

The Wyoming Jobs Project: A Guide to Creating Jobs in Carbon Tech

A Letter from the American Jobs Project

It is no secret that America's middle class is in crisis; of the millions of jobs lost during the recession, most were good-paying, middle-class jobs.¹ Unfortunately, many of the jobs created during the recovery have been in low-skill, low-paying occupations.² It is true that the United States is unlikely to attract the traditional manufacturing jobs of the past, but our research shows that with innovative policies and a smart focus on industrial sectors, states can become global hubs of innovation and create new jobs in advanced industries that capitalize on each state's strengths.

Our analysis starts with identifying the biggest market opportunity of our era. The world has embarked on a historic energy transformation, and the growing demand for advanced energy and related technology draws on "the mother of all markets" for U.S. businesses to build and sell those solutions.³ Strategically minded businesspeople are taking advantage of this accelerating market and seeing outsized returns. In 2016, the private sector reported \$1.4 trillion in global advanced energy revenues, which is equal to that of the global apparel industry and nearly twice as much as the global airline industry.⁴ And jobs? At least 9.8 million people were employed in the global advanced energy industry in 2016, and market growth could support over 14 million additional jobs by 2030.⁵ The question for the United States is: Where will those new jobs be created?

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At least 9.8 million people were employed in the global advanced energy industry in 2016, and market growth could support 14 million jobs by 2030.⁶

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We believe that our states are the answer to this question. If countries across the globe are seeking solutions for growing energy needs, how can U.S. businesses take advantage of this demand and build products locally that can be exported to the world? And how can we equip Americans with the skills those businesses need?

The American Jobs Project gives policymakers tools to spur economic growth and create good-paying jobs in their states. Our analyses chart pathways designed to accelerate and expand a state's advanced energy economy. We propose innovative solutions built on extensive research and tailored to each state. These solutions are written with a focus on streamlining bureaucracy and are seasoned with the principles of competition, local control, and fewer regulations.

The American Jobs Project empowers state and local leaders to build prosperous and equitable advanced energy economies that will transform our nation's energy future. If these recommendations are adopted, hard-working Americans will be among the first to benefit.

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About Us

The American Jobs Project

The American Jobs Project is a nonprofit, nonpartisan, think-and-do tank focused on creating good-paying jobs in advanced energy and manufacturing through bottom-up, data-driven, 360° economic development. All sources, technologies, products, and services that help meet the need for energy efficiency, reduced carbon emissions, and affordable, secure, and clean energy are advanced energy. Our experts tailor best practice strategies for bolstering advanced energy and manufacturing, identify assets across the value chain, estimate an industry's job-supporting potential, and support stakeholder-led initiatives by communicating ideas and analyses. Through engagement with a broad cross-section of stakeholders, we develop a shared vision of effective strategies to leverage the unique competitive advantages offered by each state and generate positive economic impacts.

University of Wyoming College of Business

The College of Business at the University of Wyoming strives to ensure that our students have practical skills that can be put to good use in the business world. We equip students with the necessary tools so that they can be immediate contributors to the organizations they join upon graduation. While a large part of that process involves classroom learning, we strive to provide our students additional experiential learning opportunities in many different areas to round out their academic careers. Our process takes students from “backpacks to briefcases,” beginning with resume workshops and elevator pitches, leading to career fairs and final interviews.

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Executive Summary

Wyoming's carbon tech industry is a significant economic opportunity for job growth, having the potential to support an annual average of 2,600 jobs through 2035, representing over 25 percent of the state's current manufacturing workforce.⁷ Carbon tech refers to a wide range of high-value products and chemical feedstocks produced from coal and captured carbon dioxide, including carbon fiber, concrete, graphene, cement, plastics, and carbon foam. Wyoming can capitalize on this opportunity by bolstering its innovation ecosystem, access to capital, workforce development, value chain, and local market.

Wyoming has been the country's top net energy supplier for over two decades and is home to approximately one-third of the coal reserves in the United States.⁸ Despite these abundant natural resources, Wyoming faces an urgent need to diversify its economy as the demand for coal decreases and its residents seek opportunities in neighboring states. With an economic development strategy that equips its residents with critical workforce-ready skills while prioritizing industries that have long-term economic potential, Wyoming can catalyze local economic growth to create good-paying job opportunities while maintaining its unique character and strong traditions.

Extensive research and over 40 interviews with stakeholders and experts in Wyoming have identified the carbon tech industry as a promising job creator and economic driver in the state. The global market for carbon tech products is in the billions and is expected to continue to grow substantially over the next decade. Wyoming is well positioned to tap into market growth in this industry due to its vast coal and carbon resources, extraordinary R&D assets, favorable tax environment, high quality of life, and commitment to economic diversification.

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Carbon tech includes a wide range of high-value products and chemicals that can be produced from coal and captured carbon dioxide, such as carbon fiber, concrete, graphene, cement, plastics, and carbon foam. Some of these products can be used to produce consumer goods including car parts, building insulation, plastic containers, batteries, and sporting equipment.

END CALL OUT BOX

Through the carbon tech industry, Wyoming can leverage its numerous strengths to take advantage of expanding opportunities, such as:

- **High demand for carbon tech.** The U.S. market for carbon tech products totaled nearly \$3 billion in recent years.⁹
- **Innovative research and development investments.** Wyoming's visionary public and private investments in cutting-edge R&D centers give it a key competitive advantage to study, test, and prototype the next generation of carbon tech products and processes.
- **Vast supply of key raw materials.** The state has enormous natural resource deposits and is a world leader in producing the building blocks of the carbon tech industry.
- **High quality of life.** Wyoming residents enjoy incredible outdoor recreation opportunities, a favorable business climate, and high-quality educational resources—all powerful tools to recruit top talent.

- **Strong support for a diverse economy.** State leaders are committed to diversifying Wyoming's economy by providing funding, proposing legislation, and crafting solutions to help it grow while maintaining its unique character.
- **Policy tailwind.** Recently passed state and federal incentives encourage carbon capture and utilization, creating lucrative new market opportunities.
- **Win-win chance to grow other local industries.** Two of the largest potential downstream users of Wyoming carbon tech products are Wyoming wind and transmission line developers, providing an opportunity to supply these in-state businesses.
- **Opportunity to support critically needed job growth.** With forward-thinking solutions, carbon tech could support an average of 2,600 Wyoming jobs annually through 2035, representing over 25 percent of the state's current manufacturing workforce.¹⁰

To realize these opportunities, state and local leaders can pursue strategies that create a strong foundation for industry growth in carbon tech and help Wyoming businesses grow, innovate, and outperform regional, national, and global competitors. In today's competitive, globalized economy, businesses are more likely to thrive in cities and states that offer a rich innovation ecosystem, provide fertile ground for capital investment, boast a highly skilled workforce, maintain a robust value chain, and offer clear policy signals.¹¹ By having a close network of partners and suppliers, Wyoming companies can reap the benefits of increased productivity and operational efficiency, amplifying local job creation and economic growth. Creating a prosperous industry cluster will also require a tax structure that empowers Wyoming to provide key infrastructure such as roads, water and wastewater, airports, and schools. State leaders will need to determine how to fund the critical infrastructure its new and growing businesses and workers will require.

Capitalizing on this opportunity offers real benefits for the state economy and Wyoming residents. Annually through 2035, carbon tech can support an average of 2,600 direct jobs from manufacturing, indirect jobs from suppliers, and induced jobs from spending in the local economy, representing over 25 percent of the state's current manufacturing workforce.¹² This industry offers a diverse array of good-paying jobs that cater to various education and experience levels, including chemical engineers, computer-controlled machine tool operators, material scientists, and mechanics. Policymakers can support these jobs by taking advantage of increasing global demand and overcoming barriers to industry growth.

Summary of Recommendations

The analysis presented in this report culminates in recommendations for Wyoming's leaders based on best practices in the United States and abroad. Each recommendation identifies strategies to address barriers to industry growth or capitalize on untapped opportunities in the carbon tech industry. Specifically, Wyoming could target challenges in each foundational building block: the innovation ecosystem, access to capital, workforce development, value chain build-out, and local market growth for carbon tech. While the recommendations are intended to be complementary and would be more powerful if adopted as a package, each can also be viewed as a stand-alone option and serve to stimulate discussion on long-term strategies.

Innovation Ecosystem

Policy 1: Foster a Commercialization Culture at the University of Wyoming

Although the University of Wyoming's Technology Transfer and Research Products Center is instrumental in taking carbon tech products and processes from the lab to market, the university's faculty could be better supported in their commercialization efforts. In order to improve industry relations, generate positive publicity, and discover new funding opportunities, the University of Wyoming could increase services, incentives, and support for faculty who want to develop their cutting-edge research and bring it to market. Potential measures include recognizing patents as creative scholarship in tenure policies, establishing startup support programs, and supporting entrepreneurial leaves of absence for faculty.

Policy 2: Develop a Statewide Mentorship Network

Wyoming's budding entrepreneurs, especially those in rural areas, struggle to find support and resources to help them navigate the lengthy and complex commercialization process. To ensure emerging carbon tech entrepreneurs get the help they need, Wyoming's leaders could spearhead a venture catalyst model statewide. Each venture catalyst could facilitate vital connections between local would-be entrepreneurs and the training, information, and funding opportunities they need to achieve market viability.

Policy 3: Create a Wyoming-Driven Innovation Engine

The high-tech innovation culture in Wyoming needs strengthening: Residents do not often consider starting high-tech businesses, which can lead to a lower number and quality of high-tech startups and low utilization of existing resources. There is a great opportunity to harness the state's innate sense of self-reliance to support new entrepreneurial endeavors by reenvisioning its resources for startups. To support new entrepreneurial endeavors, the state could bolster Wyoming's three incubators by expanding their mandates and providing a wider range of services to improve deal flow.

Access to Capital

Policy 4: Simplify Access to Sources of Capital

Wyoming's budding entrepreneurs must search high and low to find the capital they need to start and scale their businesses. This takes time and energy and distracts them from growing their carbon tech ventures. Wyoming's leaders could create a simple, online capital locator tool to help entrepreneurs identify the type of capital that is appropriate for their company based on maturity and industry type. By leveraging this one-stop shop, Wyoming's entrepreneurs will have more time for their ventures.

Policy 5: Establish a Technology Maturation Loan Fund to Fill Financing Gaps

Early-stage technology, such as carbon tech, needs maturation before it can be commercialized, however venture capital firms and angel investors shy away from investing in technology that has not matured or is still commercially unproven. Wyoming does not fund any programs addressing this gap, and therefore, may not reap the economic benefits of homegrown innovations. The state should consider establishing a technology maturation loan fund to increase the number of promising carbon tech innovations that reach the commercial development stage.

Policy 6: Appoint a Foundation Liaison to Increase Funding for Business Competitions

Business plan competitions are a powerful tool for increasing innovation, creating jobs, and incentivizing budding entrepreneurs to take the risk and bring their ideas to reality. Yet in Wyoming, few business plan competitions are held, the prize money is not sufficient to entice the biggest, boldest carbon tech ventures to compete, and some of those that are available are only open to a small segment of the population. Wyoming could appoint a foundation liaison to connect with, and broker support from, philanthropic foundations to increase funding for business plan competitions.

Policy 7: Establish a Fund of Funds

Wyoming lacks a range of capital resources, especially venture capital, to grow its new businesses, many of which are not eligible for traditional forms of financing, such as bank loans. This challenge is pronounced for new carbon tech ventures that are creating technology that is costly to develop and requires a longer commercialization period. Wyoming's leaders could establish a fund of funds and encourage top investors to commit funds to companies in Wyoming, thereby increasing access to capital for in-state businesses to grow and scale.

Workforce Development

Policy 8: Increase Apprenticeships for High School Students

Apprenticeships are a tried and tested training model for guiding young people into promising career tracks. However, Wyoming ranks forty-fourth nationwide in the number of apprenticeships per capita. To ensure the competitiveness of its workforce for the carbon tech jobs of the future, Wyoming could increase the number of apprenticeships by offering incentives to businesses who provide these opportunities.

Policy 9: Retain Wyoming's Brightest Students

Wyoming is experiencing a brain drain: Its best and brightest students, workers, and future leaders are leaving the state for economic opportunities elsewhere. Wyoming could retain this talent by converting its pre-eminent Hathaway Scholarship program to a loan forgiveness program. By tying the education funds to working in the state after graduation, Wyoming will provide a powerful incentive for young people to leverage their education to advance Wyoming's economy.

Policy 10: Improve Soft Skills Training for High School Students

Soft skills such as critical thinking, communication, and teamwork are critical for success in almost any workplace, yet less than fifty percent of Wyoming employers are satisfied with new hires' work skills. Wyoming could implement a statewide simulated workplace program to help its high school students gain professional skills and prepare for real-world job expectations.

Policy 11: Formalize Industry-Led Job Training Programs for Carbon Tech

Wyoming could design training programs to ensure that in-state workers are ready for jobs in the carbon tech industry. To build this talent pipeline, Wyoming could establish an industry-led job training council that identifies right-fit skills and facilitates training partnerships.

Value Chain

Policy 12: Build a Comprehensive Carbon Tech Cluster Partnership

Despite the visionary investments Wyoming has made in carbon tech research centers, the state currently lacks a comprehensive strategy to develop the industry. Across the country and the world, the most successful clusters are driven by an intentional, overarching plan to attract companies, pass enabling policies, and hit key metrics. Wyoming could benefit greatly from the creation of a formal public-private partnership with industry, research centers, NGOs, and government leaders to strategically grow the state's nascent carbon tech cluster.

