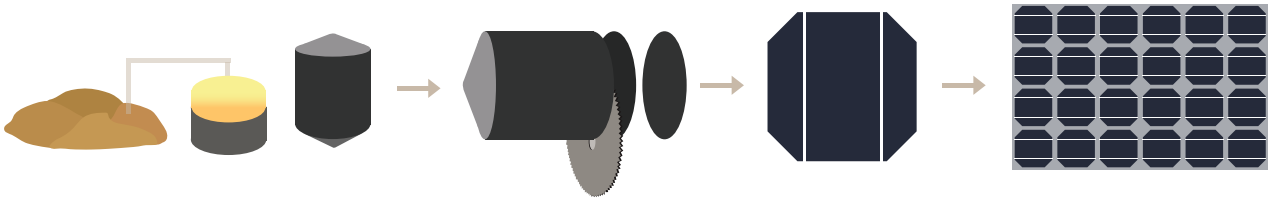
What Does Rising Solar Demand and Falling Costs Mean for Colorado?

The offshoring of U.S. manufacturing jobs was not driven by intrinsic geographic, technological, or cultural factors; rather, aggressive policies and low wages in competitor nations shifted American jobs overseas. The International Energy Agency conducted a detailed analysis of the manufacturing shift to China, which "suggests that the historical price advantage of a China-based factory over a U.S.-based factory is not driven by country-specific factors, but by scale, supply chain development, and access to finance."[39] State policy that fosters a strong market, develops the solar supply chain, promotes access to capital, and invests in solar workforce development will attract solar companies. With the right combination of policies, solar resources, available land, and access to capital, Colorado can compete nationally and globally in solar manufacturing, generation, installation, and exports.

Colorado boasts a solid manufacturing base supported by businesses that provide extensive support services. Coupled with the state's active research community and high-tech workforce, this foundation enables Colorado companies to compete in the expanding solar market as major suppliers. The growth of specific components within the value chain can help Colorado determine

The Solar Manufacturing Process

Crystalline silicon panel technology is the current standard for panels installed in the United States. There are four main steps to assemble a crystalline silicon panel.



Extracting and Purifying Silicon

The production of a PV panel begins by deriving silica from sand. After the silica is extracted, it is purified to make a high-purity silicon powder.

Manufacturing the Wafer

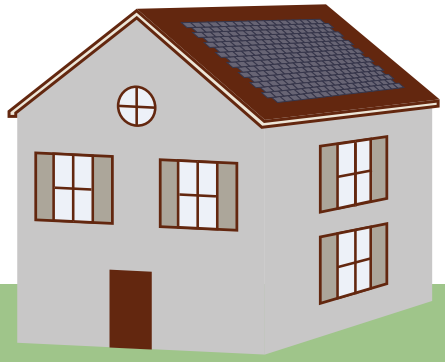
With the silicon powder, a wafer can be manufactured by doping the molten high-purity silicon with boron. Molten silicon is poured into a mold creating blocks of solid polysilicon. The block is then cut, polished, and cleaned.

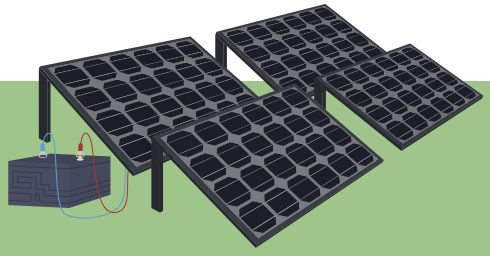
Assembling the Modules

During cell manufacturing, one side of the wafer is doped, usually with phosphorous. A conductive grid and anti-reflective coating are adhered to the top and a conductive back plate is assembled to the bottom of the cell. Cells are then combined electrically to form a module. A glass or film sheet is placed on the front and back. The module is covered by an outer frame, usually made of aluminum.

Assembling the Array

The finished solar panels are delivered to the customer. Downstream solar activities involve distribution, engineering design, contracting, installation, and servicing. There are also ancillary services involving financial, legal, and nonprofit groups that provide support for solar projects.





The Future of Solar

Research and innovation in the solar industry is leading to exciting breakthroughs

Building with Solar Cells
In the future, solar technology will be incorporated into the structure of a new building, rather than installed on a roof after construction is complete. For example, the near-medium-term future could see walls, skylights, windows, and shingles manufactured with solar materials.

Solar for the Home of the Future
"Smarter" solar panels will incorporate technology and sensors to provide real-time information about energy generation and demand. Unprecedented interconnectedness and energy management software will open the door for increased customization.

Organic Solar
Organic solar cells are a new type of carbon-based solar cell. This technology can be manufactured in innumerable applications, such as transparent paint. For example, windows could be coated in a transparent organic paint that provides electricity to the building.

Ultra-High Efficiency Solar Cells
The higher the efficiency of a solar panel, the more electricity it can create from the sun's rays. With ultra-high efficiency cells, less area is needed to obtain the same amount of electricity. Researchers project that solar cells could be four times more efficient in the near future.

Solar Soft Costs and Information Technology
Data-driven innovations will help reduce the soft costs of solar marketing and provision. Better data analytics will improve system design and uptake through performance modeling and investment projections. Lead generation firms and price comparison tools are already streamlining customer acquisition by connecting homeowners to solar installers.

Solar and Energy Storage
Solar panels only generate electricity when the sun is shining. New battery storage technology allows solar energy to be stored when excess electricity is generated during the day and then dispatched in the absence of sunlight.

the best industries to leverage the state's assets and capitalize on future growth. For example, the North American flat roof solar racking industry is projected to grow by an annual rate of 17.5 percent.[40] Colorado-based companies, such as Zilla Corporation and S-5! Metal Roof Innovations, could capitalize on this growth.[41]

Colorado could identify and fill supply chain gaps to broaden its solar manufacturing base and become a major contender in other solar-related areas. For example, the solar inverter industry is estimated to grow by 10 percent through 2018.[42] Colorado-based companies could leverage this growth and become major inverter suppliers. Increased manufacturing in Colorado will also create the possibility for exports to neighboring states to meet demand. In-state businesses, such as ProtoFlex Corporation and Sinton Instruments, currently sell solar PV process tools to international customers,[43] but Colorado could expand exports to primary components. Colorado is well-positioned to develop a strong in-state market and play a major role in solar exports, which will increase economic and job growth in the state.

Solar Manufacturing Technology

There are many types of solar cells with different manufacturing processes and assembly configurations. In order for Colorado policymakers and leaders to craft forward-thinking policy that reflects the future of solar technology, it is important to understand the solar manufacturing process and advances in the space.

Roof-integrated solar photovoltaic shingles
Photo Credit. U.S. Department of Energy

Colorado's Solar Supply Chain

The solar supply chain is comprised of companies working in different areas of manufacturing and support services. Colorado has approximately 400 firms in the solar PV supply chain.[44] Direct employment from these businesses totals roughly 4,200 jobs.[45]

Table 1. Companies in Colorado's Solar Supply Chain

CATEGORY	NUMBER OF COMPANIES	DESCRIPTION
Manufacturing	***35***	
Full System	5	Design and manufacture full solar system
Advanced Materials	0	Develop materials used for solar cells
Frames	0	Manufacture structural frames for solar cells
Sealants and Protective Films	1	Create structural sealants used to hold cells and structural frames together or manufacture films used to protect the surface of solar cells
Machine Manufacturing	9	Manufacture tools used in the process of manufacturing solar systems
Inverters	1	Manufacture inverters used in solar systems
Controllers	4	Manufacture solar charge controllers
Tracking System	4	Manufacture components such as tracking devices, gears, and motors used in solar tracking systems
Mounting/Racking	3	Manufacture structural components to mount solar systems
Other	8	Manufacture innovative system designs, batteries, and specialized use products
Services	***388***	
Contractors/ Installers	206	Design and install rooftop or utility-scale solar projects
Project Developers	34	Assist with development of full-scale utility solar system projects and have a stake in the project
Distributors	29	Distribute finished solar systems from manufacturers
Consultants	43	Assist in stages of project development
Other	76	Provide services such as financial and legal support, customer advocacy, marketing, and research
Total Companies	**423**	

(Source: Internal analysis of Solar Energy Industries Association database)

Strengths

The presence of a substantial number of companies within Colorado's solar supply chain indicates a robust in-state market. Colorado's solar energy ecosystem creates a strong foundation for the manufacturing and delivery of solar panels within the state, and can be expanded to include exports to neighboring states and international markets.

Colorado is home to an array of solar installers and contractors throughout the state. Businesses such as SolarCity work with customers to access tax credits and other state-level benefits.[46] SolarCity is also dedicated to employing local Coloradans, which bolsters the company's contribution to the state economy.[47] In total, 205 businesses are engaged in solar contracting and installation to bring solar energy to the people of Colorado. Additionally, Colorado's solar supply chain consists of numerous peripheral businesses. For example, Ampt in Fort Collins manufactures optimizers that improve the efficiency of various types of solar panels.[48] Measurlogic produces testing equipment to measure the output of solar panels and sells both DC and AC meters for solar strings.[49] Measurlogic serves commercial and industrial sectors in both the domestic and international markets.[50] Several other Colorado businesses provide solar-related components as well.

Opportunities for Growth

Strengthening Colorado's manufacturing base could expand the solar cluster and boost job growth in the state. Currently, Colorado is home to a handful of full system manufacturers and equipment providers, as well as component suppliers. However, more companies could focus on component manufacturing and advanced materials to fill supply chain gaps and enable the development of high-quality products for system manufacturers. Colorado companies could target wafers, cells, and modules; structural frames; and electrical components such as inverters, controllers, and tracking devices. Additionally, businesses could expand to supply a variety of materials for module production, including silicon or other semiconducting materials, process chemicals, solar glass, and protective films. Ascent Solar, a longstanding panel manufacturer in Colorado, has been struggling to maintain its foothold, largely due to its focus on thin-film PV technology.[51] With a greater diversity of available materials and components, new solar manufacturing firms could develop while existing companies like Ascent Solar could expand to high-demand areas. As the solar industry grows, other business sectors will begin to integrate into the solar supply chain.

Colorado's leaders could take steps to attract foreign investors to support the solar supply chain.[52] The Governor and the Office of Economic Development and International Trade could target specific companies to strengthen Colorado's solar cluster. International businesses involved in silicon wafer manufacturing include LDK Solar (China) and Wacker Chemie (Germany). Firms that support solar panel manufacturing include Sharp (Japan), SolarWorld (Germany), Yingli (China), and Suntech (China). These companies could provide the technology and expertise to expand Colorado's solar cluster.

Colorado's Solar Cluster

There are a significant number of solar businesses located in Denver. Given the proximity and diversity of these firms, they could be linked to form the basis of a strong solar cluster. Early-stage clusters can also be developed from small groups of firms around Fort Collins and Colorado Springs.

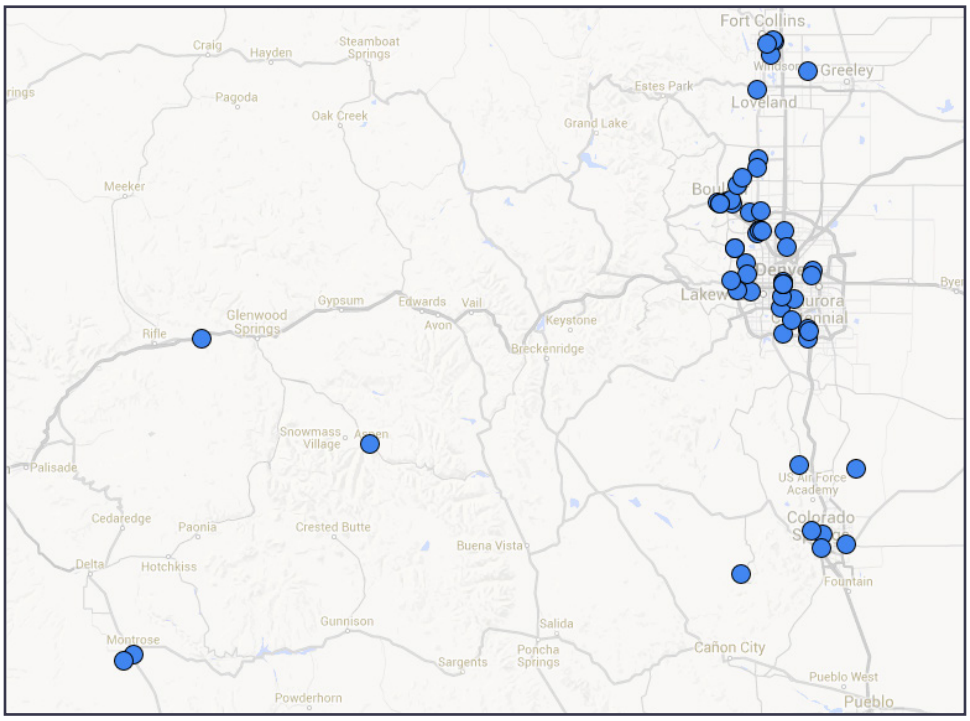


Figure 4. Solar Clusters in Colorado
(Source: Solar Energy Industries Association)

Working on a solar energy system
Photo Credit. Jamie Nolan / U.S. Department of Energy

Installing solar panels
Photo Credit. Dennis Schroeder / NREL

Colorado's Solar Employment Potential

As demand for solar skyrockets, Colorado has the opportunity to expand the solar economy, increase in-state spending, and employ an average of nearly 7,700 Coloradans annually over the next fifteen years. If optimistic projections prove to be correct and Colorado's solar companies are able to fill most of their supply chain needs with in-state purchases, over 115,000 direct, indirect, and induced job-years would be supported. While nearly 38,000 of those would be direct job-years in the state's solar industry, over 77,000 indirect and induced job-years could be supported if solar companies were able to procure supplies from in-state companies.