Policy 13: Broadcast Wyoming's Business Assets

From its abundance of land and business-friendly environment to its spirit of self-reliance and incredible recreational resources, Wyoming has much to offer carbon tech firms considering expansion or relocation. The state can highlight these resources with a marketing strategy that showcases its favorable business climate.

Policy 14: Leverage the High-Speed Internet Opportunity in Local Communities

Wyoming showed tremendous leadership by instituting a statewide broadband funding program in 2018. To maximize its impact, the state could increase incentives for competitive applications from municipalities who want to take advantage of this funding. By expanding access to internet services across local communities, Wyoming can position itself to foster a robust carbon tech value chain that supplies businesses with a pipeline of innovative R&D efforts and skilled technical workers.

Policy 15: Build a Strong Foundation for Future Foreign Direct Investment

Foreign direct investment (FDI) can be of particular value to Wyoming's carbon tech industry since many innovative companies are based outside of the United States. Wyoming could build its reputation as a global leader in carbon tech by establishing more formal relationships with potential international trade partners, which could generate future investment in the state.

Local Market

Policy 16: Create Incentives to Drive Demand for Wyoming's Carbon Tech Products

Wyoming has an opportunity to update its infrastructure, particularly roads, bridges, and dams, with locally made carbon tech products. To leverage this opportunity, Wyoming could institute a set of procurement policies for public contracts to stimulate purchases of carbon tech products manufactured in-state. Setting up a competitive process that notifies and rewards bidders on state contracts for purchasing Wyoming-made carbon tech products—such as carbon tech concrete for road repair—will drive demand and open up key business opportunities to grow the industry.

Policy 17: Unleash Wyoming's Wind Market

Wyoming carbon tech manufacturers could benefit from selling their products to the manufacturers of wind turbine components and transmission lines to be used for in-state wind projects. To fully harness this potential, Wyoming could foster its wind industry by providing dedicated leadership, policy stability, and tailored tax incentives.

Introduction

Wyoming can tap into the growing global markets to foster and support good-paying jobs for the people of Wyoming. Through the strategic cluster-based development of the carbon tech industry, Wyoming could support an average of 2,600 direct, indirect, and induced jobs annually through 2035, representing over 25 percent of the state’s current manufacturing workforce.

The American Jobs Project aims to spur job creation in the advanced energy industry by identifying state-level economic opportunities and crafting right-fit solutions for in-state growth. This national initiative takes advantage of the accelerating demand for advanced energy and leverages states’ competitive advantages to build robust economic clusters. The American Jobs Project believes that manufacturing is a cornerstone of the U.S. economy—providing workers with good wages and causing a multiplier effect on local revenue and employment—and resolves to support industry jobs that are resistant to offshoring and automation.¹³ State and local leaders who seek to capitalize on state resources to create skilled, good-paying jobs can use this report as a foundation for action.

Extensive research and more than 40 interviews with stakeholders and experts in Wyoming have identified carbon tech as showing particular promise in the state. Given its vast coal and carbon resources, extraordinary R&D assets, favorable business environment, high quality of life, and commitment to economic diversification, Wyoming is well-positioned to benefit from the rising demand for carbon tech. Opportunities to leverage these strengths to serve growing regional, national, and global markets further offer substantial benefits for both the state economy and Wyoming residents. Strategic state-level coordination and collaboration could elevate in-state companies in the marketplace and facilitate middle-income job growth. By fostering growth in the carbon tech industry, Wyoming could reasonably support an average of 2,600 direct, indirect, and induced manufacturing and supply chain jobs from 2018 through 2035 annually, representing over 25 percent of the state’s current manufacturing workforce.¹⁴

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By developing the carbon tech industry in the state, Wyoming could reasonably support an annual average of 2,600 jobs from 2018 through 2035, representing over 25 percent of the state’s current manufacturing workforce.¹⁵

END QUOTE BOX

Building Wyoming’s Economic Future

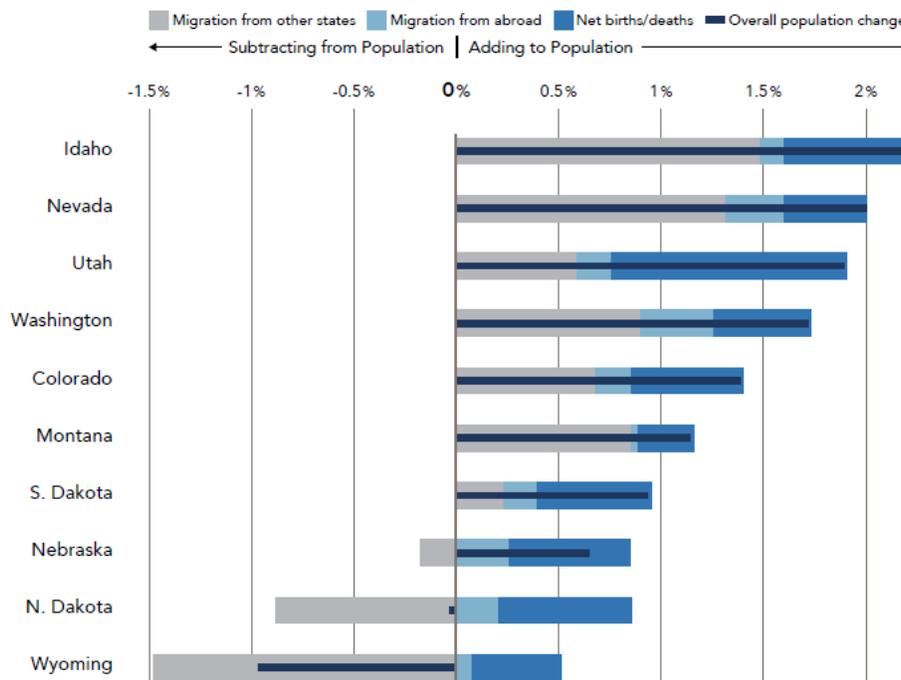
With its abundant natural resources, soaring mountains, and sprawling open plains, Wyoming is the face of America’s Rocky Mountain West. The state has been ranked as the country’s top net energy supplier for over two decades and is home to approximately one-third of the coal reserves in the United States.¹⁶ Jobs in the extractive industries comprise almost 7 percent of statewide employment, and resource extraction represented more than 20 percent of Wyoming’s GDP in 2016.¹⁷ Because coal mining plays a vital role in the state economy, the state must take action to prepare for the declining rates of coal-fired electricity generation across the country.¹⁸ Demand for coal as an electricity source fell by 25 percent between 2015 and 2018, and projections show

that coal’s share of the U.S. power mix will decrease by half by 2040.¹⁹ A downturn in Wyoming’s coal industry has already led to significant layoffs, and utilities that are currently purchasing Wyoming coal have publicly announced their intention to phase out coal from their portfolios.²⁰ Furthermore, the state’s revenue is the second-most volatile in the country, in large part because it is principally tied to taxes on the extraction of natural resources, including the declining coal industry.²¹

Wyoming faces an urgent need to diversify its economy to respond to this decreasing demand and help create a fertile climate for homegrown entrepreneurship and innovation. To maintain regional competitiveness with states like Idaho, where state leaders have worked hard to diversify and bolster the economy, Wyoming needs an economic development strategy that equips its residents with critical workforce-ready skills while prioritizing industries that have long-term economic potential.²² As the effects of population loss and key-sector unemployment continue to reverberate across Wyoming, the state will need to catalyze local economic growth that is rich in a diverse array of good-paying job opportunities that cater to a variety of education and experience levels.²³ Wyoming can support demand for coal by leveraging its vast deposits to create stable, good-paying jobs in new and emerging markets. Doing so will create an environment that encourages more community amenities and, in turn, stimulate the creation, growth, and recruitment of new businesses.

PERCENT CHANGE IN REGIONAL STATE POPULATION, 2016 TO 2017

Wyoming’s regional competitiveness has been inhibited by its population loss, which is the highest in the U.S. This trend signals a lack of employment opportunities and has impacted local spending in the economy.



Note: Component totals may not match overall bar due to residuals.
Source: U.S. Census Bureau

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Raising Tax Revenue to Support Economic Diversification

A vibrant, prosperous Wyoming economy requires the expansion of the state's sources of revenue beyond unstable severance taxes. Wyoming has established one of the best business climates in the country, but more Wyoming-grown businesses will mean more stress on the state's roads, emergency services, water systems, and airports. Similarly, retaining more of Wyoming's best and brightest workers will require additional housing and schools for their families. Wyoming currently does not have a way to pay for these services: The state is dipping into savings and making cuts to key programs, such as K-12 education.²⁴ These cuts will only serve to push people and businesses away from the state and hinder economic growth. Without a tax structure to fund important services, high-tech businesses and top talent will bypass the state. State leaders will need to determine how to fund the critical infrastructure its new and growing businesses and workers will require. A recent study conducted for the state legislature warned that attempts to diversify the economy without making sure the state has a solid tax foundation to build upon will actually worsen the state's budget crisis.²⁵

Idaho and Utah have shown that maintaining diverse sources of state revenue while keeping a low overall tax burden can facilitate a growing economy. In recent years, Utah's leaders have transformed the state into a hub for startup growth and technology commercialization. Utah now ranks sixth in the United States for economic growth, followed closely by Idaho at eleventh.²⁶ Wyoming ranks forty-ninth. Both Utah and Idaho have diverse sources of tax revenue and collect a fair percentage of overall state revenues from personal and corporate income taxes, while still maintaining a low tax burden relative to other states.²⁷ In both of these states, diversified sources of revenue have allowed public services and infrastructure to grow with the economy. This trend has helped to facilitate further economic diversification and business growth. Wyoming should carefully study the best ways to replicate the successes of neighboring states to support and cultivate new industry while maintaining its commitment to being a business-friendly culture.

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The Benefits of Cluster-Based Development

Economic clusters are regionally situated groups of interconnected companies and institutions organized around a particular industry. In today's competitive globalized economy, businesses are more likely to thrive in cities and states that cultivate the foundational building blocks of cluster development: a rich innovation ecosystem, fertile ground for capital investment, a highly skilled workforce, a robust value chain, and clear policy signals. Geographic proximity and repeated exchanges of information help foster an environment of coordination and cooperation among these companies and institutions, leveraging a trained workforce and each actor's unique expertise. By having a close network of suppliers and partners, companies can reap the benefits of increased productivity and operational efficiency, which will amplify local job creation and economic growth.²⁸

HOW DOES AN ECONOMIC CLUSTER WORK?



Wyoming's Economic Opportunity in Carbon Tech

Wyoming is well positioned to capitalize on rising market demand for carbon tech given the state's vast coal and carbon resources, extraordinary R&D assets, business-friendly climate, high quality of life, and commitment to economic diversification. Carbon tech refers to a range of high-value products produced from coal and captured carbon dioxide, including carbon fiber, concrete, graphene, cement, plastics, and carbon foam.

The carbon tech industry will experience substantial growth in the next decade.²⁹ Indeed, Wyoming can become a leader in carbon tech manufacturing by capitalizing on its extensive supply of the building blocks of carbon tech products, visionary investment in carbon tech research and development facilities, a high quality of life to recruit top talent for the carbon tech industry, and strong leadership dedicated to diversifying the state's economy.

State and local leaders could realize this potential through innovative strategies that leverage Wyoming's competitive advantages and strategically target areas for growth. By utilizing a phased approach—scaling the technologies that are currently market-ready, developing those that can be commercialized in the near-term, and nurturing those of the future—Wyoming stands ready to lead the nation in carbon tech.

What is Carbon Tech?

Carbon tech is a new and immensely promising industry. It refers to exciting and innovative processes and products related to using coal, carbon dioxide, oil, and gas to enhance or produce value-added products. Carbon tech can be used to capture carbon dioxide from the air or industrial facilities and enable new production pathways for existing products. While the consensus among scientific and business leaders about how to define the sector is emerging, this report will focus on the conversion of coal and carbon dioxide into valuable products and services that are related to advanced energy.

Carbon tech processes and products are at different phases of market development. Some carbon tech processes and products are ready for commercialization or are already commercialized, others are being field-tested before being scaled, and still others are in the earliest research phases. A snapshot of several of the processes and products—some with direct advanced energy applications and some that will provide a critical bridge as the carbon technologies mature and grow—shows the potential carbon tech holds for Wyoming's advanced energy manufacturing economy.

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Carbon Tech: Shaping the Future of Advanced Energy

Carbon tech can be used to make consumer products lighter and more efficient to transport, energy storage more flexible, housing insulation more effective, and wind turbine blades stronger and lighter. It can also be used to sequester carbon dioxide in concrete and cement. These

products have immense potential to meet the growing global demand for products that are related to advanced energy. Given the cutting-edge nature of the carbon tech industry, some of the early-stage products and processes are not strictly related to advanced energy but are essential to test, develop, deploy, and evolve related carbon technologies. The de-risking and scaling process will position Wyoming to harness the later-stage applications of this game-changing technology.

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Examples of Carbon Tech Processes and Products

Carbon Capture

Carbon tech products can be made from carbon that is either harvested directly from the air or captured from power plants and other industrial facilities that emit carbon dioxide. Sophisticated machinery is used to separate the carbon from these sources: oxy-combustion boilers, air and flue gas separation technologies, condensers, steel ducts, and CO₂ scrubber/purification units.³⁰ Some of these systems are in production; other cutting-edge technologies are being developed through innovative competitions like the NRG-COSIA Carbon XPRIZE.³¹

Enhanced Oil Recovery (EOR)

EOR is the process by which carbon dioxide (CO₂) is injected into oil and gas fields in order to stimulate increased resource extraction while also storing the CO₂ underground.³² Use of captured CO₂ in place of natural CO₂ for oil production provides a net decrease in emissions of CO₂.³³ Critically, EOR could provide a substantial market for first-generation Wyoming carbon tech companies that can either capture CO₂ from Wyoming's emission sources and then ship it via pipeline to oil and gas fields or test and prototype technologies that capture CO₂ from the air and then inject the material directly into the field. In the short term, EOR can help carbon capture and sequestration technology mature and drive Wyoming's nascent carbon tech industry into more advanced energy uses while meeting global energy needs.

Carbon Foam

Carbon foam is a low-density, high-strength material with excellent insulating and fire-resistant properties.³⁴ It can be used in fuel cells, battery electrodes, and housing insulation, as well as key applications for managing temperatures in electrical systems to prevent overheating and ensure proper functioning.³⁵

Activated Carbon

Activated carbon, also known as activated charcoal, is a highly absorptive form of carbon that is created by using steam or chemical processes to convert raw materials such as subbituminous coal into powder, granular, or extruded forms.³⁶ This substance has many uses including poison treatment, groundwater remediation or water purification, organic pesticide and feedstock, and metal finishing.³⁷

Carbon Fiber

Carbon fiber is a high strength-to-weight material with multiple advanced energy applications, including the following:³⁸

- Flexible supercapacitors, high-performance electrodes, and flywheels for energy storage³⁹

- Wind turbine blades⁴⁰
- Automotive and aerospace vehicles to decrease fuel consumption⁴¹
- High-pressure storage containers for alternative fuels, e.g., hydrogen and compressed natural gas⁴²
- Solar cell structural components⁴³

Carbon fiber is currently made with inputs other than coal, and the development of coal-based carbon fiber is still in its very early stage. Researchers from the Laramie-based Western Research Institute, Massachusetts Institute of Technology, and Oak Ridge National Laboratory are researching new cost- and process-efficient approaches for manufacturing carbon fiber from coal.⁴⁴

Concrete

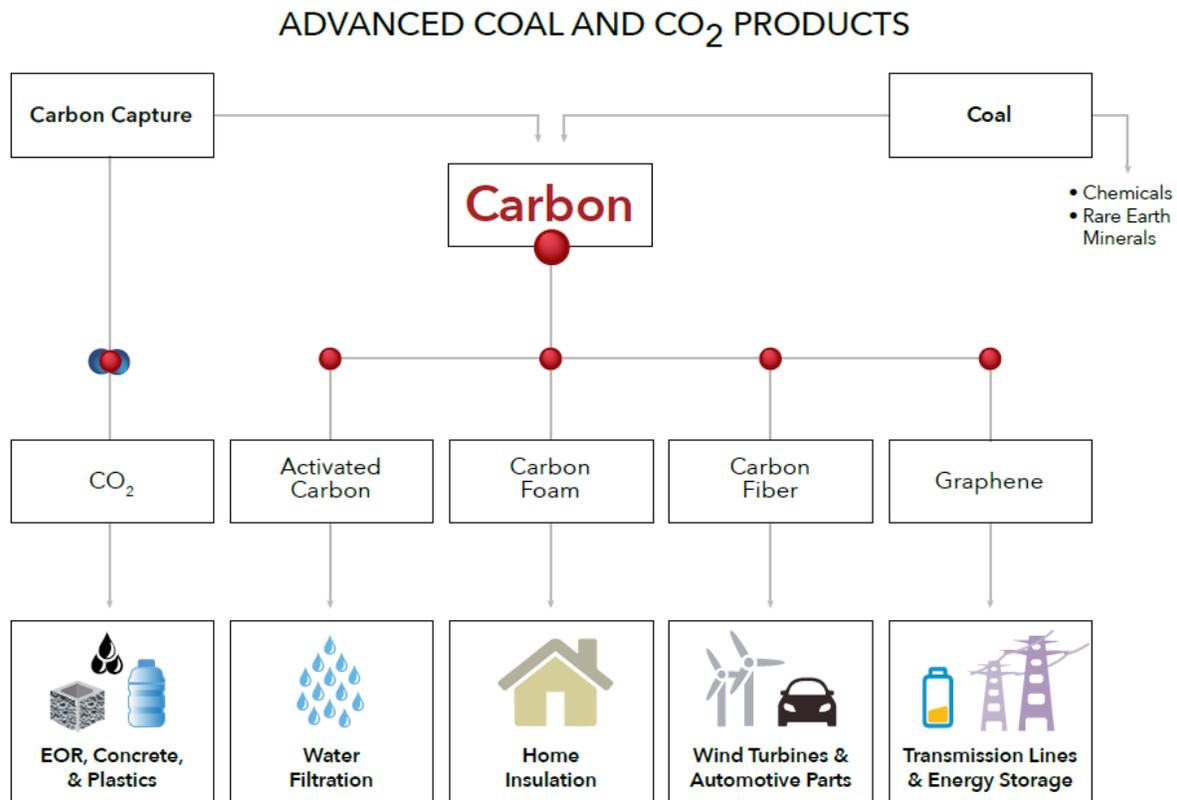
Concrete is the second-most consumed substance in the world after water, and its production accounts for 5 percent of CO₂ emissions from human activities.⁴⁵ Various CO₂ utilization technologies are being developed that aim to decrease the CO₂ emissions involved in cement and concrete production. Captured CO₂ can be used to cure concrete made from industrial waste, thereby sequestering the CO₂ in the concrete. It can also be used to produce nanoparticles that enhance the material properties of concrete and produce a low-CO₂ concrete alternative via mineralization in limestone.⁴⁶ Three research teams that are developing such approaches are currently testing their technologies at Wyoming's Integrated Test Center (ITC).

Plastics

Captured CO₂ can replace petroleum as a raw material for plastics. A number of production paths exist, some of which are already commercialized.⁴⁷ Prevailing technologies include CO₂ conversion into plastics and bioplastics via various chemical processes.⁴⁸ The resulting materials can be used in a wide range of building materials, coatings, packagings, and EOR surfactants.⁴⁹ A tenant at Wyoming's ITC is currently engaged in this research.

Graphene

Graphene can be used to conduct heat and electricity.⁵⁰ This material is one million times thinner than a piece of paper and can be engineered to be stronger than a diamond. Its advanced energy applications include making solar cells thinner and lighter; enhancing the transfer and storage of energy and data by moving electrons more quickly and efficiently; and potentially enabling hydrogen cells.⁵¹ Graphene is notably used to create carbon nanotubes. In turn, carbon nanotubes can be utilized in a variety of chemical, mechanical, and electronic applications. The material can be used to create more cost-efficient fuel cells, clean up oil spills because they are highly absorbent, increase battery life for electric vehicles, and fabricate quantum dots.⁵²



Why Carbon Tech in Wyoming?

Wyoming could catalyze economic growth and job creation by harnessing its strengths in the carbon tech industry. State leaders could capitalize on increasing national and global demand for carbon tech by mobilizing Wyoming’s investments in critical R&D facilities, leveraging the state’s high quality of life for talent recruitment and retention, harnessing its unparalleled supply of coal deposits, engaging strong support for a diverse and stable economy, riding the momentum of recent legislation, and creating quality jobs for the people of Wyoming.

Growing Demand for Carbon Tech

The U.S. market for carbon tech products and their downstream uses has totaled nearly \$3 billion recently and is expected to grow substantially in the next decade. In the United States, the activated carbon market generates \$458 million in annual revenue, the market for advanced structural carbon materials measures at \$2.3 billion annually, and the carbon dioxide production market for energy and manufacturing uses is currently estimated at \$197.5 million annually.⁵³ Notably, the U.S. graphene market is expected to experience rapid growth, from effectively zero in 2014 to \$155 million by 2020.⁵⁴ Advances in coal-to-graphene research can lower production costs by up to 700 percent, creating an incentive for graphene-based manufacturing.⁵⁵ Wyoming is well-positioned to meet this rising demand.

Innovative Research and Development Investments

Wyoming has made enterprising public and private investments in world-leading carbon tech research and development facilities, including the School of Energy Resources (SER) at the University of Wyoming. SER hosts multiple future-thinking research centers such as the Advanced Conversion Technologies Research Program and the Carbon Engineering Initiative, which develop advanced applications for Wyoming's coal and carbon—as well as the Center for Energy Economics and Public Policy, which provides data and policy analysis for the carbon tech regulatory environment.⁵⁶ In 2014, the Integrated Test Center (ITC) was launched with \$15 million in funds from the Wyoming Legislature as well as millions in matching funds from private partners.⁵⁷ Managed by the Wyoming Infrastructure Authority, this facility provides real-world opportunities to test new carbon capture, sequestration, and conversion technologies by capturing the emissions from a coal-fired power plant.⁵⁸ Finally, Ramaco Carbon is making substantial private investments in two exciting initiatives: the iCAM (Carbon Advanced Materials Center), where researchers from universities, national labs, and private industry will test emerging carbon tech products and processes, and the iPark facility where researchers will scale and manufacture market-ready coal-to-product technologies.⁵⁹ These world-class resources position Wyoming as an unparalleled location to identify, prototype, commercialize, and scale cutting-edge carbon tech products and processes.

Vast Supply of Raw Materials

Wyoming leads the nation in coal; it produces 40 percent of all coal mined in the United States, accounts for about one-third of U.S. coal reserves, and houses the top-six highest-producing coal mines in the nation as of 2016.⁶⁰ The state also generates substantial amounts of carbon dioxide through its thirteen coal-fired power plants.⁶¹ Coal, natural gas, oil, and carbon dioxide are the building blocks of carbon tech, comprising the principal raw materials in activated carbon and critical feedstock for enhanced oil recovery (EOR). New research is unlocking the processes to transform these materials into carbon foam, carbon fiber, graphene, and other products with extensive advanced energy applications.

High Quality of Life

Wyoming boasts beautiful sweeping vistas, rugged mountains, and an abundance of open space. As the least densely populated state in the country, Wyoming provides its residents with plenty of room to start new ventures, raise a family, and enjoy time outdoors.⁶² The state is rich with iconic landscapes: Half of Wyoming's lands are national parks, forests, monuments, wildlife refuges, or other types of public land.⁶³ Wyoming residents also enjoy high average salaries.⁶⁴ These high quality of life attributes are a powerful recruitment tool that can attract leading carbon tech companies, researchers, and technical talent to the state.

Strong Support for a Diverse Economy

Wyoming would benefit from diversifying its economy and developing the private sector to attract more investment and jobs to the state, particularly by growing its small manufacturing base. Wyoming has notably lost nearly 8 percent of its manufacturing jobs since the Great Recession and was last in a ranking of fastest-growing U.S. states.⁶⁵ Only 3.5 percent of Wyoming's workforce is employed in manufacturing; the state currently ranks forty-seventh in manufacturing's share of total employment among all U.S. states. Manufacturing facilitates a strong labor market with good-paying job opportunities in the local economy, which can support

groups that are facing severe employment barriers and low wages. For example, mechanics and electrical engineering technicians—two types of jobs that will be in high demand in the carbon tech industry—earn a mean hourly wage of more than \$25 and \$30, respectively.⁶⁶ Governor Matt Mead launched the Economically Needed Diversity Options for Wyoming (ENDOW) Initiative to tackle these tough challenges (*see call-out box*).⁶⁷ A thriving carbon tech industry could invigorate Wyoming by stabilizing the coal industry, diversifying the economy, and keeping homegrown Wyoming talent in the state.

START CALL-OUT BOX

Economically Needed Options for Wyoming (ENDOW) Initiative

Spearheaded by the state’s pre-eminent business and civic leaders, economic and workforce development experts, and visionary elected officials, the ENDOW Initiative is a comprehensive approach with the objective of diversifying Wyoming’s economy.⁶⁸ This initiative is engaging in listening tours, proposing state legislation, and driving efforts to expand Wyoming’s economy.⁶⁹

END CALL-OUT BOX

Policy Tailwind

By utilizing its visionary R&D network and extensive supply of coal deposits and captured carbon emissions, Wyoming can leverage recently passed federal legislation to grow its budding carbon tech industry. In 2018, the U.S. Congress passed the 45Q tax credit, which established a financial incentive to capture carbon dioxide from power plants and convert it into products. For each ton of CO₂ that is converted into value-added products, the responsible party will receive a \$35 tax credit.⁷⁰ Carbon tech companies have up to twelve years to access this reliable revenue stream; this long time span will help catalyze Wyoming’s unique carbon tech opportunities into profitable ventures. Leaders in other states from around the country either already have or are considering incentives for carbon capture and sequestration, which will also serve to bolster the industry.⁷¹

Win-Win Opportunity to Grow Other Local Industries

The Wyoming carbon tech industry offers an incredible win-win opportunity to supply two large in-state industries with its products. The state enjoys some of the best wind resources in the country, and carbon fiber is a key component to making wind turbine components cheaper, stronger, and lighter.⁷² To harness this enormous resource, scale up its production, and tap into new markets, Wyoming has supported developers that plan to build transmission lines—an important first step.⁷³ Graphene shows incredible promise in improving the performance of next-generation transmission lines.⁷⁴ Although significant barriers to further development must still be surmounted, the wind industry and transmission line construction projects represent a potentially large and lucrative local market for Wyoming-made carbon tech products.