These projections for job-years potential in Colorado's solar industry are based on tools and analysis by the Department of Energy's Office of Energy Efficiency & Renewable Energy (EERE), Energy Information Administration (EIA), and Bloomberg New Energy Finance (BNEF). Additionally, the Jobs and Economic Development Impacts (JEDI) tool was utilized to estimate job-years at different levels of local supply chain concentration for rooftop solar (residential and commercial buildings). Our projections did not indicate a significant outlook for utility scale solar.

To highlight why clustering supply chain businesses in Colorado is so important, we have estimated the number of direct, indirect, and induced jobs based on future demand and the percentage of supply chain purchases made within the state. Figure 5 shows how the number of rooftop solar job-years vary as the local share changes. The figure shows the number of direct, indirect, and induced jobs based on local purchase percentages of 25 percent, 50 percent, and 75 percent. This range was chosen to represent reasonable goals for average local purchases, as 0 percent and 100 percent both represent extremes of purchasing behavior that we do not believe are realistic. Since projections often vary, we analyzed how those supply chain differences affect three reputable estimates of future demand: BNEF's forecast as a high-demand scenario, the EERE's Wind Vision as a moderate-demand scenario, and EIA's Annual Energy Outlook 2015 Clean Power Plan Base Policy as a low-demand scenario. Figure 5 presents estimates for rooftop construction, operations, and maintenance jobs.

In all three demand scenarios, increasing the percentage of local spending by Colorado's solar companies creates thousands of job-years. For example, in the high-demand scenario, increasing in-state local purchases from 25 percent to 75 percent would support over 50,000 direct, indirect, and induced job-years. In the moderate-demand scenario, that same increase in in-state

What is a Job-Year?

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

Why Use Job-Years?

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

Direct, Indirect, and Induced Job-Years

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

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

Local Share

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

local purchases would support over 49,000 job-years. Even in the low-demand scenario, increasing the percentage of in-state local purchases from 25 percent to 75 percent would support over 25,000 direct, indirect, and induced job-years.

If a concerted effort were made by the state to fill in the supply chain and strengthen the solar cluster, Colorado companies could meet the expected demand for solar, supporting over 115,000 job-years. Increasing the number of supply chain businesses can create thousands of good-paying, skilled jobs and make Colorado a leader in the solar industry.

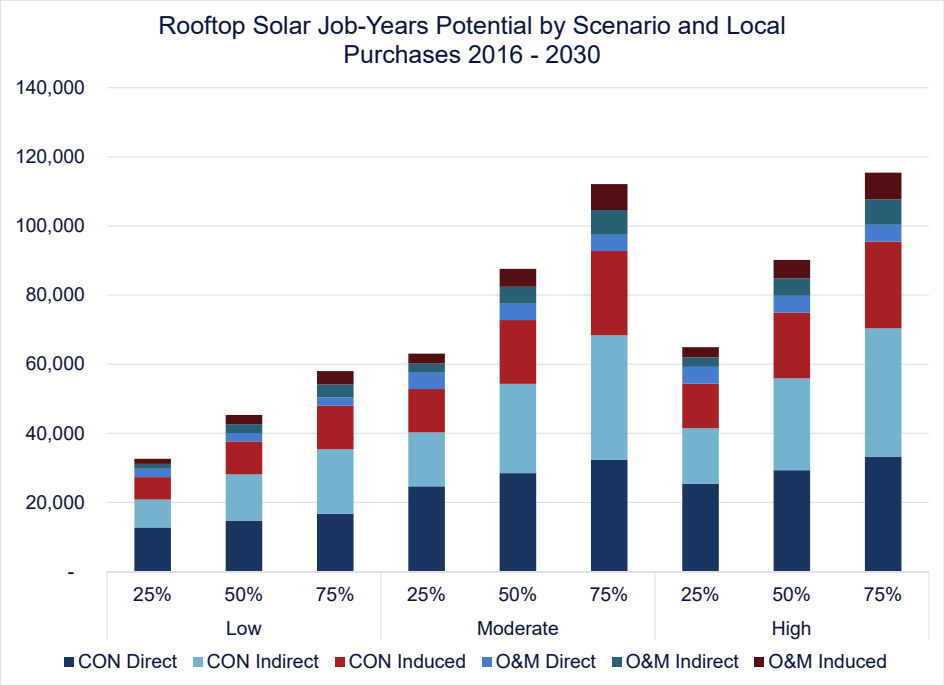


Figure 5. Increasing local spending will increase job-years for Coloradans.

Policy Recommendations

With a strong track record of renewable energy policy and a wealth of educational and training resources, Colorado is well-equipped to grow solar jobs. Colorado could jumpstart the state's solar cluster by focusing on innovative policies that remove obstacles, stimulate demand within the state, and increase access to renewable energy for both low-income residents and large corporations. Creating a robust in-state market will attract private investment, strengthen the economy, and create new value chains, which will subsequently stimulate and accelerate new export markets.

Policy 1: Create an Energy Storage Mandate

While Colorado may be able to power itself many times over with renewable energy, balancing supply and demand of electricity can be a challenge, particularly due to the intermittency of solar and wind sources. Effective energy storage options would bolster Colorado's renewable energy systems by saving excess energy for future use, especially during times of low generation. Storage is particularly beneficial to solar power systems due to the cost benefit of reducing curtailment.[56] Colorado could support storage technology by establishing long-term procurement goals for utility-scale and distributed energy storage. This storage mandate would reinforce the value that energy storage provides the grid and help reduce the cost of wasted energy.

Barriers to increasing statewide solar integration include concerns from Colorado utilities regarding load imbalances and grid reliability. As demonstrated in California, the technology is available to support widespread solar integration. In 2013, the California Public Utilities Commission (PUC) required that the three large investor-owned utilities obtain 1,325 MW of combined storage by 2020, with installations operational by 2024.[57] The California PUC also provisionally extended storage benefits to distributed solar systems by providing fee exemptions and streamlining interconnection approval for small, net-metered systems paired with storage.[58] These measures can save customers up to $3,700 in extra fees.[59] Since the mandate, the two largest utilities have procured 325 MW of various storage technologies.[60] To chart these energy futures, Colorado utilities could be required to incorporate energy storage into their integrated resource plans and provide different scenarios based on solar output and storage integration.

While the California mandate applies to only investor-owned utilities, Colorado could include municipal utilities and rural electric cooperatives at a smaller scale. For example, the state

The Value of Energy Storage

Although energy storage does not generate electricity or direct revenue, it provides multiple ancillary services to the grid that traditionally have not been assigned a value and increases the inherent grid value of intermittent renewable resources.[53] Many argue that energy storage is not cost-effective, but this is typically based on a single metric.[54] Energy storage is cost-effective as a complete system optimization tool. Most generation is built to meet cumulative peaks in demand (not just peak hours). By reducing these peaks, ratepayers can eliminate gigawatts of generation required to meet fluctuating demand.[55]

could direct these electric providers to invest in at least one storage demonstration project that has a minimum capacity of one megawatt-hour (MWh). Oregon has taken a similar approach by requiring utilities to meet a 5 MWh storage minimum.[61] The Colorado State Legislature and PUC could establish strong policies that signal a commitment to energy storage. Enacting a storage mandate would enable greater utility-scale and distributed solar generation and help Colorado achieve its aggressive renewable energy goals.

Policy 2: Support the Development of Residential PACE Programs

Colorado has legislation authorizing the development of PACE programs, but residential PACE has yet to take off in the state. Previously, Boulder County offered loans for residential property owners through its ClimateSmart Loan Program, but it was put on hold due to the 2010 Federal Housing Finance Agency (FHFA) decision.[63] The uncertainty caused by this federal decision has made it difficult to establish new PACE programs.[64] Colorado could overcome these barriers by adopting innovative ideas from other states, specifically loan-loss reserve funds and model guidelines for program development.

States such as California and Rhode Island have eased banks' concerns by creating a loan-loss reserve fund. Under this design, any money lost by a bank in a foreclosure will be repaid with money from the PACE loan-loss reserve fund. Only a small amount of initial funding is needed to establish a reserve fund. In 2013, Rhode Island used federal stimulus funds to set up a $1 million loan-loss reserve.[65] Since creating a $10 million PACE reserve fund, California has experienced a $300 million influx in private financing to create a new multi-county PACE program.[66] According to the California PACE Loss Reserve Program Office, no funds have been used from the state reserve fund, indicating a low level of risk from PACE borrowers.[67] Colorado could facilitate market certainty and stimulate private investment by creating a PACE loss reserve.

With greater financial security provided by the reserve fund, Colorado could also facilitate the development of residential PACE programs by providing tools and model guidelines for communities. Texas has led the way on this front with the creation of the "PACE in a Box" toolkit. The Texas toolkit project was seeded with $200,000 from the Texas State Energy Conservation Office and $800,000 from foundations and PACE stakeholders.[68] With that funding, the program researched best practices and developed a uniform, scalable, and turnkey program, which includes details such as bond requirements, uniform lending

PACE Financing Programs

Property Assessed Clean Energy (PACE) programs allow property owners to finance investments in renewable energy and energy efficiency with a loan that is repaid through their property tax bill. The loans are attractive for borrowers because energy investments often require more capital than would otherwise be available to many residents or commercial property owners. Lenders are willing to offer attractive interest rates because their loan is secured by a tax lien on the property. PACE financing is now available in more than 800 U.S. municipalities and over 80 percent of the country's population live in states that provide PACE financing.[62]

documents, model municipal resolutions, and underwriting and technical standards. The Texas toolkit is online and its availability should enable Colorado to write its own high-quality toolkit for a fraction of the cost. Colorado could also seed the project with minimal funding and look for partners to provide the bulk of the capital. The state has made similar efforts to create streamlined and statewide guidelines with its commercial PACE program.[69]

By establishing a PACE toolkit and a loan-loss reserve fund, Colorado could empower local governments to quickly and efficiently implement residential PACE programs, stoke in-state solar demand, attract private investment to the state, and create good-paying, skilled jobs for residents.

Policy 3: Enable Group Solar Purchasing

Although solar deployment is expanding in Colorado, many people still lack access to solar due to high upfront costs and lack of information on financial incentives. Additionally, consumers are less likely to transition to solar if neighbors are not leading the way. This solar contagion phenomenon occurs in communities regardless of income levels or population density.[73] Colorado could capitalize on this "neighborhood effect" to increase demand and access to solar by establishing a group purchasing program.

Connecticut has created Solarize programs that allow communities to buy solar in bulk at a discount rate. These programs give communities access to pre-negotiated, tiered group purchasing plans. As more community members sign up, prices fall.[74] The program has spread to dozens of communities that may not have had access to solar without the Solarize program.[75]

Colorado organized a similar initiative at the municipal level for the Denver/Boulder metro area.[76] The Solar Benefits Colorado program pooled the buying power of participants for discounts on PV systems and electric vehicles.[77] A similar program could be revitalized on a wider scale to give access to all Coloradans. With minimal administrative costs, Colorado could create or designate a state agency or a nonprofit to manage the program.[78] The managing entity could facilitate competitive contractor selection to establish discounted pricing packages for participating communities, develop outreach materials, and work closely with communities to enroll customers.[79] By creating group purchasing opportunities, Colorado would increase access to solar and boost distributed generation capacity.

A Roadblock to Residential PACE Programs

A 2010 Federal Housing Finance Agency (FHFA) decision jeopardized the impact and availability of PACE.[70] Because the FHFA was concerned about the senior status that PACE liens have over a mortgage in foreclosure proceedings, the agency advised Fannie Mae and Freddie Mac to avoid buying homes with these liens.[71] This decision has limited the use of PACE for financing residential energy efficiency improvements. In 2015, the Department of Housing and Urban Development announced that it is coordinating with the FHFA, the Consumer Financial Protection Bureau, and the Department of Treasury to provide new PACE guidance.[72]

Community Solar Gardens

Approximately 85 percent of U.S. residential customers can neither own nor lease residential systems because they are renters or have unsuitable roofs.[80] Community solar is a popular solution to this issue, and fourteen states and the District of Columbia currently offer this option to customers.[81] Solar gardens enable consumers who live in an apartment, do not have a sunny roof, or cannot afford a full system to buy or lease a piece of an array and receive credit on their electricity bill for the power their panels produce.

Policy 4: Reduce Barriers to Community Solar

Colorado has been a leader in the growth of community shared solar. In 2010, the state passed the Colorado Community Solar Garden Act, the first solar garden legislation in the nation.[82] The legislation has spurred the development of twenty-five solar gardens in the state,[83] and served as a model for Minnesota and California.[84] Recently, Colorado updated the legislation to expand customer access to projects in adjacent counties and within the same utility territory.[85] However, the community solar model could be scaled up and expanded to further increase opportunities for low-income customers.

Establish an Annual Goal and Increase Project Carve-Out for Low-Income Subscription

Currently, the Colorado Community Solar Garden Act mandates that 5 percent of each community solar project be allocated to low-income subscribers.[86] Additionally, the Colorado Energy Office has supported successful efforts by GRID Alternatives to provide community solar to rural communities[87] and other project developers have dedicated solar gardens to low-income groups.[88] Colorado could further fuel the partnership between project developers and utilities by either removing the cap on solar gardens or establishing an overall goal for low-income subscription and increasing the carve-out for each project. Increasing the annual carve-out target would encourage utilities to invest in large-scale projects with low-income residents as the primary beneficiaries.

Develop Financing Options for Low-Income Community Solar Projects

Colorado could devise financing options to sustain low-income community solar development. Funding could be provided at both the state and utility level.

State-level financing options include a statewide electricity tax and a portion of the state's Low-Income Home Energy Assistance Program funds.[89] The state could also institute a bonus payment to utilities for kilowatt-hours subscribed to low-income customers, which would incentivize developers to increase low-income registrants. The additional bonus payment could be counted as part of the utility's contribution to low-income services and could help reduce risk for developers working with participants with low credit scores.