Opportunity to Support High-Quality Job Growth

The carbon tech industry could help address Wyoming’s need for good-paying jobs while offering a diverse array of employment opportunities that cater to different education and experience levels. By employing forward-thinking solutions, carbon tech could support an average of 2,600 jobs annually through 2035.⁷⁵ This estimate includes direct jobs from manufacturing, engineering, and research; indirect jobs from suppliers; and induced jobs from spending in the local economy. (*See Appendix for more on jobs modeling methodology.*) While

economic growth may be concentrated near manufacturing facilities, Wyoming could also foster a local market for carbon tech to support job creation in installation, operation, and maintenance businesses distributed across the state.

JOB OPPORTUNITIES IN CARBON TECH



Computer-Controlled Machine Tool Operators

Operate computer-controlled machinery to tool metal or plastic parts.

TYPICAL ENTRY-LEVEL REQUIREMENTS:

High School Diploma or Equivalent

U.S. Average Wage: \$19.72



Materials Scientists & Researchers

Research and analyze natural and synthetic substances for use in the development of new products and applications.

TYPICAL ENTRY-LEVEL REQUIREMENTS:

Master's Degree or Ph.D.

U.S. Average Wage: \$48.83



Chemical Engineers

Design chemical plant equipment and create processes for chemical and product manufacturing.

TYPICAL ENTRY-LEVEL REQUIREMENTS:

Bachelor's Degree

U.S. Average Wage: \$50.68



Mechanics

Repair mechanical, hydraulic, and pneumatic equipment used in fields such as construction and surface mining.

TYPICAL ENTRY-LEVEL REQUIREMENTS:

High School Diploma or Equivalent

U.S. Average Wage: \$25.18



Electrical & Electronics Engineering Technicians

Assist engineers with design, production, and testing.

TYPICAL ENTRY-LEVEL REQUIREMENTS:

Associate Degree

U.S. Average Wage: \$30.27



Systems Software Developers

Develop underlying software systems or applications.

TYPICAL ENTRY-LEVEL REQUIREMENTS:

Bachelor's Degree

U.S. Average Wage: \$53.17

State Assets to Support Carbon Tech Cluster Development

There are five foundational building blocks for clusters: the innovation ecosystem, access to capital, workforce development, value chain build-out, and local market growth. Wyoming has many assets that can be aligned with cluster-based development, including the Integrated Test Center, iPark and iCAM, multiple research centers at the University of Wyoming, kickstart:Wyoming, and the Western Research Institute.

Wyoming can capitalize on its strengths in carbon tech by strategically building an economic cluster. Clusters require several foundational building blocks coordinated for growth: an innovation ecosystem that cultivates new ideas, access to capital for new and expanding businesses, education and training for a skilled workforce, a comprehensive value chain, and a local market for Wyoming-made goods. When reinforced by clear market signals and policy certainty, these assets translate into major opportunities for business growth and job creation in the target industry, laying the groundwork to catalyze economic opportunity for thousands of Wyoming residents.

The following visual guides break down the key assets for a robust cluster. This section will use these guides to illustrate some examples of the state's strengths in each foundational building block and showcase significant resources for Wyoming's carbon tech industry.

Innovation Ecosystem: Innovation is essential for business and industry competitiveness, and a strong knowledge hub can be a beacon for talent and investment. The innovation ecosystem supports fundamental research across universities and labs, fosters an entrepreneurial culture that seeks to advance and disrupt industries, and brings ideas to market.

Access to Capital: Access to investors or competitively priced non-dilutive capital can be the difference between success and failure for a new or expanding business. It is also important for consistent access to capital across development from the seed and early/growth stages to the late stage. An active investment environment can attract more entrepreneurs and investors to the state.

Workforce Development: Trained and skilled workers are fundamental to industry success, and strategic workforce development can support talent recruitment and retention. Workforce development requires collaboration across schools, businesses, and government offices to integrate STEM education, foster industry-ready skills via apprenticeships and career-integrated curriculum, enable stackable credentials that offer multiple entries and exits, and provide resources that match skills to available jobs.

Value Chain: An industry value chain is composed of an array of companies engaged in the manufacturing, sale, marketing, and distribution of technologies. It also includes organizations that represent business interests across platforms. This base provides a solid foundation from which to attract more companies and customers.

Local Market: Creating a local market for products sends a market signal to businesses that encourages investment in new facilities and employees. High local demand can attract a local company base that could then expand to regional, national, and global markets. Clear utility and business regulatory environments coupled with resources for project development and end-user adoption can create a strong local market.

EXAMPLES OF STATE ASSETS TO SUPPORT CARBON TECH DEVELOPMENT

Wyoming can leverage its business-friendly climate, massive greenfield development potential, carbon tech R&D centers, manufacturing support network, community college system, and growing investment environment to become a leader in the carbon tech industry.

	<h3>INNOVATION ECOSYSTEM</h3>	<p>Wyoming's research university, along with innovative coal-to-product and carbon capture centers, are the anchors for carbon tech research, development, and commercialization in the state. These world-class research centers could give Wyoming the edge to become a leader in the carbon tech industry.</p>
	<ul style="list-style-type: none">• Integrated Test Center (ITC): The state legislature established the ITC to provide the tools necessary to conduct real-time study of the capture and storage of carbon emissions from a Wyoming coal-fired plant.• Ramaco Carbon: Ramaco Carbon is building the world's only fully integrated carbon resource, R&D, and production facility in Sheridan, Wyoming.• Carbon Advanced Materials Center (iCAM): In 2017, the U.S. Department of Energy (DOE) awarded the Western Research Institute (WRI) a \$7 million grant to conduct carbon fiber research at the iCAM, a world class carbon R&D facility.	<ul style="list-style-type: none">• Wyoming iPark: This state-of-the-art manufacturing facility will utilize coal from the Brook Mine to provide entrepreneurs and businesses with the raw materials needed to create high-value products.• Wyoming Technology Business Center (WTBC): The WTBC, located in Laramie, Sheridan, and Casper, offers laboratory and office space for early-stage, technology based companies as well as mentorship and coaching services for entrepreneurs.• Advanced Conversion Technologies Research Program• Carbon Engineering Initiative• Enhanced Oil Recovery Institute• Shell 3D Visualization Center
	<h3>ACCESS TO CAPITAL</h3>	<p>Wyoming offers a limited selection of venture capital, loan programs, and investment programs to support small businesses.</p>
	<ul style="list-style-type: none">• kickstart:Wyoming: The program awards early-stage funding to Wyoming-based entrepreneurs and businesses in amounts ranging from \$5,000 to \$50,000.• Wyoming Small Business Investment Credit (SBIC) Program	<ul style="list-style-type: none">• Breakthrough 307• Temte Capital Management, LLC• Silicon Couloir• Wyoming Partnership Challenge Loan Program



WORKFORCE DEVELOPMENT

Wyoming's community colleges equip a large number of students with a range of technical skills to facilitate flexible career pathways.

- Seven community colleges serving over 30K students annually
- Dual and Concurrent Enrollment Program
- CTE Demonstration Project Grant
- Workforce Development Training Fund



VALUE CHAIN

Wyoming has the beginnings of a strong value chain for carbon tech based on its abundant natural resources, existing anchor companies, and high-potential startups.

- Ramaco Carbon
- Mitsubishi Chemical Carbon Fiber and Composites: In 2017, Mitsubishi Rayon acquired SGL Carbon Fibers LLC in Evanston, Wyoming. The company is on track to manufacture 1,000 tons of high quality, large-tow carbon fiber per year.
- Manufacturing Support Network: Wyoming promotes its manufacturing industry through the leadership of organizations such as the Alliance of Wyoming Manufacturers (AWM) and Manufacturing-Works.
- Atlas Carbon
- WellDog



LOCAL MARKET

Wyoming could leverage its supply of coal deposits and captured carbon emissions to manufacture carbon tech wind turbine blades and transmission lines as well as produce cement and concrete made with captured CO2. These industries have high potential for the local market.

- In 2016, Wyoming used 250,000 metric tons of cement; cement and its related industries contributed more than \$507 million to Wyoming's economy.
- By 2020, the wind industry will account for 60% of the market demand for advanced composites such as carbon fiber and graphene.

Policy Recommendations

To grow the carbon tech industry, state and local leaders can address barriers and capitalize on opportunities across foundational building blocks, such as supporting technological innovation and development, increasing available capital for startups, targeting talent retention and skill building, collaborating to create and execute a cluster development plan, and facilitating in-state technology deployment. These forward-thinking policies, programs, and ideas are intended to serve as stepping stones to discussion and collaboration.

To help create thousands of jobs and strengthen the state’s manufacturing industry, Wyoming’s leaders can capitalize on the state’s competitive strengths and demonstrate their commitment to the carbon tech industry by enacting smart, forward-thinking policies and implementing non-legislative solutions. In particular, state and local leaders can apply innovative strategies that address barriers and missed opportunities across foundational building blocks, as noted by the icons. These broad strategies include fostering technology development and commercialization, increasing business access to financial resources, improving workforce training, and growing the in-state value chain. Wyoming can also build a local market for carbon tech products as an opportunity for industry growth. Robust demand near manufacturing facilities can help create synergies that drive innovation, train and retain talent, and attract out-of-state investors.

Whether taken as a whole or as piecemeal solutions, the following recommendations could attract private investment, stimulate the state’s economy, and create good-paying jobs for Wyoming residents.

Innovation Ecosystem: Bridges the commercialization gap by coordinating product testing and demonstration resources for carbon tech startups and builds “connective tissue” in Wyoming’s research and entrepreneurial community.

Access to Capital: Expands available capital for Wyoming’s carbon tech startups, especially flexible, long-term funding opportunities to support commercialization.

Workforce Development: Targets talent retention through apprenticeships, financial incentives, industry coordination, and expanded pathways to careers in Wyoming’s carbon tech industry.

Value Chain: Encourages strategic collaboration across stakeholders to strengthen Wyoming’s budding carbon tech industry and attract investment from outside the state.

Local Market: Incentivizes and reduces the cost barrier of adopting carbon tech products in Wyoming’s competitive bid process for state contracts.

Innovation Ecosystem

Policy 1: Foster a Commercialization Culture at the University of Wyoming

Opportunity

Technology transfer and commercialization benefit both universities and the public. Universities can use tech transfer to uncover new fundraising opportunities and build prestige, which helps recruit the most talented students and faculty. Academic research environments are often the site of innovation breakthroughs that allow new industries to take root, leading to compounding returns in job creation and economic growth. The Wyoming Technology Transfer and Research Products Center at the University of Wyoming (UW) can help faculty members bring their academic innovations to market, but barriers make commercialization difficult in practice.⁷⁶ There is no allowance in the university's guidelines for faculty members to take paid leaves of absence for non-academic purposes; professors who take leave for other reasons, such as to launch a startup, do so at the cost of their fringe benefits accrual and their chances of attaining tenure.⁷⁷ While UW's tenure promotion policies make passing reference to patents as creative scholarship, there is no emphasis on entrepreneurship or the commercialization of ideas as a basis for career advancement.⁷⁸ Given these and other factors, UW was completely left off the Milken Institute's 2017 ranking of the top 225 U.S. universities for tech transfer.⁷⁹ Maintaining the highest standards of academic freedom and integrity is critical, but underachieving in tech transfer could lead to huge missed opportunities for Wyoming.

Solution

To capitalize on these opportunities, UW could adopt policies that would encourage and enable the commercialization of on-campus innovation. Recognizing technology transfer and commercialization activities in tenure review processes, expanding faculty mentorship and startup support programs, and supporting entrepreneurial leaves of absence are three proven methods for stimulating commercialization at universities.⁸⁰ UW could acknowledge faculty members for accelerating university innovation by expressly including technology transfer or entrepreneurial activities in the criteria considered for promotion and tenure (*see call-out box*).⁸¹

UW could also expand the Wyoming Technology Transfer and Research Products Center and the Wyoming Technology Business Center to help faculty members take their ideas to market. New program services could include connecting faculty members with seasoned entrepreneurs and establishing pre-negotiated relationships with firms providing legal, accounting, and other critical professional services to startups, as seen at The University of Utah and the University of California, Los Angeles (*see case studies*). Drawing on the University of Minnesota's innovative policy, a complementary strategy could be to allow one- to two-year entrepreneurial leaves of absence for faculty, during which fringe benefits would still be available and accruable (*see case study*). Enabling entrepreneurial leaves of absence without jeopardizing faculty member's pay and benefits would make it much easier for professors to take the risk that launching a startup entails. Any of these measures could accelerate commercialization opportunities at UW. Funding needs for these programs would need to be met by additional allocations by the state legislature or foundations (*see Policy 6*).

Key Players

University of Wyoming, Wyoming Technology Business Center, Wyoming Legislature

Case Study: The University of Utah

The University of Utah has led the way in creating programs that encourage faculty entrepreneurship. In 2007, it launched the Entrepreneurial Faculty Scholars (EFS) program to create a broad network of support for faculty members commercializing their research.⁸² The network, comprised of 155 members from all fourteen colleges at The University of Utah, connects seasoned faculty entrepreneur mentors through an online platform and regular meetings to faculty entrepreneurs to guide them through the process of commercializing research.⁸³ Alongside EFS, The University of Utah's Center for Technology & Venture Commercialization offers the Lean Cohort, a seven-week accelerator program to help faculty navigate commercialization.⁸⁴ As a result, there is a strong culture of innovation at the university. Between 2012 and 2015, The University of Utah generated \$211.8 million in licensing income and recorded sixty-nine startups.⁸⁵ The University of Utah was ranked first on the 2017 Milken Institute University Technology Transfer and Commercialization Index.⁸⁶

Case Study: University of California, Los Angeles (UCLA)

UCLA recognizes that a strong entrepreneurial culture provides several benefits to the university, including supporting small businesses, generating revenue from licensing intellectual property, and providing job opportunities to their graduate students. Among other innovative programs, UCLA has created a dedicated program for university community members interested in commercialization that has resulted in multiple spin-off companies.⁸⁷ The "Startup in a Box" program aims to launch startups by using university intellectual property. The program offers pre-negotiated partnerships with local law, accounting, commercial real estate, marketing, web, human resource, insurance, and financial firms.⁸⁸ Due in part to this initiative, UCLA was recently ranked first for performance in startups by the Milken Institute.⁸⁹ As of fiscal year 2016, UCLA had \$65.9 million in revenue from licensing and 1,075 active U.S. patents.⁹⁰

Case Study: University of Minnesota

The University of Minnesota's entrepreneurial leave of absence policy allows faculty members up to eighteen months of unpaid leave to explore commercializing university intellectual property without compromising their benefits.⁹¹ While faculty members pursue startup projects, they continue to maintain health benefits, accrue vacation time, and earn other fringe benefits.⁹² In addition to the Venture Center, the policy is among a slate of resources that the University of Minnesota has advanced to maximize the impact of internal research and strengthen connections to the local business community.⁹³ This effort has fostered a robust startup ecosystem that has included over 120 spin-offs since 2006, with 78 percent still active.⁹⁴ The University of Minnesota also ranked fourteenth on the Milken Institute's ranking of top universities for technology transfer.⁹⁵

START CALL-OUT BOX

Sample Language for Incorporating Entrepreneurial Activities in Tenure and Promotion Review⁹⁶

- Virginia Polytechnic Institute and State University (Virginia Tech)
 - "Economic contributions and entrepreneurship: 1. Startup businesses (including competitive grants and contracts such as SBIR awards and other notable business

achievements), 2. Commercialization of discoveries, 3. Other...Intellectual properties: 1. Software, 2. Patents, 3. Disclosures (pre-patent)”

- The University of Arizona
 - “...integrative and applied forms of scholarship that involve cross-cutting collaborations with business and community partners, including translational research, commercialization activities, and patents”

END CALL-OUT BOX

Policy 2: Develop a Statewide Mentorship Network

Barrier

Wyoming’s entrepreneurship resources are few and far between. Many people in areas around the state might have great ideas but are not able to travel to where entrepreneurship resources are located. With widely dispersed and minimal startup resources, would-be entrepreneurs do not understand what resources exist for them and cannot find support. This problem becomes especially acute for hardware-focused startups such as those in carbon tech, which require streamlined access to expertise and resources to be successful. While the Wyoming Small Business Development Center (SBDC) Network has resources to assist existing businesses, more support is needed to foster the entrepreneurship culture throughout the state and help people all over Wyoming turn their ideas into reality.

Solution

Wyoming could improve access to entrepreneurial resources and grow the entrepreneurship culture throughout the state by co-funding a statewide network of “venture catalysts,” modeled after an existing program in Oregon (*see case study*). Each venture catalyst would be a seasoned entrepreneur or investor with extensive experience and be well versed in resources for funding and scaling up.⁹⁷ The venture catalysts would work at three levels: providing direct services to businesses, addressing critical gaps in the entrepreneurial ecosystem, and coordinating resources among stakeholders. They are described as coaches, connectors, and strategists. A statewide network of venture catalysts would be comprised of individuals dedicated to each county throughout the state. Each venture catalyst would be charged with traveling throughout their respective counties, connecting startups to resources and promoting collaboration between service providers. They could also disperse news on other regional events, success stories, funding opportunities, and industry trends. In order to ensure that venture catalysts efficiently collaborate amongst themselves and are well informed about available resources and best practices, they could hold monthly meetings or annual conferences. The conference agenda could address best practices employed by entrepreneurial support organizations within Wyoming and throughout the country.

Key Players

Wyoming Legislature, Wyoming Business Council, Local Governments, Foundations, NGOs, Wyoming Small Business Development Center Network, Foundation Liaison (*see Policy 6*)

Case Study: Oregon’s Venture Catalyst Initiative

In 2009, the Oregon Entrepreneurs Network (OEN), in partnership with Economic Development for Central Oregon (EDCO), created the first Venture Catalyst position in Central Oregon.⁹⁸

Since then, OEN has supported Venture Catalysts with local partners in Southern Oregon and the South Willamette Valley.⁹⁹ These Venture Catalysts identify entrepreneurs throughout rural regions and connect them with training, services, and investors.¹⁰⁰ In addition to raising awareness of business development tools in Oregon, the Venture Catalysts help support startup events like pre-accelerator boot camps and angel investment conferences.¹⁰¹ The Venture Catalysts are funded by a combination of municipal governments, private foundations, and other local entities.¹⁰² Venture Catalysts in these three areas have provided services to over 500 companies, which have created 346 jobs and generated over \$55 million in revenue since 2016.¹⁰³ Since 2014, Venture Catalysts in the South Willamette Valley have helped startups obtain over \$15 million of investment capital.¹⁰⁴ From an initial investment of only \$450,000, Venture Catalysts in the three regions assisted more than 270 companies from 2015 to 2016, directly facilitating \$21 million in investment capital and creating 188 jobs.¹⁰⁵

START QUOTE BOX

“The return on investment for this initiative has been remarkable wherever the model has been deployed, resulting in not only more successful companies and jobs, but also in the development of critical entrepreneurial infrastructure. In Central Oregon alone, the Venture Catalyst position at EDCO has been key in the growth of the Bend Venture Conference and local PubTalks, as well as the establishment of the region’s first accelerator, a regional angel fund, and mentor database, to name a few.” *Oregon Entrepreneurs Network*¹⁰⁶

END QUOTE BOX

Policy 3: Create a Wyoming-Driven Innovation Engine

Opportunity

Wyoming is well known for its values of self-reliance and problem-solving, which are key traits of the local business environment. In 2016, the state ranked at the top of the national survey for best places to start a business, and more recently, Silicon Couloir has pioneered an innovative startup training program specifically for Wyoming residents who want the tools, framework, and mentorship to launch winning ideas.¹⁰⁷ However, the state has yet to capitalize on its potential as an entrepreneurial hub for high-growth, technology-focused businesses. In 2016, Wyoming was home to 250 technology startups and only 12.9 out of every 100,000 employer businesses were high-growth companies.¹⁰⁸ Notably, Utah had 1,783 technology startups and its high-growth company density was 174.8 percent in 2016.¹⁰⁹ These data indicate a slow-growing innovation culture in Wyoming, which can lead to a low deal flow and an underuse of existing resources. A great opportunity exists to harness local innovation and entrepreneurship and support new ideas that could turn into high-growth endeavors by re-envisioning the state’s resources for startups.

Solution

Wyoming’s three incubators could be expanded to provide a wider range of services to stimulate the innovation culture and improve the deal flow throughout the state. By providing targeted support to help entrepreneurs take ideas from the lab to the market, these incubators could help mobilize Wyoming’s high-growth, technology-focused startup culture. State leaders could look at best practices from several successful models from around the country to enhance services provided in the state. For example, a newly reimagined accelerator could provide strong mentor networks, online tools, and annual events as was done in Tennessee (*see case study*). Or leaders

could look to Boomtown Accelerators for how to tailor support for each startup effectively (*see case study*). Ben Franklin Technology Partners serves as a good example of a successful long-standing accelerator that proved it stimulated economic development by investing in and advising technology companies (*see case study*). The state could also look at a successful model that facilitates in-state manufacturing of locally developed technologies (*see the Greentown Labs case study*).

Key Players

Wyoming Business Council, Incubators

Case Study: Providing Strong Mentor Networks and Online Tools at Launch Tennessee

Located in Nashville, Launch Tennessee is dedicated to supporting in-state entrepreneurs at every phase of development. The organization offers a suite of resources to startups with high growth potential, including seed-stage investments from its \$1.7-million impact fund, technology transfer assistance, and access to a network of expert mentors.¹¹⁰ They also provide an online resource matching tool for entrepreneurs to discover potential sources of capital, talent, office space, and other critical startup resources in their region quickly and easily.¹¹¹ As a public-private partnership, the organization's overall goal is to turn Tennessee into the nation's most startup-friendly state by collaborating with the private sector and government to improve access to capital and markets, talent pipelines, commercialization efforts, and business-friendly policies.¹¹² With its annual entrepreneurship conference and festival, Launch Tennessee takes the lead in facilitating connections and building a community of entrepreneurship.¹¹³ Launch Tennessee's comprehensive approach to building startup capacity is a model for states across the country.

Case Study: Tailored Startup Support at Boomtown Accelerators

Like most accelerators, Boulder, Colorado-based Boomtown Accelerators provides its portfolio companies with workspaces and mentorship. What sets it apart is its personalized, entrepreneur-centric approach to startup development. Boomtown boasts a 2:1 founder-to-staff ratio, allowing for programs and coaching that are tailored to each startup's unique needs.¹¹⁴ With specialized expertise in nearly every aspect of startup management, from team building to customer discovery, data security, financial strategy, and public speaking, the staff is ready to help founders with almost any challenge.¹¹⁵ The accelerator also provides founders with great perks, such as hosting, discounts on business software, and legal assistance.¹¹⁶ Boomtown boasts a network of 200 experienced mentors to help its portfolio companies thrive.¹¹⁷ With this approach, Boomtown has supported over ninety companies in its program and has expanded to a second campus in Atlanta.¹¹⁸

Case Study: Ben Franklin Technology Partners' Targeted Investments and Support

Ben Franklin Technology Partners (BFTP) is Pennsylvania's nationally acclaimed and award-winning technology-based economic development program.¹¹⁹ With four locations throughout the state, BFTP spurs economic growth by providing access to capital, business expertise, and a resource network to startups and established businesses.¹²⁰ BFTP makes direct investments in Pennsylvania companies to fund technology commercialization as well as corporate growth.¹²¹ BFTP's meticulous investment vetting process often inspires confidence in its funding recipients and thus enables companies to secure follow-on funding. BFTP also invests in seed- and early-

stage investment funds. In addition to direct investing, BFTP provides support directly to entrepreneurs by reviewing business plans; assessing technology; advising on intellectual property rights, operations, and marketing; and fostering relationships between entrepreneurs, investors, incubators, state-level economic development resources, and R&D assets. BFTP conducted an independent, third-party evaluation of its impact on the overall state economy and found that the program has boosted the state economy by more than \$23.5 billion since 1989.¹²² From 2007 through 2011, BFTP is attributed with generating a total of 20,200 jobs and \$3.60 of new tax revenue for every \$1 invested in the program.¹²³

Case Study: Greentown Labs' Manufacturing Initiative Keeps Manufacturing Local

Greentown Labs provides co-located prototyping, event, and office space to meet the needs of hardware-focused advanced energy startups.¹²⁴ Through its Manufacturing Initiative, Greentown Labs establishes relationships with manufacturers across Massachusetts and then connects startups with those manufacturers.¹²⁵ The goal is to entice Massachusetts startups to work with local manufacturers as they scale up, instead of looking outside the Commonwealth.¹²⁶ In addition to connecting startups and manufacturers, Greentown Labs provides assistance with design for manufacturing, product development, and sales and pitching.¹²⁷ Since its founding, Greentown Labs has incubated over 120 startups, leading to the creation of more than 900 jobs and \$260 million in investment.¹²⁸

Access to Capital

Policy 4: Simplify Access to Sources of Capital

Barrier

For first-time entrepreneurs, navigating the array of funding options to find sufficient capital can be onerous.¹²⁹ One reason this process can be so complicated is that investment options vary based on what stage of development the company is in. A company that has yet to develop a prototype would have very different funding options than a company that was nearly ready to go to market with its product. Because so many entrepreneurs struggle with securing funding, Coursera, the leading provider of online courses, offers a four-week online class focused solely on startup funding.¹³⁰ Entrepreneurs in Wyoming do not have any readily available tools to help them navigate the myriad of financing options available across the state and around the country.

Solution

Wyoming's leaders could create a simple online capital locator tool to help entrepreneurs identify the type of capital that is appropriate for their company's maturity level and industry. The tool would consolidate the sources of funding found both in-state and nationally and be filtered by industry and maturity level. The newly launched Wyoming Invests Now crowdfunding resource, which provides an opportunity for Wyoming investors to finance in-state companies, could be a central feature of the capital access tool.¹³¹ The tool could also consolidate the in-state entrepreneurial resources available by type and region, such as incubators, accelerators, and mentor programs (*see case study*). Collecting this information in one easy-to-use place and allowing users to filter the information in useful ways could save entrepreneurs valuable time. Furthermore, it could connect entrepreneurs with funding options

and entrepreneurial support they may not have found on their own. This is especially important in a state with such a dispersed population.