Additionally, utilities could create an innovative funding model that connects ratepayers with community solar projects. Through a voluntary payment program, customers could sign up to pay

a premium on their bill to support shared solar projects in low-income and rural communities. A similar model in the United Kingdom has raised over £400,000 to fund solar projects for schools,[90] and customers of Florida Power and Light's pilot program have helped build two public solar canopies.[91] Given this program would not provide consistent funds, it could be supported by a sustainable baseline fund. To establish this baseline, utilities could allocate a portion of their Renewable Energy Standard Adjustment (RESA) fund, which is made up of mandatory ratepayer fees to support utility renewable energy projects.[92] By offering this unique program, utilities could effectively crowdfund large-scale projects for communities that have limited access to solar.

Extend Community Solar Mandate to Municipal Utilities and Rural Electric Cooperatives

Current community solar legislation requires investor-owned utilities to purchase a minimum quantity of electricity from community solar gardens.[93] However, this requirement is not extended to municipal utilities and rural electric cooperatives, which account for a combined 37.2 percent of the state electricity market.[94] Colorado could extend its community solar legislation to require municipal utilities and rural electric cooperatives to obtain electricity from community solar gardens. This would ensure compliance with the low-income carve-out and equal opportunities for community solar throughout the state. By allowing projects to scale up and expand their reach, Colorado can broaden its leadership in community shared solar.

Dual surface panels produce up to 30 percent more power
Photo Credit. Department of Energy

What is Net Metering?

Under net metering, customers with renewable electric generators can reduce their electric bill by generating some or all of their power and receiving a credit from their utility for any excess generation.[95] Net-metered customers are credited at the full retail electricity rate, which includes the cost of grid services and equipment.[96] Colorado also allows aggregate net metering (for property owners with multiple meters on the same property or adjacent properties) and community net metering (for multiple users to benefit from a single net-metered system).[97] Aggregate and community net metering policies enable renters, multi-property owners, and customers in multi-unit residences, commercial spaces, and government-owned facilities to take advantage of net metering incentives typically only available to single-property owners.

Policy 5: Create Safe Harbors for Net Energy Metering

In Colorado, net energy metering (NEM) is the primary mechanism for compensating customers for solar generation from their system or subscription to a community solar project. NEM offers market certainty of return on investment, making it a major driver of solar deployment.[98] However, there have been consistent efforts by utilities to impose additional fees, which significantly reduces the benefits.[99] Colorado policymakers should consider establishing safe harbor provisions to ensure that NEM customers are protected from unfair costs and to preserve the in-state solar market.

In many states, utilities are allowed to set a "standby charge" for NEM customers to recover the cost of producing additional electricity for demand not met by intermittent distributed generating systems.[100] Based on this intermittency, utilities may require NEM customers to pay a fee, purchase insurance, or obtain more equipment.[101] These charges can place a significant burden on small generators (most residential customers) and community solar subscribers, enough to diminish the benefits of NEM.[102] Additional charges can also decrease the cost-competitiveness of PV, limit the resiliency of customers to rate changes, and signal a higher level risk to investors, all of which negatively impact the soft costs of solar deployment.[103] Nevada recently experienced a similar shock to the market when major solar installers, SolarCity and Sunrun, shut down operations in the state following the decision to cut rates and add fixed charges for existing net metering customers.[104]

Alternative Rate Designs

Utilities should consider holistic, transparent, and equitable rate designs that keep the solar soft costs relatively low and that do not impose a disproportionate burden on NEM customers. An integrated approach for fixed cost recovery would include (1) revenue decoupling to recover fixed costs from all customers and properly value energy savings measures such as solar PV; (2) a customer-wide "bare minimum" monthly contribution that effectively captures zero net energy customers; and (3) gradually phased-in time-of-use pricing which better reflects marginal supply costs.[105] Currently, Colorado does not allow revenue decoupling, but this mechanism could be adopted to increase energy efficiency efforts.[106] The state could also look to California for model legislation on the minimum charges and time-of-use pricing.[107] This design accounts for various factors in revenue loss and does not unfairly target NEM customers and the solar industry.

Net metering has been a critical policy tool for making rooftop and community solar payback periods economically feasible for Colorado customers. Safe harbor provisions would protect current NEM customers and support greater solar deployment. By safeguarding this incentive, distributed solar generation can play a greater role in maximizing Colorado's solar resources and fueling economic development.

Policy 6: Offer a Green Source Rider Program

Corporate demand for renewable energy is growing, and Colorado is primed to capitalize on this demand. As renewable energy has become increasingly cost-effective, companies have started setting sustainability goals that include purchasing more renewable energy. Fortune 500 companies, including Intel Corporation and Starbucks, have increasingly declared their commitment to renewable energy.[108] By the end of 2015, fifty-one companies had signed on to a collaborative declaration demanding access to clean electricity.[109] These firms purchased 3.4 GW of renewable energy in 2015—three times the amount purchased in 2014.[110]

For many corporations, solar-powered electricity is a desirable option. Corporate buyers have more than doubled their installed solar capacity since 2012.[112] Colorado utilities could meet this demand through a Green Source Rider program, which would allow large corporate customers to voluntarily purchase renewable energy without shifting costs to other ratepayers.[113] Similar programs have been adopted in ten states across the country, including North Carolina, Virginia, and Nevada.[114] Colorado's largest utilities, Xcel Energy and Black Hills Energy, could draw from recent innovations by Duke Energy in implementing a similar program.

Benefits of Green Source Riders

If designed well, green source riders can provide benefits to society, utilities, and key account customers. Green source riders can:[111]

- reduce overall soft costs by providing economies of scale and optimizing avoided cost benefits, reducing transaction costs, and lowering customer acquisition costs;
- increase tax base and jobs by companies locating in the areas where the riders are offered;
- expand access to renewable energy;
- improve customer retention; and
- minimize impact on other customers.

Duke Energy's Green Source Rider in North Carolina

Duke Energy Carolinas offers the Green Source Rider program in North Carolina, which provides large energy-intensive customers (e.g., manufacturers, big-box retailers, college campuses, or data centers) with the option to offset their planned energy consumption with renewable energy.[115] Under the program, customers who have added at least 1 MW of new demand since June 30, 2012 can apply for a three- to fifteen-year contract to buy power from renewable sources.[116] Rates are negotiated on a case-by-case basis and customers are charged a monthly administrative fee and an additional two-tenths of a cent per kilowatt-hour.[117] Participating companies have a different rate structure through the program to ensure that non-participating ratepayers do not pay any additional costs.[118] Google was the first customer to participate in the program, purchasing 61 MW of energy from a solar project in Rutherford County in December 2015 to serve its data center.[119]

The Colorado PUC could investigate the impact of allowing utilities to offer non-residential customers voluntary renewable energy tariffs, as Oregon has done.[120] If the renewable energy tariff is deemed to be feasible, the PUC could expressly permit utilities to develop Green Source Rider Programs for companies in their territory and streamline the application process for program approval. Colorado is home to several Fortune 500 companies, with the potential to attract additional businesses to the state.[121] A Green Source Rider program would foster a solar- and business-friendly climate, while boosting the state's economy and creating jobs for Coloradans.

Chapter Summary

Smart, strategic policies can help Colorado leverage the state's strengths to create a thriving solar economy. As clusters coalesce around a nucleus of activity and relationships, Colorado policymakers should consider removing barriers and stoking in-state demand to create a more diverse and robust solar sector. Colorado can achieve this by encouraging solar plus storage technology; developing new financing models with residential PACE and group purchasing; securing equitable solar access through community solar projects and safe harbors for net metering; and attracting major businesses with a Green Source Rider program. The state has many opportunities to strengthen and expand its advanced energy economy, maximize solar potential, and create good-paying jobs for Coloradans.

Chapter 3: Wind Technology

Colorado's policymakers will play a key role in the future of the state's wind energy industry. By building on the state's existing success in wind energy manufacturing, the state can expand into new markets and export products to meet regional demand for wind-generated energy. With policies that encourage manufacturing and export of wind turbine components, Colorado can meet the demand for wind in regional, national, and international markets while continuing to power the state with wind-generated energy.

This chapter is a guide to further expand Colorado's wind economy. After analyzing Colorado's potential for creating good-paying wind jobs, the chapter culminates in policy recommendations for future growth. These recommendations chart a course for Colorado policymakers to generate and enhance jobs in the wind manufacturing sector.

Transporting a wind blade
Photo Credit. Nuon / Jorrit Lousberg

Strengths, Weaknesses, Opportunities, and Threats for Wind Technology in Colorado

STRENGTHS	WEAKNESSES
• Robust higher education and research and development (R&D) network • Existing 2,992 MW of installed capacity with potential for ninety-fold increase[1] • Existing incentives for wind power generation and installation[2] • Home to twenty-three wind R&D and manufacturing companies and the only Vestas manufacturing center in the United States[3] • Available state and local renewable energy grants and loans[4] • Easy access to railroad infrastructure	• Lack of regulatory consistency between local-level jurisdictions • Aging transmission infrastructure cannot meet demand of growing population[5] • Deterioration of road infrastructure for large cargo and containers
OPPORTUNITIES	**THREATS**
• Almost 300 GW of wind energy potential throughout the state[6] • Net metering and interconnection standards for distributed technologies also apply to small wind[7] • Regional demand for renewable energy • Potential for wind turbine installation on existing farmland	• Competitive wind industry growth in nearby states • Burdensome siting and permitting requirements • Potential inability to export to adjacent electricity markets due to lack of a central balancing authority[8] • Competition from out-of-state companies innovating wind technology

Wind-Generated Energy in Colorado

As a regional leader in wind-generated power and wind turbine manufacturing, Colorado is well-positioned to grow the in-state market and export products and services to neighboring states. With strong winds[9] and supportive policies—including the first ballot-approved renewable portfolio standard in the country[10]—Colorado has been able to meet nearly 14 percent of its electricity demand with wind power.[11] As of December 2014, Colorado ranked tenth in the nation for installed wind capacity with a total of 2,600 MW.[12]

Despite Colorado's current efforts, there remains considerable untapped wind energy potential in the state. Estimates suggest that 60 percent of Colorado's landmass is suitable for wind development, with the potential to generate 274 GW of power using current wind technology at 80-meter hub heights.[13] The Department of Energy projects that Colorado will double installed wind capacity by 2050, totaling approximately 4,640 MW.[14]

The wind industry provides significant economic benefits for Coloradans, generating more than 6,000 direct and indirect jobs in the wind industry.[15] Additionally, landowners in Colorado received nearly $8 million annually in lease payments from wind developers.[16]

Wind Market Trends

Rising Demand

Between 2004 and 2013, global investment in wind power grew from $14 billion to $80 billion.[17] Total global installed wind capacity currently stands at 370 GW, which covers nearly 5 percent of electricity demand worldwide.[18] Additionally, 2014 brought a record growth rate in global installations: the 50 GW of added capacity surpassed the 35.6 GW installed in 2013 and 45 GW installed in 2012.[19]

National demand for wind power tripled from 2008 to 2013, while large-scale wind installations increased 300 percent in capacity from 2013 to 2014.[20,21] In 2014, 24 percent of all new electric-generating capacity in the United States came from wind power.[22] The number of total wind installations increased by 77 percent between 2014 and 2015, which added another 8,598 MW of capacity. Altogether, installed wind capacity in the United States totals 74,472 MW.[23] Growth in the domestic wind sector is projected to continue: forecasts estimate that installed wind capacity in the United States will triple by 2030 (see Figure 6).[24]

As a result of the 74,000 wind turbines installed across the country, onshore distributed wind capacity in the United States totaled 906 MW in 2014.[25] While this is a promising start, the distributed wind market has substantial room for growth: the installed capacity of distributed wind in the United States could reach 1,000 GW by 2030.[26]

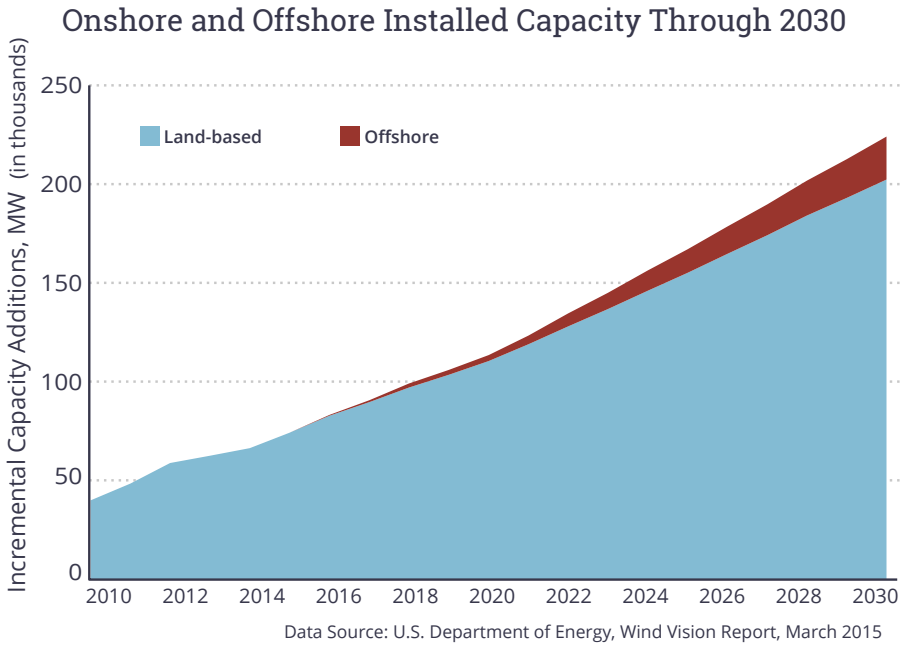


Figure 6. Installed onshore wind capacity could more than double between 2016 and 2030.

Falling Costs

What is Levelized Cost of Electricity?

The levelized cost of electricity (LCOE) is a summary measure of the cost of energy-generating technologies. The LCOE represents the per-kilowatt-hour (kWh) cost of building and operating a generating plant based on the plant's assumed lifespan and utilization level. To calculate the LCOE, a variety of factors and inputs are assessed, including capital costs, fuel costs, operation and maintenance costs, and financing costs.[30] LCOE is often reported in dollars per kWh, which allows utilities or policymakers to compare costs of installing a wind power system to other generation sources, such as a coal-fired power plant. Wind technologies have no fuel costs for generation and relatively low variable operation and maintenance costs, so the LCOE is determined mostly by capital and financing costs.[31]

Distributed Wind Systems

Distributed wind systems include power-generating technologies that produce electric power close to the site of consumption. These technologies can be either off-grid—meaning they only serve the facility they are located on—or connected to the grid, where the majority of consumption still occurs on-site.[27] However, distributed wind is not sent to substations for distribution to distant users. Distributed wind systems can range in size from a 10 kW turbine used on a farm to a larger-scale MW turbine used at a university.[28]

Small, Medium, and Large Wind Systems

According to NREL, wind turbines can be classified as small, medium, and large. Small turbines are those up to 100 kW, while mid-size turbines are those that range from 101 kW to 1 MW. Any turbine over 1 MW is considered a large turbine.[29]

Costs for wind-generated energy will continue to fall as technology develops and global investments increase. Most studies estimate a 20 percent to 30 percent decrease in onshore wind's LCOE between 2010 and 2030.[32] Indeed, this trend is already apparent: wind power costs fell by more than one-third between 2008 and 2015.[33] As a result of increased design and production scale, improved operations, and growing global investment, the cost of onshore wind power has dipped to $0.05 per kWh.[34]

Photo Credit. U.S. Department of Energy

(Left) Transporting a wind turbine blade, Photo Credit. Evert Kuiken / Foter / CC BY-ND. (Right) Tripile offshore wind turbine foundations, Photo Credit. U.S. Department of Energy

Colorado's Wind Employment Potential

As demand for wind energy skyrockets, Colorado has the opportunity to expand the wind economy, increase in-state spending, and employ an average of over 5,300 Coloradans annually over the next fifteen years. If optimistic projections prove to be correct and Colorado's wind companies are able to fill a larger share of their supply chain needs with in-state purchases, over 79,000 direct, indirect, and induced job-years would be supported. While over 16,000 of those would be direct job-years in the state's wind industry, over 63,000 indirect and induced job-years could be supported if wind companies were able to procure more of their supplies from in-state companies.

These projections for job-years potential in Colorado's wind industry are based on tools and analysis by the Energy Information Administration (EIA), the National Renewable Energy Laboratory (NREL), and Bloomberg New Energy Finance (BNEF). Additionally, the Jobs and Economic Development Impacts (JEDI) tool was utilized to estimate job-years at different levels of local supply chain concentration for wind.

To highlight why clustering supply chain businesses in Colorado is so important, we have estimated the number of direct, indirect, and induced jobs based on future demand and the percentage of supply chain purchases made within the state. Figure 7 shows how the number of wind job-years vary as the local share changes. The figure shows the number of direct, indirect, and induced jobs based on local share percentages of 25 percent, 50 percent, and 75 percent. This range was chosen to represent reasonable goals for average local purchases, as 0 percent and 100 percent both represent extremes of purchasing behavior that we do not believe are realistic.

Since projections often vary, we analyzed how those supply chain differences affect three reputable estimates of future demand for wind energy: NREL's Renewable Energy Futures Incremental Technology Improvement as a high-demand scenario, EIA's Annual Energy Outlook 2015 Clean Power Plan's Base Policy analysis as a moderate-demand scenario, and BNEF's forecast as the low-demand scenario. Figure 7 presents estimates for wind construction, operations, and maintenance jobs.

In all of the demand scenarios, increasing the percentage of local spending by Colorado's wind companies creates thousands of job-years. For example, in the high-demand scenario, increasing in-state supply chain purchases from 25 percent to 75 percent would support over 39,000 direct, indirect, and induced job-

What is a Job-Year?

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

Why Use Job-Years?

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

Direct, Indirect, and Induced Job-Years

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

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

Local Share

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

years. Even in the low-demand scenarios, an increase of in-state supply chain purchases for wind companies from 25 percent to 75 percent would support over 5,000 job-years.

If a concerted effort were made by the state to fill in the supply chain and strengthen the wind cluster, Colorado companies could meet the expected demand for wind, supporting up to 79,000 job-years. Increasing the number of supply chain businesses can create thousands of good-paying, skilled jobs and maintain Colorado as a leader in the wind industry.

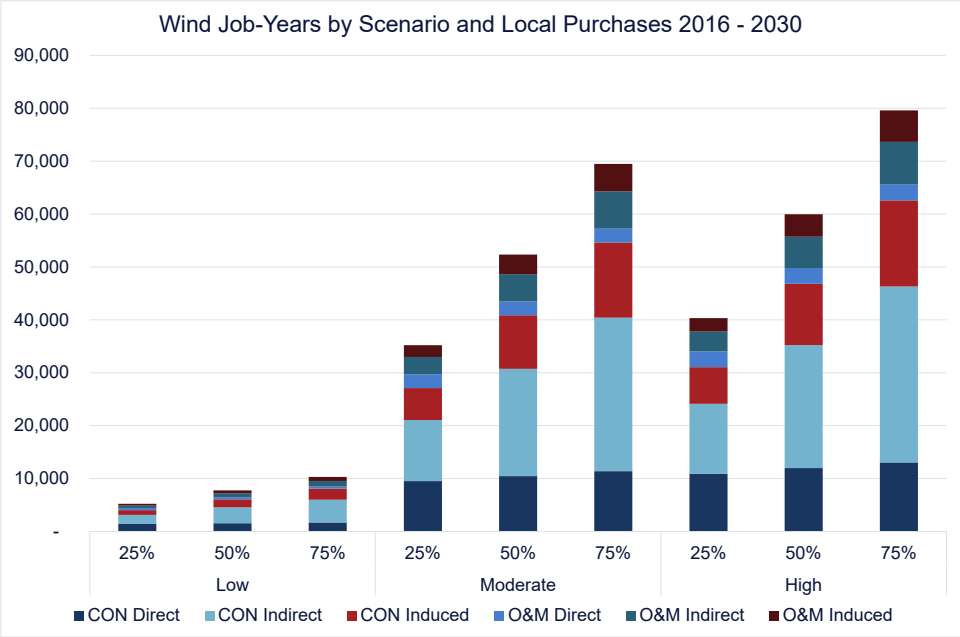
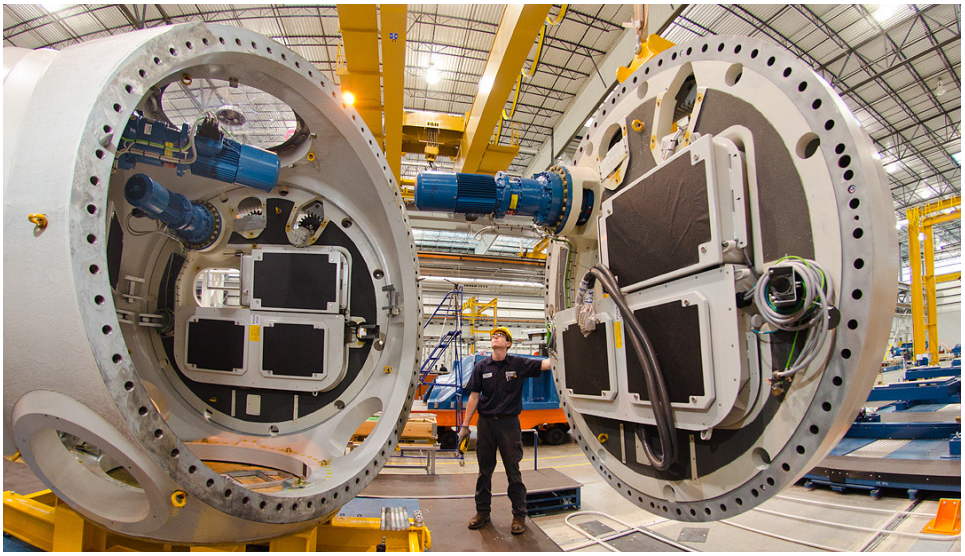


Figure 7. Increasing local spending will increase job-years for Coloradans.



Manufacturing a wind turbine
Photo Credit. U.S. Department of Energy

Colorado's Wind Industry: A Strong Foundation for Growth

Strengths

Colorado is home to nineteen wind manufacturing facilities, which amount to 1.4 percent of total U.S. manufacturing capacity.[35,36] The state's largest manufacturer, Vestas, employs 1,000 Coloradans.[37] The company has multiple Colorado locations, including a blade manufacturing facility in Windsor, a nacelle assembly plant in Brighton, and a tower facility in Pueblo.[38] Vestas has invested more than $700 million in Colorado manufacturing facilities and is the only in-state company solely dedicated to wind.[39,40] The Danish company has the largest global market share of wind production and the second largest share of U.S. wind production.[41]

Other contributors to the Colorado wind energy manufacturing supply chain include O'Neal Flat Rolled Metals' headquarters in Brighton and O'Neal Manufacturing Services in Pueblo.[42] Both companies contribute to Colorado's tower manufacturing industry.

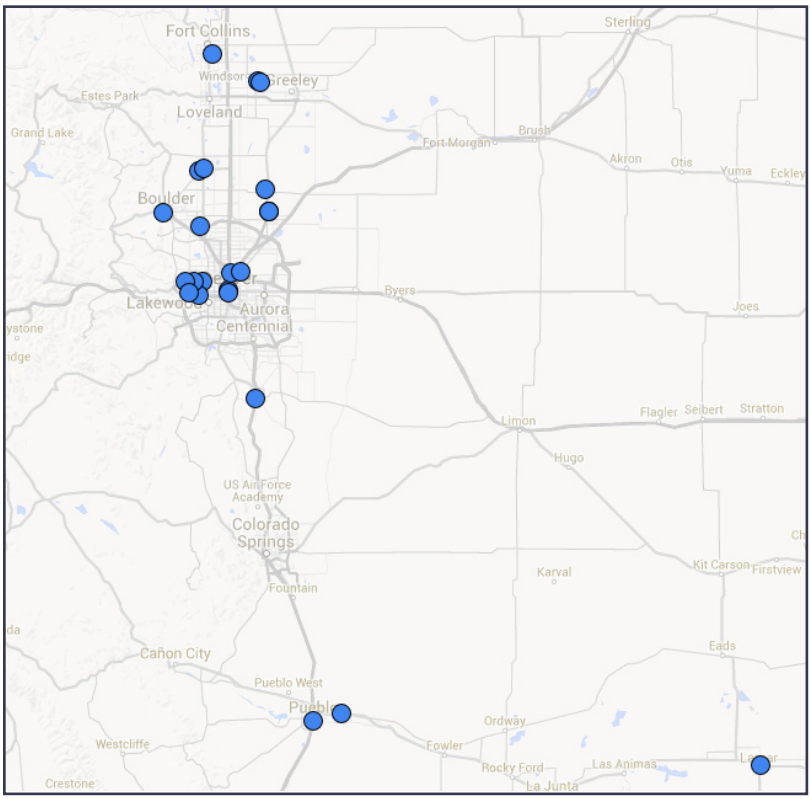
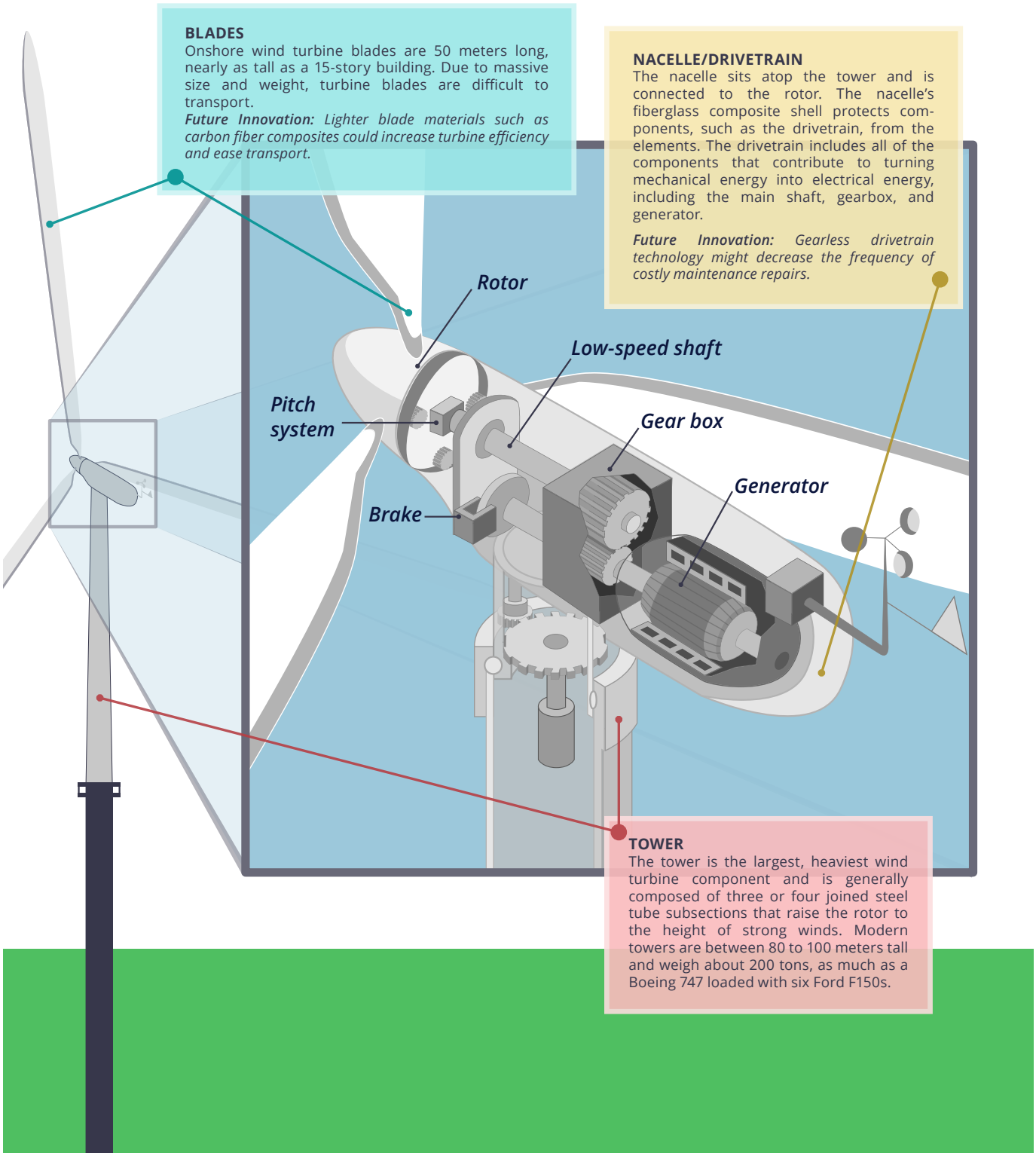