Key Players

Wyoming Business Council, Incubators, NGOs, Wyoming Secretary of State, Wyoming Invests Now

Case Study: Michigan Economic Development Corporation's Capital Locator Tool

Michigan has simplified the process of looking for funding by creating a free capital locator tool. Hosted by the Michigan Economic Development Corporation, the tool lists roughly 150 potential sources of capital.¹³² The tool divides the sources by category: venture capital firms, commercial banking resources, state programs, federal programs, web resources, business plan competitions, and business services.¹³³ Entrepreneurs can utilize the tool to narrow down the funding sources by the stage of businesses they fund. Specifically, users can identify whether they are looking for funding for a business in the idea stage, the startup stage, the growth stage, or the mature stage. Additionally, the tool offers the ability to filter capital sources by thirteen industries, including alternative energy.¹³⁴

Policy 5: Establish a Technology Maturation Loan Fund to Fill Financing Gaps

Barrier

Early-stage technology, such as carbon tech, needs maturation before it can be commercialized; prototyping and testing in simulated or actual conditions to de-risk the technology must be completed to attract commercial investment.¹³⁵ Venture capital firms and angel investors shy away from investing in technology that has not matured or has not yet proven to have commercial applications.¹³⁶ This shortage of funding opportunities, often called the “valley of death,” causes many promising innovations from reaching commercialization. Twenty-five U.S. states are funding at least one program that aims to mature locally developed technologies to benefit the state economy.¹³⁷ Wyoming does not fund any programs addressing this gap and is missing out on the economic benefits of homegrown innovations.

Solution

Wyoming could consider establishing a dedicated loan fund to increase the number of promising innovations that reach commercial development in the state. The State Legislature could create a new technology maturation loan fund (TMLF) to serve this purpose. This financing can be structured as low-interest, non-recourse loans on a two-year repayment cycle and converted into equity when the company secures its next round of private financing (*see Maryland case study*). If the resulting intellectual property leaves the state or is licensed out of state, the funds should be payable immediately. The TMLF could eventually be self-funded by liquidity events. To limit risk, the loans could be tranching or structured so that specific amounts of funds were released at set milestones. The goal of this program should be to establish cooperative development and engage in private sector partnerships to drive investments, possibly aiming for a 1:1 match of funds from outside sources. The TMLF should be managed by a team of scientists as well as industry and finance experts, who are well equipped to evaluate technology commercialization potential and the likelihood of success. It should have full transparency and be subject to regular

audits. Alternatively, the state could establish a technology commercialization fund that provides grants to companies, rather than loans, like Utah's successful USTAR program (*see case study*).

Key Players

Wyoming Legislature, Wyoming State Treasurer, Scientists, Industry, Capital Investors

Case Study: Maryland's Technology Commercialization Fund

Maryland launched its Technology Commercialization Fund (TCF) in 2004 to support companies as they develop and market innovations.¹³⁸ The TCF offered convertible notes in two tranches to companies that need funding for product development and technology commercialization.¹³⁹ Interest on the convertible notes was charged at 8 percent.¹⁴⁰ As of December 2016, the TCF provided \$12 million in funding to 176 companies, which then went on to earn more than \$532 million in downstream funding.¹⁴¹

Case Study: Utah's USTAR Technology Acceleration Program

The Utah Science Technology and Research (USTAR) initiative is a comprehensive cluster-based program that supports Utah's technology innovation pipeline.¹⁴² In 2016, USTAR launched the Technology Acceleration Program to support private-sector companies advancing new technologies at the proof of concept, validation, and early product development stages.¹⁴³ Companies must be Utah-based and have fewer than fifty employees to apply for this grant-based program.¹⁴⁴ Grants were structured to be available on a rolling basis and were not capped.¹⁴⁵ Additionally, all grantees gained access to USTAR's broad partner networks.¹⁴⁶ This grant program complements the Technology Commercialization and Innovation Program, which provides grants to small businesses and university teams that are commercializing their technology.¹⁴⁷

Policy 6: Appoint a Foundation Liaison to Increase Funding for Business Competitions

Barrier

Business plan competitions are a powerful tool to increase innovation, create jobs, and incentivize budding entrepreneurs to take the plunge to bring their idea to reality. These competitions have immense benefits: In one study, entrepreneurs who participated in business competitions created double the number of jobs, generated twice as many sales, and raised nearly three times as much capital as compared to those startup ventures that did not.¹⁴⁸ However, in Wyoming, there are few state-based and local business plan competitions. The prize money is not sufficient to entice the biggest, boldest ventures to compete, and some are only open to a small segment of the population, such as students.¹⁴⁹ The NRG-COSIA Carbon XPRIZE is an example of a global competition for startups in the carbon tech space that offers a large prize and Wyoming-based facilities to test and prove technology.¹⁵⁰

Solution

Wyoming could appoint a foundation liaison to connect with and broker support from philanthropic foundations to increase funding for business plan competitions. The state is home to many charitable organizations, which share the goals of supporting youth education, fostering arts and culture, promoting public health, and serving the needs of communities.¹⁵¹ In 2015, the

state hosted 301 Wyoming-based foundations, which raised \$1.2 billion in revenue.¹⁵² The foundation liaison could also attract and solicit support from national philanthropic organizations with potential interests in Wyoming, such as those wanting to support displaced coal workers. By opening up competitions to all Wyoming residents and increasing the prize money, the state can spur more high-potential ventures.

The Governor's Office could reach out to the leading foundations in the state and enlist their help in appointing a foundation liaison and contributing a portion of the liaison's salary. This nonpartisan, state-level position could work closely with the state's various entrepreneurship stakeholders to leverage their network and expertise. Key priorities of the foundation liaison could include identifying gaps in the existing business competition ecosystem, conducting market research to identify the exact type of competition and the size of prize money to entice the greatest participation, and establishing relationships with program-related investments (PRIs) and mission-related investments (MRIs) to help fund the competition winners (*see call-out box*). The foundation liaison could also help secure funding for the venture catalysts suggested in Policy 2. Through this position, Wyoming and the grantmaking community could leverage one another's investments and efforts, working together to support in-state business, innovation, and jobs.

Key Players

Wyoming Governor, Philanthropic Community

Case Study: Michigan Governor's Office of Foundation Liaison

As the first of its kind in the nation, the Michigan Governor's Office of Foundation Liaison (OFL) builds funding partnerships and strategic collaborations between the state government and the philanthropic community to support programs that improve education and health for all Michigan residents.¹⁵³ Foundations are actively engaged throughout OFL activities. The nonpartisan Foundation Liaison comes to the state government on loan from participating foundations while contributing funders and nonprofits partly comprise the OFL Advisory Committee.¹⁵⁴ Since 2003, OFL has brokered investments from seventeen foundations, totaling more than \$150 million.¹⁵⁵

Case Study: Newark Philanthropic Liaison

Based on the success of Michigan's OFL, the Council of New Jersey Grantmakers and the City of Newark established the city's first Philanthropic Liaison in 2007.¹⁵⁶ In close partnership with the Office of the Mayor, the Office of the Newark Philanthropic Liaison garners and leverages support for public projects from the grantmaking community.¹⁵⁷ From 2007 to 2016, the office brokered over \$50 million in philanthropic investments for initiatives, such as expanding summer youth employment and improving community literacy.¹⁵⁸

START CALL-OUT BOX

Program-Related Investments and Mission-Related Investments

In addition to brokering support for business competitions, Wyoming's foundation liaison could connect with foundations to target their investments toward early-stage companies and small businesses with limited financial capital for growth and development. Foundations are able to make two kinds of investments that offer long-term capital to companies; these are known as a

program-related investments (PRI) and mission-related investments (MRI).¹⁵⁹ PRIs and MRIs are investments made by a foundation in the pursuit of its philanthropic goals, not primarily to generate returns.¹⁶⁰ The investment can be a loan, equity investment, or guaranty that benefits a for-profit business or a nonprofit organization.¹⁶¹ Because foundations can prioritize the impact of the investment rather than narrowly looking at the direct market return, they can invest in high-risk, cutting-edge technologies, such as carbon tech, and provide capital on longer timelines than traditional financing options.¹⁶² For instance, PRIME Coalition, a national nonprofit that serves as an intermediary investment vehicle, solicits PRIs from major philanthropic organizations and re-invests that capital in early-stage energy technology companies.¹⁶³ The Bill & Melinda Gates Foundation is just one example of a foundation that has been focusing heavily on long-term investments, having \$1.5 billion dedicated to PRIs around the globe.¹⁶⁴

END CALL-OUT BOX

Policy 7: Establish a Fund of Funds

Barrier

In 2015, Wyoming's small businesses employed 62 percent of the private workforce, yet early-stage companies and small businesses have limited financial capital for growth and development.¹⁶⁵ These companies tend to lack physical assets that can be leveraged for bank loans, which is an issue that is particularly acute for new technologies that may be costly to develop and exhibit longer commercialization periods, like carbon tech.¹⁶⁶ Wyoming lacks a range of capital resources to support these startups, particularly venture capital investment dollars. From 2011 to 2016, there were no venture capital investment deals made in Wyoming.¹⁶⁷ In 2017, Wyoming was ranked in a national survey as the fifth worst state for startup funding.¹⁶⁸ These data indicate Wyoming's need for an active investment environment that offers multiple sources of funding.

Solution

Wyoming's leaders could establish a fund of funds and encourage top investors to devote their capital to companies in Wyoming, thereby increasing access to capital for in-state businesses. A fund of funds is a fund that invests in other investment funds as opposed to investing directly in stocks, bonds, and other securities.¹⁶⁹ Because a fund of funds has a diverse portfolio, investors are better protected from high-risk investments and exposed to more ventures.¹⁷⁰ A fund of funds not only fosters the state's investment community but also increases access to capital for in-state businesses. Wyoming can look to different successful models in Illinois, Utah, and Wisconsin to stimulate investment and grow its economy (*see case studies*).

State leaders could consider improving on these successful models in a few ways to achieve certain goals. Since high-tech hardware products can take many years to develop fully, Wyoming could encourage fund of fund managers to make patient capital investments. Patient capital refers to funds invested in a company for the long term to allow technologies with longer development horizons to grow into valuable investments. The fund of fund managers could also look to evaluate fund performance by looking at comprehensive returns to the economy and state revenues, as private funds in other states have done.¹⁷¹ Comprehensive returns include both direct financial returns from an investment and the indirect economic development returns from

that investment. These returns are important to value and track since the goal of a fund of funds would be to produce both financial and economic development returns.

The fund of funds' managers could ensure that the fund of funds achieves the goal of increasing investments in Wyoming by setting managing criteria to govern how the funds are invested. The fund's managing criteria could include to (1) invest in Wyoming companies, (2) provide comprehensive returns, (3) hold investments in excess of five years, and (4) invest in advanced technologies. Encouraging investments in a wide variety of local companies will help bring the state's best ideas to the market and build thriving businesses in Wyoming.

Key Players

Wyoming Legislature, Capital Investors

Case Study: Illinois' Fund of Funds

Illinois first began investing in venture funds in 2002, using funds from the \$13 billion invested by the state treasurer.¹⁷² The fund invests no more than 15 percent in any given venture or private-equity fund, which then, in turn, invests in high-potential startups.¹⁷³ The state receives a financial return for its investments, with past rates of financial return around 6 percent.¹⁷⁴ Since 2005, Illinois has channeled \$66 million of state funds into eighteen private investment funds.¹⁷⁵ These investments have supported almost 6,300 new Illinois jobs.¹⁷⁶ In 2016, Illinois refinanced its fund of funds with \$222 million, which is expected to create over 18,000 jobs.¹⁷⁷ An advisory board oversees the investments, which are targeted towards local technology and bioscience companies.¹⁷⁸

Case Study: Utah's Fund of Funds

The Utah Fund of Funds program was established in 2003. This \$300 million economic development program is managed by a nonprofit, quasi-governmental organization (Utah Capital Investment) rather than a third-party firm.¹⁷⁹ This structure allows for greater capacity to directly engage with entrepreneurs, businesses, venture capital, and private equity funds. As of February 2016, Utah's twenty-eight partner funds have invested \$723 million in sixty-seven Utah companies, supporting over 2,700 new jobs.¹⁸⁰

Case Study: Wisconsin's Badger Fund of Funds

Wisconsin's Badger Fund of Funds demonstrates another model for attracting venture capital: public venture capital fund of funds. In 2013, Governor Scott Walker signed legislation to approve \$25 million to seed the Wisconsin Badger Fund of Funds.¹⁸¹ The state required that an additional \$5 million be raised from private investors, and the Fund of Funds far exceeded that requirement, raising \$10 million from private individuals and institutions.¹⁸² For every \$4 invested in a venture capital fund, that fund must raise an additional \$6 from other investors.¹⁸³ As of mid-2017, the Badger Fund had invested in three private venture capital funds, which in turn would invest the money into early-stage companies; the authorizing legislation required these companies to employ at least 50 percent of their full-time staff in Wisconsin.¹⁸⁴ This bipartisan program is already sending strong signals to entrepreneurs and investors that Wisconsin is committed to attracting venture capital and talent to the state.¹⁸⁵

Workforce Development

Policy 8: Increase Apprenticeships for High School Students

Barrier

Wyoming has room for improvement in preparing its youth for the jobs of the future and providing a pathway to these fulfilling careers. Although the high school graduation rate in Wyoming was 80 percent during the 2015-2016 school year, the state lagged almost four percentage points behind the national average.¹⁸⁶ In 2016, Wyoming ranked thirty-ninth in the United States by high school graduation rates.¹⁸⁷ Today, critical challenges persist across Wyoming's high schools, with underserved communities lagging behind; for example, Native American students on the Wind River Reservation graduated at a rate of 63 percent in 2017.¹⁸⁸ Paired with this challenge is the fact that Wyoming ranks forty-fourth in the country for the number of apprenticeships per capita.¹⁸⁹ The end result has a negative ripple effect across the state economy: Without a sufficient pipeline of highly skilled local workers, Wyoming will struggle to position itself at the forefront of the growing carbon tech industry and advanced manufacturing.