Figure 8. Wind Supply Chain Companies in Colorado

Anatomy of a Wind Turbine



Colorado has public and private wind research facilities that bolster the state's supply chain. The National Renewable Energy Laboratory (NREL) in Golden houses the National Wind Technology Center, which tests new wind energy technologies and grid interconnection systems.[43] Siemens' wind turbine R&D center in Boulder researches aerodynamics and blade efficiency.[44]

Table 2. Companies in Colorado's Wind Supply Chain

TYPE OF FACILITY	NUMBER OF COMPANIES	DETAILS
Manufacturing		
Drivetrain/Nacelle	3	Main Shaft, Gearbox, Generator, Nacelle Assembly
Rotor	2	Blades, Pitch System, Spinner
Tower	2	Tower and Supporting Components
Structural	3	Main Structural Frames, Fasteners
Electrical	6	Power Inverter, Logic Boards, Control Systems
Materials	2	Composite Material, Steel Foundries
Power Transmission	1	Equipment to Connect Wind Farm to Grid
Services		
R&D	3	Research Facilities
Distributed Wind Turbines	2	Small Wind Turbines and Supporting Components
Total Companies	**79**	**Key:** Strength and Opportunities*

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

(Source: Internal analysis of American Wind Energy Association and Great Lakes Wind Network databases)

Opportunities for Growth

Although Colorado has a robust wind energy supply chain, the state is well-positioned to further expand and strengthen the wind sector. For example, Colorado does not have a strong small wind turbine manufacturing presence: AnemErgonics and Primus Windpower are the only two companies currently operating in the state.[45,46] AnemErgonics manufactures foundations and towers for small wind systems, while Primus Windpower provides complete wind energy systems.[47,48] Expanding the small wind sector could increase the number of jobs in wind turbine manufacturing and installation in the state.

Policy Recommendations

Colorado could leverage its existing wind sector by focusing on innovative policies that remove obstacles and boost demand within the state. Expanding the in-state market will attract private investment, strengthen the economy, and create new value chains, which will subsequently stimulate and accelerate new export markets, including small-scale wind.

Policy 1: Encourage Small Wind Turbine Manufacturing and Deployment

Small and medium-sized firms in the United States typically manufacture small- to medium-sized wind turbines. Although the domestic market for small, distributed wind systems has stagnated in recent years, the growing international market is an opportunity for U.S. manufacturers.[49] Of the 3.7 MW of small wind turbines sold in the United States in 2014, 82 percent came from domestic suppliers.[50] Small to medium-sized wind turbine manufacturers in the United States have exported products to more than 130 countries, with exports accounting for up to 80 percent of total sales in recent years.[51] Worldwide installations of small wind turbines are predicted to reach almost 3 GW by 2020.[52] The technical potential for U.S. distributed wind capacity is 1,100 GW by 2030,[53] representing an untapped domestic resource.

While Colorado currently ranks eighth in the country for distributed wind capacity,[54] the state could increase production of small wind turbines to help meet increasing national and global demand.[55] Colorado could bolster existing policies, such as the distributed generation carve-out,[56] to stimulate the in-state market for small, distributed wind. Firms such as United Wind have begun offering distributed wind leases in the state, representing an opportunity for distributed wind growth in Colorado.[57] Colorado could also meet international demand for smaller turbines by encouraging exports.

Benefits of Distributed Generation

Distributed renewable electricity generation has several benefits: it can increase in-state renewable energy demand, improve grid reliability, and diversify the local energy supply.[58] Distributed generation sources can include solar, small-scale wind turbines, and biomass.[59] Schools, farms, data centers, and manufacturing facilities can all benefit from locally produced energy and distributed generation systems.

Institute a Small Wind Tax Credit

To encourage Coloradans to install distributed wind systems, the state could implement a small wind tax credit, modeled after North Carolina's solar and wind tax credit. North Carolina provides a personal and corporate tax credit of up to $10,500 per installation to eligible taxpayers.[60] Installations must not be used for the purpose of selling electricity, and allowable credit must not exceed 50 percent of an individual's tax liability.[61] A similar tax credit in Colorado would reduce upfront costs of installation and encourage widespread adoption of distributed wind systems.

Expand the Solar Garden Act to Include Small Wind Turbines

Colorado's Community Solar Garden Act requires investor-owned utilities to purchase a minimum quantity of electricity from community solar gardens.[62] However, this legislation excludes other forms of shared, locally produced energy that can facilitate access to clean energy for Coloradans. Rural landowners and farmers can especially benefit from community wind projects, and states such as Iowa, Illinois, and Oregon have had success with community wind projects.[63] Colorado policymakers should consider expanding the Community Solar Garden Act to include small wind turbines to encourage adoption of community wind, thus providing economic benefits to rural Coloradans.

Benefits of Community Wind[64]

- Community wind provides more employment than conventional wind projects.
- Community wind projects do not need additional transmission lines and can be connected to the grid.
- Community wind allows for increased local control.

Create an Export Tax Credit for Small and Medium-Sized Qualified Industries

Colorado currently encourages exports through incentives, such as the Colorado Export Grant, which subsidizes international business development costs.[65] With increased demand for wind-generated energy in the United States and abroad, Colorado could encourage production of small-scale wind turbines by small and medium-sized businesses. Indeed, small wind turbine production is dominated by small businesses: 95 percent of U.S. small-scale wind turbines were manufactured by small businesses in 2009.[66] As the international market continues to grow, Colorado policymakers could encourage the production and export of small wind turbines by establishing an export tax credit for small and medium-sized businesses in Colorado's designated qualified industries, including advanced manufacturing, energy, and natural resources.[67] Coastal states, including Mississippi, have traditionally subsidized export costs to encourage economic development.[68] Colorado's tax credit could be similarly used to offset the costs of exporting to foreign markets. By encouraging small and medium-sized businesses in key industries, Colorado could increase local manufacturing and create good-paying jobs for residents.

Restore Funding for CSU's Anemometer Loan Program

If Colorado adopts polices to encourage deployment of small wind turbines, the state could amplify these efforts by providing Coloradans with access to needed tools and resources. The first step to installing a small wind turbine in a household, farm, school, or business is a wind resource assessment. Lack of access to assessment tools, like an anemometer to measure wind speed, can prevent residents and businesses from installing a small wind system.

Anemometer

An anemometer is a device used to measure wind speed.

Colorado State University's anemometer loan program was initiated by the Governor's Energy Office and U.S. Department of Energy's Wind Powering America Program. However, funding for the program has ceased.[69] To complement potential efforts to encourage adoption of small wind turbines, state policymakers could fund Colorado State University's anemometer loan program to provide interested Coloradans with the knowledge and tools needed to install a small wind turbine.

Policy 2: Create an Anchor Company Tax Credit

Colorado's wind manufacturing industry has a strong foundation that includes Vestas, the company with the largest global market share of wind production.[70] Despite this advantage, a wind turbine consists of up to 8,000 components,[71] which represents a significant hurdle in supply chain management. The state could partner with Vestas and other anchor companies to fill gaps in the wind supply chain through incentives such as the Anchor Company Tax Credit.

Rhode Island's Anchor Company Tax Credit

As the first state to develop an offshore wind pilot project, Rhode Island created an Anchor Institution Tax Credit to bolster the offshore wind industry. If a Rhode Island anchor company is responsible for a job-creating supplier locating in Rhode Island, the anchor company receives a tax credit.[72] For instance, if a wind developer lures a tower manufacturer, the wind developer will receive a tax credit.

To facilitate the growth of a robust supply chain and wind manufacturing center, Colorado leaders could establish a policy similar to Rhode Island's Anchor Institution Tax Credit. The credit could be extended to other industries in the state with complex supply chains, contingent on the number of jobs created for Coloradans. With its complex supply chain needs, incentives like the Anchor Company Tax Credit could boost the wind manufacturing industry, resulting in good-paying jobs for Coloradans.

Policy 3: Create a Consolidated Balancing Authority

Colorado's electricity market lacks a central balancing authority, such as a regional transmission organization (RTO) or independent system operator (ISO).[73] Colorado has two distinct balancing authorities—Western Area Power Administration Colorado-Missouri (WACM) and Public Service Company of Colorado (PSCo)—which forecast electricity needs and balance supply and demand of electricity on the grid.[74,75] Separate, uncoordinated efforts by WACM and PSCo represent a missed opportunity to pool resources and decrease costs.

After Minnesota combined separate balancing authorities into a single, central body, the need for balancing services were reduced up to 50 percent[76] due to reduced variability of power loads and increased pool of energy generation sources. A central balancing authority also decreases costs: an NREL study projects that the Western Electricity Coordinating Council will save a total of $2 billion as a result of balancing cooperation.[77]

In order for Colorado to use its renewable energy sources in an efficient and cost-effective manner, the Colorado State Legislature and PUC could establish a coordinated balancing authority. Policymakers could look to Texas's Electric Reliability Council of Texas (ERCOT) or interstate models such as the Midcontinent Independent System Operator (MISO) to create an effective balancing authority.

In 1996, ERCOT became the first ISO in the nation.[78] ERCOT's responsibilities include management of wholesale electricity prices, systems planning and operation, and facilitation of transmission access.[79] ERCOT operates as a membership-based 501(c)(4) nonprofit corporation, with oversight from both the Texas Legislature and PUC.[80] While ERCOT only serves the state of Texas, MISO oversees electric markets and transmission reliability in fifteen different states. MISO was federally approved as the nation's first RTO in 2001.[81]

The creation of a unified balancing authority not only decreases costs and market regulation requirements, but also allows for more efficient use of wind and solar energy, which typically peak at complementary times.[84] Colorado could create a unified balancing authority with a neighboring state such as Wyoming. A balancing authority between these states "would yield price stability benefits and emission reduction benefits midway between what wind resources from either state would provide individually."[85] Regardless of whether Colorado partners with nearby states, a balancing authority would decrease costs and

What are Regional Transmission Organizations and Independent System Operators?

Regional Transmission Organizations (RTOs) and Independent Systems Operators (ISOs) are third-party grid operators that plan for regional transmission infrastructure, coordinate regional electric reliability, ensure that supply meets energy demand, and manage real-time wholesale market prices. RTOs and ISOs manage more than two-thirds of the U.S. electricity load.[82] An RTO is required to have federal oversight and approval, while an ISO does not require federal approval.[83]

allow for more solar and wind-powered energy on the grid, potentially boosting in-state demand for wind manufacturing.

Policy 4: Modernize Transport Pathways to Improve Wind Turbine Export

Transporting wind turbines requires considerable planning and expense due to size and weight of components. Each blade can weigh approximately 77 tons per transportation unit and towers can be up to 410 feet tall.[86] Transportation and logistics can account for as much as $150,000 per turbine, or about 20 percent of total installed cost.[87] As a result of this high cost burden, wind turbine manufacturers must give serious consideration to transportation and logistics issues as facility locations are chosen.[88]

In order to attract turbine manufacturers, capitalize on the wind components export market, and help meet demand in neighboring states, Colorado should consider various ways to improve ground and inland water transportation pathways.

Upgrade Roadways

Nearly 40 percent of Colorado's highways and 17 percent of major roads are considered to be in poor condition and are anticipated to cost Colorado motorists $2 billion per year ($535 per motorist) annually in vehicle repair and operating costs.[89] The current state of Colorado's roads are not sufficient to accommodate cost-effective and continued movement of heavy components like wind turbine towers or blades. In order to prepare Colorado's highways and rural roads for wind turbine transportation, policymakers could allocate state Department of Transportation (DOT) funds for road upgrades. Additionally, the state could consider adopting Florida's model of transportation development, which encourages private-sector involvement and investment.

The Colorado Statewide Transportation Improvement Program (STIP) is the state's six-year transportation development plan, prepared by the Colorado Department of Transportation and various stakeholder groups.[90] This proposal could be revised to include an assessment of the economic benefits associated with road upgrades that would facilitate movement of large goods, such as wind turbine components. If the Colorado DOT determines that these investments provide sufficient returns to the state, a portion of DOT funds could be allocated to road upgrade projects.

Colorado leaders could also adopt and customize Florida's model, which encourages new private-sector development

through locally managed transportation improvements. Florida's Economic Development Transportation Fund, also known as the "Road Fund," provides funds to help solve transportation problems that hinder economic development. Grant funds are awarded to a local government on behalf of specific businesses that want to establish or expand a facility, but cannot locate due to inadequate local infrastructure.[91,92] Infrastructure upgrades that qualify include constructing access roads, installing signals, and widening roads.

Colorado leaders could encourage private road development by extending the sales and use tax exemptions for renewable energy to include materials used directly for the road upgrades necessary for wind energy production and transportation.[93] A dual public and private-sector approach to modernizing Colorado's roads will bolster the local wind power sector by mitigating transportation challenges associated with exporting to other states.

Encourage Rail Transport of Heavy Goods

Colorado has 2,688 miles of rail transport and 15 freight railroads.[94] Encouraging the use of Colorado's extensive railway system to transport heavy goods like wind turbine components would not only increase access to nearby markets, but decrease wear and tear on the state's highways. Colorado could encourage wind manufacturers to use the state's extensive rail system by instituting a rail usage tax credit, similar to Virginia's barge and rail usage tax credit.