Solution

To ensure the competitiveness of its future workforce and help more students graduate, Wyoming could foster more apprenticeship opportunities for its youth. Apprenticeships that begin in high school offer many benefits, including increasing student classroom engagement, providing avenues for students to learn practical skills, and offering opportunities to pilot different career tracks.¹⁹⁰ High school apprenticeships have been associated with a more than 20 percent increase in the high school graduation rate.¹⁹¹ For employers, the benefits include lower costs compared to hiring and training permanent staff, improved retention, and increased visibility among soon-to-be graduates who are potential future employees.¹⁹² Establishing apprenticeship career pathways in high schools can further bolster Wyoming's high school education system and increase the number of STEM-trained graduates available to support Wyoming's carbon tech industry.

Wyoming could increase the number of apprenticeships offered in the state by establishing regionally or locally coordinated apprenticeship programs based on Wisconsin's successful model (*see case study*). Alternatively, Wyoming could encourage interested employers to offer apprenticeships by offsetting their cost of the apprenticeship to those employers; this method has been successfully used by leaders in South Carolina (*see case study*). Another strategy to entice employers to offer apprenticeships would be to expand eligibility requirements for the business training grants offered by the Wyoming Workforce Development Training Fund to include youth apprenticeships.¹⁹³ In so doing, the state would offset the cost of apprenticeships to interested employers and empower students to benefit from this apprenticeship opportunity.

Key Players

Wyoming Department of Education, Wyoming Community College Commission, Wyoming Legislature, Wyoming Governor, Wyoming Business Council, Manufacturing-Works

Case Study: Youth Apprenticeships in Wisconsin

With its program originating in the early 1990s, Wisconsin was one of the first states to support youth apprenticeships for high school students. Participating students enroll for one or two years and must complete 450 hours of work-based learning annually.¹⁹⁴ As part of the work-based component, students are assigned a worksite mentor who provides them with regular feedback on their work and progress.¹⁹⁵ Many programs also take place year-round, so it is common for students to work over the summer.¹⁹⁶ Supplementary classroom learning is provided by trained instructors with relevant field expertise, and apprenticeships are offered in a wide variety of workplaces, from agriculture to information technology.¹⁹⁷ Each program has learning goals established by a local coordinating body.¹⁹⁸ With \$3.9 million in state funding, matching funds from local consortia, and a cost limit of \$900 per student, Wisconsin's Youth Apprenticeship program will have supported over 4,300 students in the 2017-2018 school year.¹⁹⁹ The program has been remarkably successful in driving outcomes: In 2013, the program resulted in offers of employment to 84 percent of students who completed their apprenticeship.²⁰⁰

Case Study: South Carolina's Apprenticeship Tax Credit

South Carolina has demonstrated one path to incentivize businesses to participate in youth apprenticeship programs. The state's apprenticeship system offers a modest \$1,000 tax credit per apprentice per year to help offset planning and administration costs.²⁰¹ In order to count towards the credit, an apprentice must be employed for at least seven months each year of their program, for up to four years.²⁰² In addition to the tax credit, administrative assistance from the state's Apprenticeship Consultants helps to increase program uptake by providing dedicated experts who work with businesses interested in establishing apprenticeships in the state.²⁰³ The system has served over 26,000 apprentices.²⁰⁴

Policy 9: Retain Wyoming's Brightest Students

Barrier

Wyoming is losing its best and brightest students, workers, and future leaders as many young people leave the state. From 2014 through 2017, nearly 15,000 more people moved out of the state than in.²⁰⁵ This trend is particularly pronounced among educated Wyoming residents: According to the most recent American Community Survey data, over 63 percent of out-migrants from Wyoming had at least some college education.²⁰⁶ As this talent exits the state, businesses struggle to find skilled workers, leading to enormous challenges recruiting firms to the state, including potential carbon tech manufacturers.²⁰⁷ Wyoming's Hathaway Scholarship program tries to address this challenge: By providing a range of merit-based scholarships for qualifying Wyoming students, it provides an incentive for talented Wyoming students to get their degree in-state.²⁰⁸ However, the state does not provide an incentive for students to stay in Wyoming after they graduate. A 2017 study found that 57 percent of the state's college graduates leave after attaining their degrees, the eleventh-highest rate in the nation.²⁰⁹

Solution

Wyoming could provide an incentive for the best and brightest Wyoming students to stay in the state by converting a portion of the Hathaway Scholarship program into a forgivable loan program. Instead of reducing students' tuition, the program could provide interest-free cash loans of equal value. After graduating, a student's loan balance could decrease by a portion for each year they continue to live in Wyoming. By tying loan forgiveness to post-graduation Wyoming

residency, the state can ensure that the money it spends educating talented students truly benefits the state long-term, as is done in Maine (*see case study*). At the same time, Wyoming students would still be able to count on the Hathaway Scholarship funds to help them pay for college. By tying the Hathaway Scholarship program to in-state residency, Wyoming would create a powerful incentive to keep future managers, engineers, and scientific researchers of its carbon tech industry in the state. Doing so will unleash a virtuous circle—enticing carbon tech firms to set up shop in Wyoming to take advantage of this homegrown talent.

Key Players

Wyoming Department of Education, Wyoming Legislature, Wyoming Governor, Wyoming Department of Revenue, Wyoming Department of Workforce Services

Case Study: Opportunity Maine

In 2008, Maine established the Opportunity Maine program to retain college graduates and recruit newcomers to the state in response to the pressure of an aging workforce and a high rate of “brain drain.”²¹⁰ The program provides individuals or employers with a tax credit for student loan payments.²¹¹ Eligible candidates include graduates who work and pay taxes in Maine for at least nine months out of the year.²¹² Individuals receive refundable tax credits for associate and bachelor's degrees in STEM fields, while non-STEM degree recipients and graduate degrees earned in Maine are nonrefundable, carrying forward for up to ten years.²¹³ If an employer pays the employee's monthly student loan balance, the value is deducted from the state tax return. There is a cap of \$377 per month for individual credit, but there is no credit cap if the employer pays.²¹⁴ The program was expanded in 2016.²¹⁵ While not attributable to the Opportunity Maine program alone, Maine was ranked second in the nation for domestic net migration of people with a bachelor's degree or higher from 2010 to 2014.²¹⁶

Policy 10: Improve Soft Skills Training for High School Students

Barrier

In a 2013 survey of 500 U.S. business leaders, 44 percent of executives identified soft skills such as critical thinking, communication, teamwork, and punctuality as lacking among new hires and job candidates.²¹⁷ This skills gap has directly impacted Wyoming's businesses. In a 2015 survey, less than 50 percent of Wyoming employers were satisfied with new hires' work skills, which included metrics such as critical thinking and reading comprehension.²¹⁸ Wyoming could more effectively address the widespread lack of workforce readiness through intervention at its high schools, where state leaders have already identified a need for comprehensive workforce training.²¹⁹ While business leaders have begun to leverage the Wyoming Excels initiative to combat this issue, there remain further opportunities to boost youth academic engagement and workforce readiness.

Solution

Wyoming could pilot West Virginia's successful simulated workplace model across its high schools to help students gain professional skills and prepare for real-world job expectations (*see case study*). In a simulated workplace, students receive technical training in an environment designed to mimic that of a real company.²²⁰ Through industry partners, program organizers can integrate the professional needs of local employers.²²¹ For example, students may have to apply

and interview to enroll in the class, clock in on time, undertake leadership positions, submit quarterly and annual reports, and participate in random drug testing.²²² By offering students “on-the-job training” and insights into potential employer expectations, simulated workplaces could keep students involved in school and engaged in the workforce post-graduation.

Key Players

Wyoming Department of Education, Wyoming Legislature, Wyoming Governor, Wyoming Business Council, Wyoming Department of Workforce Services

Case Study: Simulated Workplaces in West Virginia

The West Virginia Department of Education established the first simulated workplaces in 2013 to address local business leaders’ need for workers with both technical and professional skills, ranging from punctuality to safety.²²³ Funding from the state’s workforce development board and employer engagement mobilized by the West Virginia Chamber of Commerce helped drive the program’s initial success.²²⁴ Students play the role of employees to transform the classroom into a business environment for technical training, and all simulated workplaces adhere to twelve guidelines designed in partnership with business experts to mimic the needs of West Virginia employers.²²⁵ The model has since been scaled up to support roughly 24,000 students in over 1,200 classrooms each year.²²⁶ Simulated workplaces have a significant impact on student achievement: 37 percent of high school seniors completed a technical degree program in 2016, more than double the percentage in 2010, and 98.4 percent of participants graduate drug-free.²²⁷ Ninety-six percent of students were satisfied with the program while employers gave overwhelming approval of the program and its outcomes.²²⁸

Policy 11: Formalize Industry-Led Job Training Programs for Carbon Tech

Barrier

Forthcoming investments in the Integrated Test Center (ITC), iPark, and future carbon tech research facilities and the resultant spinoff companies will require skilled workers with the knowledge and capabilities to drive forward advanced carbon manufacturing and materials development. Since many carbon-based technologies are still in development, Wyoming will need to identify the skill sets carbon tech workers need and design training programs to entice companies in this emerging technology sector to locate and expand in the state.

Solution

Wyoming’s Workforce Development Priority Economic Sector Program is an excellent first step toward establishing industry-led job training programs. Under this program, the Wyoming Department of Workforce Services will foster partnerships between businesses, the state, and a training provider to provide employees with education and training for strategic industries, which may include carbon tech.²²⁹ The state will provide a matching grant for each full-time and part-time position that requires additional training.²³⁰

Wyoming can take these efforts to the next level by formalizing these partnerships and establishing an industry-led council to help coordinate training and ensure that a future pipeline of workers is available to meet carbon tech industry needs. The council could work in collaboration with leading research facilities in the state, such as the Carbon Engineering

Initiative at the University of Wyoming and the iPark, to identify emerging processes and technologies and to help establish relevant credentials and training pathways in carbon tech manufacturing.²³¹ The council could look to similar organizations in Kentucky and Massachusetts for best practices to adopt, such as apprenticeships and credential pathways (*see case studies and Policy 8*). Doing so will provide a feedback loop to ensure that Wyoming workers are trained for the exact types of jobs carbon tech employers have available.

Key Players

Wyoming Department of Education, Wyoming Legislature, Wyoming Governor, Wyoming Business Council, Wyoming Department of Workforce Services, Wyoming Community College Commission, Manufacturing-Works

Case Study: Kentucky Federation for Advanced Manufacturing Education (KY FAME)

KY FAME is a partnership of regional manufacturers who have created dual-track apprenticeship programs in collaboration with Kentucky's higher education network. KY FAME is divided into regional chapters organized around local manufacturing clusters, allowing programs to be customized to the needs of specific employers and regional economic conditions.²³² Students spend a combined forty hours per week working for a partnership member and taking classes at a community college.²³³ Most students earn enough to graduate debt-free.²³⁴ After five semesters, students receive an A.A.S. in Industrial Maintenance Technology-Advanced Manufacturing Technician Track.²³⁵ KY FAME was named the "Best Career Program in the U.S." in 2013 by the U.S. Department of Labor and has been replicated in seven states.²³⁶

Case Study: Massachusetts' Manufacturing Advancement Center Workforce Innovation Collaborative (MACWIC)

MACWIC was founded in 2012 to help improve the coordination of manufacturing-related training programs in the state.²³⁷ Led by manufacturing employers of all sizes in collaboration with a number of educational institutions, MACWIC's membership has grown from forty to just over 200 firms.²³⁸ One of MACWIC's core achievements is the Applied Manufacturing Technology Pathway Certification, a five-tiered series of consecutive training modules offered at area community colleges, vocational-technical high schools, and other organizations.²³⁹ This credential pathway includes multiple entry and exit points, provides opportunities for work-based learning, and helps workers progress from as low as middle school-level math and reading skills to completing an associate degree in manufacturing technology. The pathway certification is also officially registered as a CNC Machine Operator apprentice program with the state's Division of Apprentice Standards.²⁴⁰ MACWIC has been recognized as an excellent model of industry-led coordination by Massachusetts Institute of Technology, Jobs for the Future, and the Center for Law and Social Policy (CLASP).²⁴¹

Value Chain

Policy 12: Build a Comprehensive Carbon Tech Cluster Partnership

Barrier

Wyoming is home to a growing community of carbon tech research and innovation centers and is attracting world-class researchers to the state. Yet no comprehensive action plan exists for the diverse constituents of the carbon tech industry to coordinate efforts to grow a cluster and translate these efforts into meaningful economic development. Indeed, virtually every successful cluster—both domestically and internationally—was developed through deliberate policy, a clear strategy, and a set of collaborative stakeholders who drove the cluster development process forward.

Solution

Wyoming's nascent carbon tech industry could benefit from the creation of a formal public-private partnership specific to carbon tech, wherein industry executives join together with existing research centers, industry associations, NGOs, and government leaders to create a specific plan for growing the cluster. Doing so will position Wyoming to enjoy the benefits of cluster-based development: Workers within a cluster receive wages about 6 percent higher than workers employed in the same industry but outside of a cluster; additionally, clusters help small- and medium sized-companies—a mainstay in Wyoming—overcome size limitations to grow and thrive.²⁴²

The partnership could take the lead on enabling collaboration across the value chain in areas such as knowledge sharing, asset growth, policy advocacy, and cluster development. Specifically, this public-private partnership could conduct a variety of inward- and outward-facing activities to support its participants and grow the industry. Inward-facing activities could pursue shared interests through internal coordination, such as:

- Mapping the supply chain and broader value chain of the state's carbon tech industry to serve as a business resource, marketing asset, and recruitment tool, using Wisconsin's Supply Chain Marketplace as a model (*see case study*).
- Identifying skill areas employers most need to create industry-specific worker training programs.
- Advocating for actions such as targeted foreign direct investment recruiting (*see Policy 15*).
- Developing a shared research agenda that tackles industry challenges.
- Collaborating on large regional and federal contract opportunities.