Equivalent Lengths

Virginia's Barge and Rail Usage Tax Credit

To decrease movement of goods along highways and incentivize river and railway transport, Virginia offers a barge and rail tax credit. The credit can be claimed against a number of state taxes including individual income tax, corporate income tax, and tax on public service corporations. The tax credit equals $25 per 20-foot equivalent unit of shipping container.[95] This modest incentive encourages the use of alternative transport methods, such as railways and waterways.

Policy 5: Encourage Foreign Direct Investment

Colorado is a leader in wind turbine manufacturing and is strategically located in the West. Colorado could strengthen its supply chain and recruit more distributed turbine manufacturers in order to capitalize on growing wind power demand throughout the West. An influx of foreign wind manufacturers would not only add suppliers to Vestas' existing operations, but also grow the state's capacity to manufacture and export turbine components and ultimately create new jobs for Coloradans.

Table 3. Potential Foreign Direct Investors in Turbine Components

Turbine Component	FDI Target
Distributed Wind	Endurance Wind Power (China), Ghrepower (China), and Superwind (Germany)
Large-Scale Turbine Blades	DeWind (Germany), SGL (Germany), and LM Wind Power (Denmark)
Wind Towers	Marmen Inc. (Canada)
Wind Generators	Ingeteam (Spain)
Gearbox Repair	Mekanord (Denmark)

By recruiting these foreign companies, Colorado stands to attract foreign capital, expand the state's wind sector, and stimulate job growth.

Chapter Summary

With a robust wind industry and prime location for exporting, Colorado is poised to lead the nation in wind turbine manufacturing and wind energy generation. Given the rapidly increasing global demand for wind energy, Colorado leaders must act quickly. State policymakers could strategically recruit companies to fill gaps in the supply chain, create demand for small-scale wind turbines, upgrade the state's transportation networks to increase export volumes, and unite balancing authorities to plan for future energy needs. Implementing these recommendations would increase local generation of wind energy, strengthen Colorado's economy, and provide good-paying jobs for its citizens.

Chapter 4: Innovation Ecosystem and Access to Capital

In today's competitive, globalized economy, businesses are more likely to thrive in cities and states that offer a rich innovation ecosystem and break down barriers to capital. 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. State and local government institutions, as well as private entities, can take action and collaborate to maximize the impact of innovation, support new and expanding businesses, and create good-paying jobs in Colorado.

Innovation ecosystems promote R&D, bring new technologies to market, and incubate early-stage businesses. Allowing ideas to be easily transferred from the lab to the marketplace accelerates further entrepreneurship and job creation. Robust innovation ecosystems include efficient intellectual property protection mechanisms, mentoring for entrepreneurs, and engagement of business and venture capital.

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

Access to capital is critical for the success of advanced energy technologies. New and growing businesses face severe financial hurdles during technology development, commercialization, and expansion. Having access to investors and non-dilutive capital can be the difference between success and failure. In order to maximize the success of advanced energy businesses that create good-paying jobs, states should consider actively facilitating access to capital.

Seamless connections between researchers, entrepreneurs, investors, and non-dilutive capital are vital to the success of advanced energy technology businesses. The new energy economy is a race, and the winners will be capable of bringing innovative ideas to the marketplace quickly and efficiently.

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

Non-Dilutive Capital

Non-dilutive capital funding, such as grants and loans, does not affect ownership of a company. These funding sources may carry interest rates or have restrictions on how they are used, but will not affect the shares of the company.

Colorado's Innovation Ecosystem

Colorado fosters a strong culture of innovation. The U.S. Chamber of Commerce Foundation recently ranked Colorado fourth in the country for entrepreneurship and innovation, while Forbes ranked it the fifth-best state for business.[1,2] Additionally, the state ranked eighth on Bloomberg's Top 20 Most Innovative States List and fifth on the Kauffman Foundation's Entrepreneurial Index in 2014.[3] Business Insider recently named Colorado the fastest-growing state economy, with the state's GDP increasing by 3.8 percent in 2013.[4]

Colorado supports a robust innovation ecosystem through its prominent academic institutions. The state incentivizes cooperation and specialization among public research universities by promoting grant proposals that include collaboration among multiple institutions.[5] Despite Colorado's strengths, gaining the necessary capital for technologies to move out of the lab and into the market remains a significant barrier. Colorado leaders have an opportunity to overcome this hurdle by leveraging forward-thinking government initiatives, industrial partnerships, and university institutions.

Research Institutions and Initiatives

Colorado boasts a robust advanced energy innovation ecosystem. The state is home to several research institutions, including the University of Colorado at Denver and Boulder (CU-Denver, CU-Boulder), Colorado State University (CSU), and Colorado School of Mines (CSM). The state also houses the National Renewable Energy Laboratory (NREL), which is the only federal laboratory in the country dedicated to renewable energy and energy efficiency technology research.[6] Other prominent research centers in the state include the Colorado Energy Research Collaboratory,[7] the Rocky Mountain Institute,[8] the Colorado Cleantech Industry Association,[9] the Solar Technology Acceleration Center,[10] the National Institutes of Standards and Technology (NIST) Boulder Laboratories,[11] the National Center for Atmospheric Research (NCAR),[12] and the David Skaggs Research Center for the National Oceanic and Atmospheric Administration (NOAA).[13]

The CSU campus houses the Energy Institute, which includes the Center for the New Energy Economy. The university also partners with Front Range Community College to provide a small-scale power plant laboratory for training students and conducting research.[14] CSU also participates in EcoCAR 3, a national automotive engineering program sponsored by the Department of Energy and General Motors.[15] CU-Boulder is home to the Renewable and Sustainable Energy Institute, a joint venture

with NREL.[16] CSM boasts the Renewable Energy Materials Research Science and Engineering Center and the Colorado Energy Research Institute.[17,18] Additionally, CSM is part of a joint effort with ConocoPhillips that focuses on sustainable energy production and water resources.[19] CSU, CU-Boulder, and CSM have technology transfer offices, as do NREL, NOAA, NIST, and NCAR.[20]

NREL and the Electric Power Research Institute recently launched the Clean Energy Incubator Network, which is funded by the U.S. Department of Energy and aims to improve the performance of clean energy business incubators, connect industry partners, and advance technologies emerging from universities and federal laboratories.[21]

National Renewable Energy Laboratory

Based in Golden, Colorado, NREL is the country's primary research facility for renewable energy and energy efficiency. Cutting-edge wind and solar research occurs at the laboratory's National Center for Photovoltaics and the National Wind Technology Center. The laboratory employs 1,721 fulltime employees along with 678 visiting researchers, interns, and contractors. NREL is funded by Congress and receives approximately $360 million per year.[22]

Resources for Startups

Many startups struggle to acquire the necessary capital to bring their products to market. Colorado addresses this funding gap by supporting business incubator and accelerator services. Accelerators and incubators provide a variety of valuable resources for early-stage startups, including office and lab space, financial support, mentorship, and an innovative environment. Numerous accelerators and incubators are spread throughout the state, including Techstars (Boulder), Unreasonable Institute (Boulder), Telluride Venture Accelerator (Telluride/Mountain Village), Boomtown (Boulder), MergeLane (Boulder), Galvanize (Denver and Boulder), Colorado Springs Technology Incubator (Colorado Springs), Innovation Pavilion (Centennial), Business Incubator Center (Grand Junction), Innosphere (Fort Collins), and several others on university campuses.[23,24,25]

Incubators and Accelerators

An incubator is designed to provide support services to early-stage startups. Incubator assistance can include office space, professional networks, access to financing, and business skill training. Accelerators assist companies in the later stages of business development, usually addressing short-term needs.

FortZED is a net zero energy district that encompasses several blocks of downtown Fort Collins. Financed by a $6.3 million grant from the U.S. Department of Energy and $4.9 million in state and local support, FortZED unites civic leaders, engineers, scientists, businesses, and community members to work on advanced energy solutions, including financial and business models, efficient behaviors, energy efficiency and conservation, transportation fuels, renewable energy generation, energy management and storage, and smart grid technology.[26] FortZED was established in collaboration with the City of Fort Collins, the Colorado Clean Energy Cluster, and CSU.[27]

CSU recently opened the Powerhouse Energy Campus, a 100,000-square-foot, LEED Platinum-certified campus that combines the Engines and Energy Conversion Lab with four stories of office space, meeting rooms, and research labs for thirty-nine startup companies in an on-site incubator known as the Rocky Mountain Innosphere.[28]

Government Programs

Several existing state initiatives stimulate R&D efforts in Colorado's advanced energy economy. For example, the Job Growth Incentive Tax Credit Higher Education Partnership incentivizes businesses to create new jobs by partnering with in-state higher education institutions, junior colleges, and vocational schools. Businesses can tap into the academic knowledge, expert faculty skills, and specialized equipment and facilities at these educational institutions. Businesses that utilize the partnership to hire five or more full-time equivalent employees with a wage of at least the state average are eligible for a 50 percent tax credit on the FICA expenses associated with new hires.[29]

The state's R&D Increase Tax Credit is equal to 3 percent of a company's increase in research and experimental expenditures.[30] Qualified research must be technological in nature, useful for the development of new or improved products, and must utilize the process of experimentation.[31] These credits and other business incentives are available only in state-designated enterprise zones. In 2015, total statewide R&D investments increased by $35 million in these zones.[32]

Access to Capital

Access to capital is essential for entrepreneurs to grow their businesses, bring products to market, and create new jobs. Capital pricing can make the bottom-line difference in product affordability and market viability, yet businesses are unable to secure the necessary capital to survive the commercialization phase. As shown in Figure 9, companies nationwide face funding shortages during the prototyping and commercialization phases, commonly known as the "valleys of death." In 2014, approximately 75 percent of all venture capital funding went to companies in California, New York, and Massachusetts; businesses in the other forty-seven states had to compete over the remaining 25 percent, stifling innovation across the country and emphasizing the importance of state policies for new venture capital investments.[33] Colorado has a strong history of prioritizing early investment to help new companies survive the double "valleys of death" and bring innovative technologies to market.

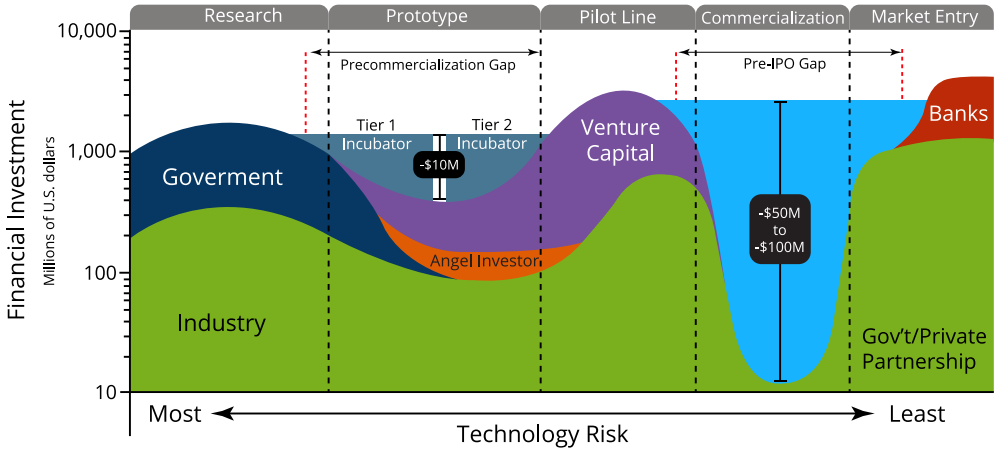


Figure 9. New technologies need help crossing the second "valley of death" during the commercialization process (Source: U.S. Department of Energy)

Venture Capital

Since 2013, Colorado has ranked seventh in the nation in terms of venture capital investments, with more than $2.07 billion invested in a total of 265 deals.[34] In 2015, Colorado ranked eighth in total venture capital investments, showing a slight decline in total investments.[35] From 2013 to 2015, venture capital investments in the United States totaled approximately $140 billion across more than 13,000 deals, meaning Colorado accounted for 2 percent of all deals and 1.48 percent of total investment.[36]

Colorado boasts several venture capital (VC) firms, including angel investor networks and individual firms. The Colorado Office of Economic Development and International Trade (OEDIT) currently lists thirty-nine active VC firms in the state.[37] The Colorado OEDIT also manages a Funding and Incentives Wizard on its website, which helps organizations find various funding and incentive opportunities in the state.[38]

Established in 2004, the Venture Capital Authority (VCA) makes seed and early-stage investments in Colorado businesses.[39] The VCA was allocated $50 million in premium tax credits, which it subsequently sold to insurance companies. The VCA selected High Country Venture, LLC, an independently operated fund manager, to make funding decisions. State involvement in funding decisions is limited. Additionally, the VCA established Colorado Fund I and Colorado Fund II, each with approximately $25 million in initial funding. Investments typically range from $250,000 to $3.38 million.[40]

Non-Dilutive Capital

As a result of recent support from Colorado policymakers, entrepreneurs have access to several grant and loan programs, including the Advanced Industry Grant Program (AIGP) and Advanced Industries Export Acceleration Program (AIEAP). AIGP is funded with an annual appropriation of $5.5 million.[41] The Colorado Economic Development Commission distributes the funds to in-state laboratories and companies through a variety of grants.[42]

AIGP manages several grant programs, including Proof-of-Concept, Early-Stage Capital and Retention, and Infrastructure Funding.[43] Proof-of-Concept Grants are awarded to technology transfer offices to develop theoretical technologies into tangible prototypes. To be eligible to receive AIGP's Proof-of-Concept Grant, a university's technology transfer office must demonstrate the estimated economic impact of the technology and prove that the project has funding from its affiliated research institution equal to at least one-third of the requested grant.[44] Proof-of-Concept Grants can total up to $150,000.[45] To date, the AIGP has awarded twenty-one Proof-of-Concept Grants worth $1.5 million to Colorado's public research institutions.[46] Approximately one-third of the awarded funding has been matched dollar-for-dollar by private and institutional research dollars.[47]

Early-Stage Capital and Retention Grants are awarded to accelerate the commercialization of advanced manufacturing products.[48] Funding is granted to Colorado-based companies with 50 percent of their workforce located in-state and an annual revenue of less than $10 million.[49] Eligible companies must provide an analysis that demonstrates how their proposed project will enhance the commercialization of advanced industry products.[50] Additionally, companies must prove that they have funding equal to at least twice the grant amount.[51] The maximum individual award is $250,000.[52] To date, nineteen grants have been awarded, resulting in the commercialization of twelve patents.[53]

Infrastructure Funding Grants are awarded to advanced industry projects that utilize infrastructure to support the commercialization of advanced industry products.[54] To be eligible, a project must increase alignment between private companies and research institutions and have access to funding equal to at least twice the amount of the grant.[55,56] Projects focusing on manufacturing-oriented facilities are given priority.[57] A single project cannot receive more than $500,000 from an Infrastructure Funding Grant, except under exceptional circumstances.[58] To date, almost $1 million in grants have been awarded, but only $86,800 has been spent.[59]

The AIEAP provides support to Colorado-based companies exploring out-of-state markets for their products. Companies can apply for an AIEAP grant to reimburse 50 percent of the costs of airfare, lodging, participation fees for tradeshows and conferences, legal fees related to international business, and advertising in industry trade publications, provided that the total bill is $15,000 or less.[60] To qualify, a company must employ less than 200 workers with at least half of its workforce based in Colorado.[61]

Tax Incentives

Colorado provides a number of tax credits to incentivize businesses of all sizes at different stages. For example, the Job Growth Tax Incentive is available to businesses undertaking job creation projects. To be eligible, companies must create at least twenty new jobs in Colorado with an average annual wage equal to at least the county average where the business is located. Additionally, the Strategic Fund Incentive supports new business developments, expansions, and relocations that generate new jobs in Colorado. The Manufacturing Sales and Use Tax Exemption provides tax relief on purchases of capitalized equipment and machinery used for in-state production.[62] The Advanced Industry Investment Tax Credit helps small and early-stage companies attract investment by offering a 25 percent credit on the investment, up to $50,000. If the business is located in an economically distressed area, the credit increases to 30 percent.[63]

Policy Recommendations

Policy 1: Facilitate New Partnerships Within the Energy Innovation Ecosystem and Set Statewide Goals

Colorado's Energy Research Collaboratory is a shining example of cross-university collaboration. This presents a larger opportunity within the federal government's goal of doubling the country's current level of investment in advanced energy over the next five years.[64] The complex nature of the advanced energy space requires partnerships across sectors with specific goals and strategies to foster innovation and growth in the industry. Colorado could further leverage the Collaboratory by establishing statewide goals, including the advancement of shared policy objectives, the enhancement of visibility around energy innovation issues, and the coordination of resources. Colorado could look to Ohio's Federal Research Network as an example of a similar effort to strengthen the coordination between research institutions to attract research and development funding.

Ohio Federal Research Network

Recognizing the importance of coordination within and across sectors, the state of Ohio funded the Ohio Federal Research Network in July 2015. Wright State Applied Research Corp. will receive $20 million over the course of two years and Ohio State University will receive an additional $5 million to establish collaboration between the state's research universities, Wright-Patterson Air Force Base, NASA Glenn Research Center, and the private sector. Approximately half of this funding will be used to create a model of how the research network will run.[65]

The goal of the Ohio Federal Research Network is to bring in $300 million in new federal research contracts to Ohio-based companies in the next five years. It is estimated that this funding will result in 2,500 new jobs, $250 million in private sector investment, and the creation or expansion of 100 companies.[66]

Clear goals and strategic alignment between Colorado's leading research universities, private companies, nonprofits, and government entities could accelerate advanced energy sector growth and create good-paying jobs. Expanding these partnerships could attract more capital to the state, bring breakthrough research to market, and maintain Colorado's role as a key player in the advanced energy space. The Colorado Economic Development Commission could expand on the Collaboratory's success by investing in coordination and expansion efforts throughout the energy innovation ecosystem, which could attract more public and private research money and venture capital funding to the state. Proactively aligning efforts to broaden the Collaboratory's network and set clear statewide goals can help Colorado continue to thrive as an engine for innovation.

Policy 2: Create an Advanced Energy Equity Crowdfunding Hub

Compared to other top-tier states, Colorado has a relatively low rate of venture capital investments per capita.[67] The state currently spends about $150 per person on venture capital.[68] Although this is approximately equal to the national average, states such as Massachusetts and California are spending more than double that amount per capita. Colorado made eighty-six venture capital deals in 2014, almost half the national average of 164 deals and far below other top-performing states.[69]

Colorado Crowdfunding Act

The Colorado Crowdfunding Act was signed by Governor Hickenlooper on April 2015.[74] The law "authorize[s] on-line intermediaries to match a Colorado investor with a Colorado business that wishes to sell securities (an 'issuer') pursuant to a simplified regulatory regime."[75]

Crowdfunding Hubs

- Wisconsin offers a licensed crowdfunding hub called CraftFund where Wisconsin investors can browse specialized companies seeking investors.[76,77]
- USEED is a service that helps educational institutions of all sizes develop customized crowdfunding portals. USEED runs the day-to-day operations of the platform for any campus group—whether it is the advancement office, specific departments, or student groups.[78]
- PennState created a customized platform, PennState Crowdfunding, through USEED and piloted twelve projects.[79,80]

Equity crowdfunding is an innovative mechanism utilized to attract private funding for new companies. Over the past four years, twenty-five states and the District of Columbia have enacted intrastate securities exemptions that allow equity crowdfunding from non-accredited investors.[70] These exemptions align with updates to the federal exemption for equity crowdfunding under Title III of the JOBS Act.[71]

Online equity crowdfunding hubs allow entrepreneurs to advertise their business ideas and gather smaller investments from many investors.[72] By creating a single location for investors across the world to find new businesses, equity crowdfunding hubs can significantly increase a state's access to capital. Colorado already has equity crowdfunding-enabling legislation in the form of the Colorado Crowdfunding Act, and has created an equity crowdfunding hub for businesses in all industries.[73] However, to target growth in advanced energy startups and launch Colorado as a national leader in wind and solar energy, the state's leaders could consider creating an equity crowdfunding hub specific to advanced energy industries.

The Colorado Clean Energy Cluster[81] or one of the state's major universities could be allocated funds to coordinate an advanced energy equity crowdfunding hub for private investors and individuals. Colorado's leaders could also provide a matching grant to help secure funds through the online platform for activities in wind and solar research. This could ultimately open up a new pool of investors in local advanced energy startups and fuel economic growth in the state.

Chapter Summary

Colorado's leaders have demonstrated a strong commitment to the state's innovation ecosystem. The state provides significant support to emerging companies through its public university system, government programs, and partnerships with established innovative businesses. However, Colorado could do more to increase the availability of capital for startups and incentivize investments in local companies. Colorado's innovation ecosystem has the capacity to develop and retain firms that will create good-paying jobs for residents and establish the state as a pioneering hub for advanced energy technology solutions.

Chapter 5: Workforce Development

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

With high unemployment or underemployment rates across the country and firms unable to find workers with the right skills, prioritizing workforce development is essential for any emerging or established industry. In November 2015, Colorado's unemployment rate registered at 3.6 percent.[1] This is a significant improvement over 2010 numbers, which came in at 8.9 percent.[2] Despite this positive trend, reports suggest that unemployment statistics frequently overlook the significant number of Coloradans who are either underemployed or have abandoned the job search completely.

Many Colorado residents, regions, and businesses are still struggling to fully recover from the Great Recession. Indeed, current in-state workforce participation rates have dipped to 1978 numbers.[3] According to the *Denver Post,* if the percentage of the state population participating in the labor force today was similar to 2008 rates, there would be an additional 250,000 people in Colorado's workforce.[4] Additionally, wages for Colorado workers have stagnated. The Federal Reserve estimates that the real median income for Colorado households were $60,940 in 2014, which is 13 percent less than average household earnings in 2007 before the Great Recession.[5]

Coloradans have the opportunity to build entirely new careers within rapidly growing advanced energy industries, but they must be adequately prepared with the skills required for these jobs. Colorado is home to many advanced energy job training programs, some of which are considered models of success for other states. However, many training programs specific to the wind and solar sectors remain underutilized. This is particularly true for training programs that address the wind industry's primary area of need: wind technicians. In-state demand for wind technicians is extremely high, but there is currently a dearth of workers with the necessary skills and training. Meanwhile, the number of solar jobs in Colorado declined from 5,300 in 2010 to

3,600 in 2013. A primary cause of this decline was the uncertainty surrounding the future of solar policies in the state.[6]

To capitalize on opportunities in the advanced energy space, Colorado policymakers could take proactive steps to address skill gaps and structural challenges in the workforce. By stoking advanced energy clusters, the state could provide good-paying jobs for its labor force and encourage residents to pursue careers in their home state.

A thoughtful, sector-based workforce development approach should include industry best practices for recruiting, hiring, training, promotion, and compensation; education and training infrastructure (including community colleges, project-based learning experiences, and apprenticeship programs); and public policy, specifically rules, regulations, and funding streams related to workforce and education. Leaders in the state could focus efforts on those regions and populations still experiencing high unemployment.

Skills for Participating in the Wind Sector

Wind energy jobs are typically divided into three categories based on where they fall in the wind power production process: manufacturing, project development, and operations and maintenance.

In terms of wind manufacturing, associated jobs include machinists, computer-controlled machine tool operators, assemblers, welders, quality-control inspectors, and industrial production managers.[7] Many of these roles require general manufacturing skills that are often acquired in other industries and fine-tuned with on-the-job training.[8] However, a few skills are specific to wind turbine manufacturing, the most notable of which is submerged arc welding. The need for workers with this specialized welding skill in Colorado prompted a partnership between Vestas' manufacturing plant and Pueblo Community College. More than 1,000 Vestas employees have been trained at Pueblo Community College.[9]

Jobs in the project management and development category include land acquisition specialists, asset managers, and logisticians.[10] A majority of these positions require a bachelor's degree in business, economics, or engineering. As a result of the state's high rate of per capita degrees, Coloradans have been able to fill demand for wind energy project management positions.

Relevant training and academic programs at the university-level have also helped meet workforce demand in this area.

Operations and maintenance of wind turbines requires knowledge of safety climbing, electrical systems, and mechanical maintenance, which are the focus of Northeastern Junior College's wind technology program. To work on turbines, technicians must be able to install and measure electrical currents with various types of equipment, calibrate and physically align systems, operate a crane, upkeep mechanical parts with lubricants and filter changes, and know proper climb and rescue procedures. This category of wind energy jobs currently presents the best opportunity for workforce expansions in Colorado.

Skills for Participating in the Solar Industry

The solar industry includes scientists, engineers, and various workers in manufacturing, construction, and installation. Electricians, plumbers, and solar PV installers work in solar installation, which is the fastest-growing portion of the solar industry. Installers are often self-employed or employed by solar panel manufacturers or installation companies. Installers can take courses at trade schools, apprenticeship programs, or through PV module manufacturers to gain the necessary credentials.[11]

Engineers are in high demand within the solar power industry. A 2015 study showed that U.S. executives spend an average of 26 percent more time finding qualified engineers than skilled production workers.[12] The solar industry requires materials engineers, chemical engineers, electrical engineers, industrial engineers, mechanical engineers, computer software developers, and engineering technicians. Engineering positions in the solar industry require a minimum of a bachelor's degree in engineering. Further specialization in the form of a master's degree, doctorate, or professional engineering license is frequently required as well.[13]

Most solar manufacturing positions, including semiconductor processors, computer-controlled machine tool operators, electrical and electronic equipment assemblers, and industrial production managers require specific credentials and may include formal training programs or apprenticeships.[14]

Another field of solar work is solar power plant development and management. Typically, real estate brokers, atmospheric

scientists (including meteorologists), and environmental scientists, all play a role in this type of work.[15] Additionally, solar power plant development requires construction workers, civil engineers, welders, and structural iron and steel workers. Training and education for these positions can include anything from a master's degree for engineers to on-the-job training and formal apprenticeship programs for welders.

Solar power plant operations workers include power plant operators, pump operators, electricians, plumbers, pipefitters, steamfitters, electrical and electronics installers and repairers, and electrical engineers. Power plant workers typically require a combination of education, on-the-job training, and work experience.

Existing Training Opportunities

Currently, two of Colorado's community colleges and a few private institutions provide training for wind and solar technicians. In an effort to be responsive to changing job requirements, these training programs maintain a close working relationship with employers and industry experts.[16]

The Colorado Community College System (CCCS) offers wind technician programs at Northeastern Junior College in Sterling and Red Rocks College in Lakewood.[17] Private institutions, such as Ecotech and Redstone, offer similar wind-specific degree and certificate programs in Aurora and Broomfield.[18] Colorado Mountain College, Arapahoe Community College, and Red Rocks Community College offer solar energy training programs, as does the Independent Electrical Contractors Rocky Mountain.[19]

Additionally, the CCCS is in the process of launching various energy technician specialist programs. These programs will provide students with the necessary mechanical background to work in the energy industry. Although this Associate of Applied Science (AAS) degree will focus primarily on general skills, the programs will offer concentrations in solar PV, solar thermal, and wind energy technology.[20]

Benefits of Early College Programs

Early college programs are an innovative way to help increase the number of students who complete college or obtain a postsecondary credential. These programs show particular promise for STEM-related fields. Through strategic partnerships between high schools, community colleges, and four-year colleges or by integrating both curriculums and services in one campus as seen in the Colorado Early Colleges, students are able to earn a high school diploma and an associate or bachelor's degree concurrently.[27] Additionally, early college programs create a clear pathway and expectation for students to ascend into higher education. They are often supplemented with mentorship and advising programs that foster open dialogue and critical feedback throughout the duration of the program. Evaluations of early college programs in North Carolina found that participating students reported higher levels of academic engagement, were more likely to be on track to graduate high school, and less likely to be suspended than students in comparable schools.[28]

Policy Recommendations

More robust workforce development efforts will enable Coloradans to pursue careers in rapidly growing advanced energy sectors, which include employers such as Vestas, NextEra Energy, and SolarCity. Like Vestas' approach of investing in the local community and partnering to train residents of Pueblo,[21] existing workforce development programs in Colorado could be more optimally utilized by establishing direct relationships with the state's high schools[22] and military bases. High school students and former military personnel are prime candidates for good-paying careers in the wind and solar sectors.

Policy 1: Enhance Workforce Training Opportunities Through Dual Enrollment Programs

In most cases, a strong mechanical background is a prerequisite for success in wind and solar technician occupations. The current lack of training and certification programs in this specialty area is a major workforce development barrier in Colorado. To address this knowledge gap, Colorado could expand its innovative dual enrollment programs to target high-growth industries through technical certificates and apprenticeships.

Colorado leaders could facilitate regional partnerships between school districts, community colleges, and businesses to promote technical Science, Technology, Engineering, and Mathematics (STEM) education and work-based learning opportunities in its dual enrollment programs. High school students are able to concurrently take college-level courses towards a certificate or degree through the CCCS or the Colorado Early Colleges (CEC). These dual enrollment programs have been very successful in Colorado: 964 students received credentials through the CCCS in the 2013 school year and CEC Fort Collins was named the top Colorado high school in 2015.[23,24] To effectively expand these programs, state leaders could look to the nationally recognized Missouri Innovation Campus at the University of Central Missouri.[25,26]

Missouri Innovation Campus

The Missouri Innovation Campus program is a collaboration between the University of Central Missouri, Lee's Summit School District, and Metropolitan Community College. The program allows students in the greater Kansas City, Missouri area to graduate with a four-year degree shortly after completing high school and with minimal student debt. Degree programs offered include a bachelor's degree in systems engineering technology, drafting and design technology, and computer science.[29] The program is primarily funded through a state grant. Missouri has established the innovation campus grants at nine campuses with only $9 million in funding.[30] This has significantly expanded educational opportunities for students throughout the state. Foundations and local businesses have provided additional support in the form of paid internships for participating students.[31,32] Dozens of businesses are active partners in the program. These partnerships have been critical to the success of the program.[33]

In order to expand the state's workforce, Colorado leaders could establish industry-specific early college and dual enrollment programs that address existing skill gaps in the wind and solar sector. Establishing a targeted grant fund could strengthen the reach of these programs and facilitate valuable relationships between students and advanced energy employers.

Policy 2: Create and Improve Pathways for Veterans to Transition to Advanced Energy Jobs

The Census Bureau estimates the veteran population of Colorado accounts for 7.5 percent of the entire population.[34] In 2014, the unemployment rate was 5.9 percent for all veterans in Colorado,[35] which is more than the average unemployment rate for all Coloradans and the national average for veterans.[36]

The relatively high unemployment rate of Colorado veterans offers an opportunity to help this skilled population get back to work. Nationally, 42 percent of former military personnel engaged in medium-skill maintenance, machinery, and electrical technician work during their service.[37] This presents the state with a significant opportunity to tap into a well-trained and motivated sector of the workforce to contribute to the growth of advanced energy sectors.

As military personnel prepare to re-enter civilian life they normally take transition classes, sometimes called "helmets to hardhat"

classes. Partnerships between these transition programs and advanced energy training programs could result in transition classes that count toward a degree or apprenticeship in Colorado, helping veterans leverage their previous experience and re-enter the workforce. Additionally, solar and wind employers could host recruitment days on military bases to attract potential workers to the industry.

SunShot Initiative

President Obama recently launched a program in solar energy jobs for veterans called the SunShot Initiative. This program connects up to thirty military personnel at each base with accredited solar training institutions.[38]

New Jersey's upSKILL Initiative

Colorado could look to the New Jersey Institute of Technology's upSKILL initiative for a successful example of leveraging the veteran workforce.[39] Funded by the U.S. Department of Labor, this program provides free job search boot camps.[40] The initiative also offers free consulting services to determine the best technical degree or certification program for veterans based on past military duties. UpSKILL then connects veterans with employers based on their technical training and the company's needs.[41] Finally, this program does not require that participants use their G.I. Bill benefits, allowing veterans to save their funding for future education and workforce training opportunities.[42]

Colorado could further expand upon its Veterans Green Jobs program that mostly targets the energy efficiency sector.[43] The Veterans Green Jobs program could adopt the upSKILL model through partnerships with local workforce development boards, community colleges, and the Department of Military and Veterans Affairs. Local workforce boards and colleges could help build awareness of good-paying manufacturing and maintenance positions in the advanced energy industry, specifically within the growing solar and wind power supply chains. Workforce boards could help translate veterans' technical work to civilian practice and disseminate information regarding specific technical accreditation and up-and-coming advanced energy jobs. Additionally, Colorado could offer specialized college orientation for veterans to ensure they are aware of relevant credits and certifications they may have already achieved as a result of their prior military service.

Policy 3: Establish Incentives to Promote Apprenticeships in Advanced Energy Industries

In order to match Coloradans with jobs in the solar and wind power industries, workers must have the necessary skills. Creating more apprenticeship opportunities and certification programs tailored to the needs of employers in the region can provide workers with the necessary tools to be competitive in the job market. As of 2015, Colorado added another seven new apprenticeship programs to its existing 201 apprenticeship programs.[44] This trend indicates a potential opportunity to bolster workforce development in advanced energy sectors by incentivizing businesses to expand apprenticeship programs.

Apprenticeship Carolina™

South Carolina's Apprenticeship Carolina™ system offers a simple model for improving apprenticeship opportunities statewide. The state's successful system offers employers a modest $1,000 state tax credit per apprentice per year.[45] Additionally, the state engages businesses through training consultants, who work with employers to guide them through the process of establishing a qualifying apprenticeship program. The program has served over 14,000 apprentices and averages more than 120 new apprentices per month.[46] Registered apprenticeship programs have a significant return on investment: tax returns over the career of an apprentice amount to more than $27 per dollar invested and career earnings are on average $240,037 higher among program graduates compared to similar nonparticipants.[47]

Colorado's legislature could follow South Carolina's lead by providing financial incentives for apprenticeship programs and working directly with employers to tailor apprenticeship requirements, wages, and associated curricula with specific technical needs.[48] Colorado currently allows tax credits to be used by employers for apprenticeships in some designated enterprise zones, but there is no statewide tax credit available to businesses.[49]

Colorado could establish a link between apprenticeship opportunities and existing community college certifications and relevant early college programs. Additionally, the state could collaborate with unions, trade associations, and corporations to engage in outreach programs that target high schools and encourage students to take advantage of apprenticeship opportunities in advanced energy sectors.

Chapter Summary

Colorado has the potential to expand the solar and wind power sectors by leveraging the state's existing training programs and investing in targeted workforce development initiatives. Coordinated efforts at the state and local levels could spur significant growth in the state's advanced energy economy, attract good-paying jobs, and furnish the workforce with highly trained individuals.

Solar training
Photo Credit. pennstatenews / Foter / CC BY-NC-ND

Conclusion

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

Policy leadership in the advanced energy space can play an important role in promoting Colorado's advanced energy clusters and creating quality jobs for Coloradans. Advanced energy clusters focused on wind and solar offer great opportunities for the state to grow its economy, create jobs for the state's residents, and become a leader in the production and deployment of advanced energy technology.

If Colorado's policymakers take swift and purposeful action to grow the wind and solar clusters, these industries can support up to 13,000 jobs annually through 2030.

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

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

Appendix

Economic Impact Methodology

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

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

The solar jobs analysis used the Job and Economic Development Impacts (JEDI) model and evaluated growth estimates across different levels of local share spending for scenarios from the EIA's Annual Energy Outlook 2015 Clean Power Plan Analysis, EERE's Wind Vision, and Bloomberg New Energy Finance. Wind jobs analysis also used JEDI and estimates from Bloomberg New Energy Finance, EIA's Annual Energy Outlook 2015 Clean Power Plan Analysis and NREL's Renewable Electricity Futures.

Tools for Economic Impact Analysis

A number of modeling tools are available for estimating economic impacts from advanced energy industry growth. This report employs two of the most common tools available for advanced energy: Jobs and Economic Development Impact (JEDI) and IMpacts for PLANning (IMPLAN). Results from the JEDI model only show job gains and do not evaluate losses in other industries. They are based on approximations of industrial input-output relationships, and do not include intangible effects.[1] The JEDI model is widely used because it estimates the economic impacts of construction and other project elements at the local (usually state) levels.[2] IMPLAN estimates the economic impact of each dollar invested into a sector and the resulting ripple, or multiplier, effects across the economy.[3] Multipliers are used to generate the economic impacts of the project across three different categories of jobs: direct, indirect, and induced.[4]

It is important to note the limitations of these modeling methods. As mentioned, the estimates shown are only gross job-year creation. Job losses in industries that compete with those in our analysis are not evaluated. Models do not dictate behavior, so indirect and induced jobs estimates could vary greatly based

on the reality of what is actually purchased locally. Also, foreign and domestic competition can play a significant role in limiting the potential for job creation. The estimates presented in this report are highly dependent on sustained local action towards developing and maintaining these industries.

Estimates Used in the Colorado Report

Solar Industry

JEDI was used to estimate jobs potential for the solar industry in Colorado. We show the jobs potential from several scenarios based on different percentages of local share, (i.e., how much of the total industry supply chain and service expenditures could happen in the state to serve local and national demand). In the report, we show a range of 25 percent to 75 percent of local share at 25 percent increments—0 percent would represent an unlikely situation where no products or services are purchased in the state and 100 percent would represent an equally unlikely scenario in which all products and services are provided by a perfect in-state supply chain. The true potential likely lies somewhere in between, but is dependent on the options and incentives for purchasing local goods and hiring local firms to provide services. In cases where there were only regional estimates, we assume that Colorado would maintain its current weighted average of solar capacity in the region over time. Where detailed information was not available for rooftop solar, estimates are based on "Tracking the Sun" weighted average distribution for residential, small commercial, and large commercial buildings.[5] This was also used for average capital costs per MW for analyses in JEDI. Job-years included in this analysis represent all job-years that exist during the timeframe of 2016–2030.

Data used in the JEDI analysis were collected from the three sources listed below.

DOE Office of Energy Efficiency and Renewable Energy: Wind Vision

The Wind Vision Study Scenario includes projections for utility-scale solar PV and rooftop solar PV deployment.[6] The input parameters are similar to those found in the DOE's 2012 SunShot Vision Study, a comprehensive review of U.S. solar electricity generation potential that was managed by NREL.[7,8] The Wind Vision projections are based on updated assumptions about the phasing out of the solar investment tax credit.[9] Wind Vision's cost assumptions are based on SunShot Vision Study's 62.5 percent solar cost reduction scenario, where the 62.5 percent reduction is reached in 2020 and a 75 percent reduction is reached in 2040.[10]

Wind Vision's authors compared those cost estimates to a sample of leading costs projections and found them to be consistent with the average estimates in the literature.[11]

Energy Information Administration: Annual Energy Outlook 2015 Clean Power Plan

> This report considers the proposed Clean Power Plan as modeled using EIA's National Energy Modeling System (NEMS). NEMS is a modular economic modeling system used by EIA to develop long-term projections of the U.S. energy sector, currently through the year 2040.[12]
>
> The level of regional disaggregation in NEMS varies across sectors. For example, Lower 48 states electricity markets are represented using 22 regions, coal production is represented by 14 regions, and oil and natural gas production is represented in 9 regions. In many but not all cases, regional boundaries follow state borders. To the extent possible, this analysis represents the Clean Power Plan using regional targets derived from the state-level targets in the EPA's proposal.
>
> The Reference case projections developed in NEMS and published in the Annual Energy Outlook 2015 generally reflect federal laws and regulations and state renewable portfolio standards (RPS) in effect at the time of the projection. The Reference case does not assume the extension of laws with sunset provisions. In keeping with the requirement that EIA remain policy-neutral, the Reference case does not include proposed regulations such as the Clean Power Plan.
>
> By explicitly modeling the intensity targets, NEMS does not require or assume specific levels for individual compliance strategies. The discussion of EIA's analysis presents results in terms of the compliance options used to meet the regionalized Clean Power Plan targets.[13]

We used the Base Policy Scenario for this analysis.

Bloomberg New Energy Finance

Data from the "Medium-term outlook for US power: 2015 = deepest de-carbonization ever" report were provided by Bloomberg New Energy Finance (BNEF).[14] The projections build off an empirical process of research, based on market projections, EIA information, and interviews with industry stakeholders. These projections are updated and published annually, though the back-end data is private and cannot be shared except by permission. BNEF graciously provided the data to us on the condition that

we would not publish it and only use it for our economic impact analyses. This in no way implies an endorsement of our project or our projections by BNEF.

Wind Industry

JEDI was used to estimate jobs potential for the wind industry in Colorado. We show the jobs potential from several scenarios based on different percentages of local share, (i.e., how much of the total industry supply chain and expenditures could occur in the state to service local and national demand). In the report, we show a range of 25 percent to 75 percent of local share. Job-years included in this analysis represent all job-years that could exist during the timeframe of 2016–2030.

Data used in the JEDI analysis were collected from the three sources listed below.

National Renewable Energy Laboratory: Renewable Electricity Futures

NREL's Renewable Electricity Futures study examines the extent to which renewable energy supply can meet U.S. electricity demands over the next several decades.[15]

> The study explores electricity grid integration using models with unprecedented geographic and time resolution for the contiguous United States to assess whether the U.S. power system can supply electricity to meet customer demand on an hourly basis with high levels of renewable electricity, including variable wind and solar generation.[16]

The study explores very high renewable electricity generation levels between 30 percent and 90 percent of all U.S. generation in 2050, with a particular focus on 80 percent.[17] The Incremental Technology Improvement scenario was used for our projections.

Bloomberg New Energy Finance

Previously discussed.

Energy Information Administration: Annual Energy Outlook 2015 Clean Power Plan

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