Outward-facing activities could help to communicate the industry's economic impacts and market opportunities by:

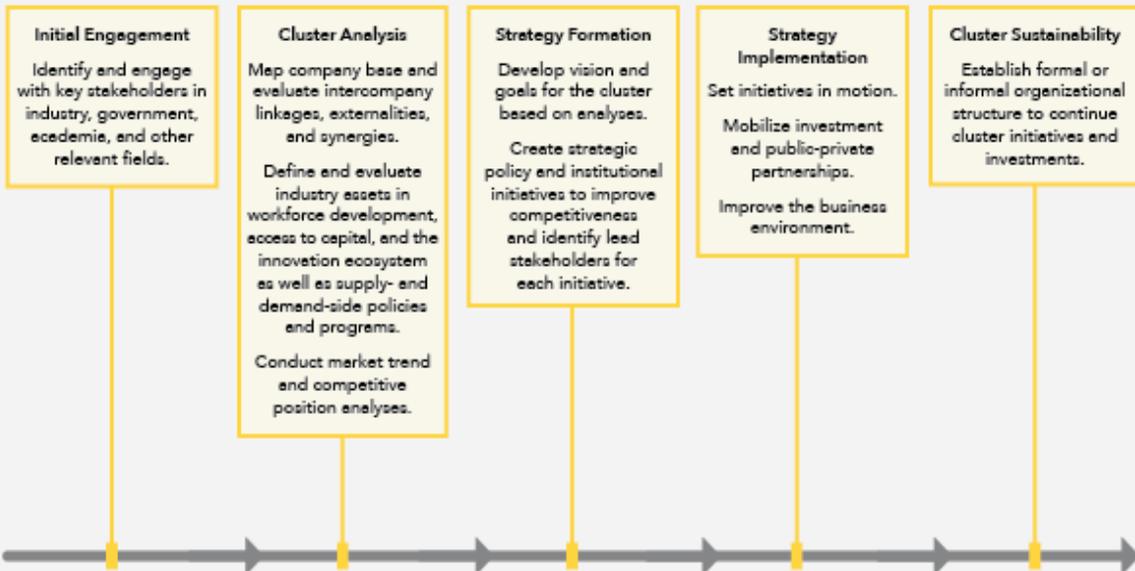
- Conducting a cohesive and high-impact outreach campaign to promote the state's assets in carbon tech (*see Policy 13*).
- Hosting knowledge-sharing events for policymakers and other stakeholders.
- Organizing research projects and hackathons to solve industry challenges.
- Supporting participation in trade shows and networking events.
- Leveraging relationships with manufacturers to help startups develop an initial customer base.
- Facilitating out-of-state funding opportunities for startups (*see Arizona case study*).
- Advocating for policies that increase demand for carbon tech and support business development.

The partnership could engage and draw on the existing resources, expertise, and networks that are working to advance the interests of carbon tech companies in the state. Wyoming could look to North Carolina and Kansas as strong public-private partnership models for cluster development (*see case studies*).

Once the partnership has solidified a cluster growth plan, it could formalize and create a Carbon Tech Center of Excellence to oversee ongoing initiatives. Centers of Excellence, when structured in tandem with industry, are an effective means to coordinate industry-wide growth efforts. Wyoming could replicate the successful model from South Carolina (*see case study*). A Carbon Tech Center of Excellence would signal Wyoming’s commitment to cultivating the cluster in the state and would create the buzz that the state’s industry needs to attract investment.

Wyoming’s Carbon Tech Partnership

Wyoming’s carbon tech partnership could be a key driver of cluster development, convening stakeholders and resources to engage in strategic initiatives.



Key Players

Wyoming Governor, Wyoming Business Council, Local Economic Development Organizations, Wyoming Infrastructure Authority, Western Research Institute, Industry, University of Wyoming School of Energy Resources, NGOs

Case Study: Wisconsin Supply Chain Marketplace

The Supply Chain Marketplace is a dynamic online platform for Wisconsin suppliers to engage new customers and to facilitate buyer connections, supporting local business growth and providing access to new market opportunities. The Marketplace is open to all businesses free of charge, where suppliers can showcase their business capabilities; be readily searchable to potential buyers by targeted industry sectors, certifications, and ownership; and access requests for proposals and calls for innovation.²⁴³ The Supply Chain Marketplace was initially launched by New North, the northeast Wisconsin economic development group, as a regional economic diversification asset, with support from the U.S. Department of Defense's Office of Economic Adjustment.²⁴⁴ In 2017, the state awarded \$99,000 to New North to expand the platform statewide, and it now boasts over 1,000 local businesses.²⁴⁵

Case Study: Arizona's BioAccel

Based in Phoenix, Arizona, BioAccel is a nonprofit organization dedicated to providing funding and entrepreneurial expertise to life science companies.²⁴⁶ A main goal of the organization is to foster an entrepreneurial ecosystem through education, outreach, training, and mentorship. Since over 95 percent of venture funding for bioscience comes from outside the state, bioscience companies relocate from Arizona to wherever capital is available.²⁴⁷ BioAccel helps combat this trend by providing proof-of-concept and seed funding to bioscience startups and facilitating later-stage financing from local venture funds when appropriate.²⁴⁸ Since its inception in 2009, BioAccel has helped launch seventeen firms.²⁴⁹

Case Study: North Carolina's Cleantech Cluster

North Carolina's Research Triangle Regional Partnership—an association of economic development agencies in the state's Research Triangle region—founded the Research Triangle Cleantech Cluster (RTCC) as a way to strategically engage industry leaders in the regional development of the cleantech industry.²⁵⁰ Notably, while RTCC's Advisory Council bridges the public-private divide by drawing from industry, academia, and government, the Board of Directors that steers the cluster is composed exclusively of business leaders.²⁵¹ This organizational structure positions industry players to contribute valuable insights and to substantially influence the industry's regional growth strategy. Among other technology areas, RTCC strategically targeted the smart grid industry for growth and engaged local anchor companies to spearhead efforts to build the state's cluster.²⁵²

Case Study: Kansas Aviation Research & Technology Growth Initiative

The Kansas Aviation Research & Technology Growth Initiative aims to fortify the state's robust aerospace industry by leveraging university expertise, industry leadership, and government funding. Based at Wichita State University's National Institute for Aviation Research (NIAR), the program uses \$5 million from the Kansas Department of Commerce and requires matching funds from industry, university, and philanthropic partners to support industry-driven research projects and equipment/infrastructure upgrades at NIAR.²⁵³ The executive committee is comprised of the state's anchor companies and identifies research projects based on industry needs and the potential for improved competitiveness.²⁵⁴

Case Study: Clemson University International Center for Automotive Research (CU-ICAR)

CU-ICAR is an automotive center of excellence dedicated to quality education, industry-focused research, public outreach, and economic development.²⁵⁵ The center anchors South Carolina's automotive cluster and grew out of early discussions with BMW on how to stimulate technology commercialization and build a local skilled workforce. The South Carolina Department of Commerce provided an initial investment of \$40 million and other founding partners across government, academia, and industry—including BMW, Michelin, and Timken—have contributed follow-on funding.²⁵⁶ CU-ICAR houses the only U.S. graduate program in automotive engineering and has seven strategic research areas derived from industry needs.²⁵⁷ With over twenty campus partners, CU-ICAR actively engages its network to locate and collaborate on commercial R&D projects, to support graduate student internships and capstones, to lease office spaces, and to leverage the center's commercial-scale equipment and testing services.²⁵⁸ Since 2003, the center has attracted \$250 million from public and private investments, supported 770 on-campus jobs and thousands more across partner companies, and channeled hundreds of graduates into automotive jobs, while keeping a quarter employed in the state.²⁵⁹

Policy 13: Broadcast Wyoming's Business Assets

Barrier

From its stunning physical landscape to its business-friendly climate and problem-solving spirit, Wyoming has much to offer firms considering expansion or relocation. However, the state marketing materials do little to broadcast these advantages to executives regionally and around the United States. While the state's polished pitch to tourists succeeds in selling Wyoming as a potential vacation destination, the state lacks a consistent and impactful brand that gives corporate recruitment prospects a sense of the benefits of locating in the state. The Wyoming Business Council's website and social media properties lack the kind of visual assets that can make a deep impression on viewers; meanwhile, the website makes it difficult for decision-makers to find useful information.²⁶⁰ Without more proactive, skilled, and evocative storytelling of its business advantages to a wide audience, Wyoming risks going unnoticed by recruitment prospects and will be bypassed in favor of its neighbors.

Solution

The starting point for an improved marketing strategy could be a new Wyoming brand that reflects the state's business-friendly environment and frontier spirit of self-reliance. This brand could be placed front and center on a revamped, world-class Wyoming Business Council website. Research shows that a visually-appealing, user-friendly website is the most important component of an effective economic development marketing strategy, and the state could improve its current online presence by enhancing its landing page while making information about incentives and site locations easier to access.²⁶¹ Wyoming could create a stronger connection with visitors by adding images of the state's unmatched natural splendor, which are currently underutilized on Wyoming's web properties. Finally, Wyoming could dedicate professional marketing resources to oversee these initiatives and focus on business recruitment. The experiences of Tennessee and South Carolina show how modest investments in brand strategy followed up with a digital media campaign aimed at small- and medium-sized business leaders can bring jobs and investment to a state (*see case studies*).

Key Players

Wyoming Business Council, Wyoming Legislature

Case Study: Mastered in Tennessee

In 2015, Tennessee launched its award-winning “Mastered in Tennessee” campaign.²⁶² The campaign used a state-of-the-art website, high-quality video content, and an active presence on all major social media channels to showcase the quality of Tennessee’s artisanship.²⁶³ To build these assets, Tennessee contracted with a local design firm.²⁶⁴ Their website includes a visually stunning landing page, easily available site selection information, and navigable menus offering a variety of content depending on the site visitor’s industry.²⁶⁵ Tennessee supported these assets with an annual investment of \$600,000 in highly targeted digital advertising.²⁶⁶ The state’s investment paid off; in 2016, Tennessee led the nation in small business job growth.²⁶⁷ In a recent survey of economic development organization members, Tennessee was rated the third highest of all fifty states in economic development marketing program success.²⁶⁸

Case Study: South Carolina is “Just Right”

South Carolina also has one of the best-regarded economic development marketing programs in the country. It is not surprising: Their website is appealing and clear, with a wealth of relevant information that is easy to find for all kinds of businesses. South Carolina’s program began with the creation of a statewide brand, “Just Right.” With uniform messaging and a consistent look and feel across all assets and communications, South Carolina’s marketing team has over-performed. In 2014, South Carolina’s economic development team directly won 146 projects, representing \$5 billion in investment and leading to the creation of over 19,000 jobs.²⁶⁹

Policy 14: Leverage the High-Speed Internet Opportunity in Local Communities

Opportunity

In early 2018, the Wyoming Legislature allocated \$10 million to create a statewide broadband funding program and \$350,000 to establish a broadband coordinator position and broadband advisory council.²⁷⁰ This legislation allows municipalities and counties to access grant funds for the purpose of expanding reliable broadband services to underserved communities.²⁷¹ This influx of capital is critical: Wyoming is forty-sixth in a ranking of U.S. states by highest rate of connectivity.²⁷² Notably, 28 percent of Wyomingites are underserved by their local internet providers.²⁷³ The state has astutely recognized that it must overcome these barriers by making key investments in information infrastructure, enabling communities to cultivate local entrepreneurship and promote upward mobility. By expanding access to internet services across local communities, Wyoming can position itself to foster a robust carbon tech value chain that supplies businesses with a pipeline of innovative R&D efforts and skilled technical workers.

Solution

While Wyoming’s leaders have already taken the much-needed step of allocating funds and providing support for broadband upgrades, an opportunity exists to ensure that these resources achieve maximum impact throughout the state. Local leaders in municipalities and counties can submit a grant request to the Wyoming Broadband Advisory Council, which must include items such as the location of a proposed project, the amount of requested funding and sources of in-kind contributions, and the number of households and businesses expected to benefit from the

project.²⁷⁴ To maximize the competitiveness of their applications, communities that apply for grant funds could propose innovative strategies that utilize local expertise and existing infrastructure. These often critically underserved communities could encourage homegrown solutions that are based on models in Ohio, Maryland, Kentucky, and Tennessee (*see case studies*). Wyoming can replicate these examples by establishing public-private partnerships, deploying unused television channels, relying on local talent to staff voluntary broadband boards, or partnering with a local utility.

Key Players

Wyoming Business Council, Wyoming Broadband Coordinator, Wyoming Broadband Advisory Council, Local Communities

Case Study: Public-Private Partnerships in Coshocton County, Ohio

In 2007, the Appalachian Regional Commission awarded Coshocton County a \$38,000 grant to lease space on the radio towers that broadcast the state-owned Multi-Agency Radio Communications System (MARCS). Since then, the county entered into a public-private partnership with an internet service provider (ISP) who agreed to finance the investment in broadband provided that the county would supply the vertical infrastructure.²⁷⁵ Sixteen towers have been raised with the goal of expanding high-speed internet access to rural communities.²⁷⁶ While the ISP retains profits through user fees, the county has seen similar positive impacts: Between 2008 and 2011, the percentage of residents with access to broadband internet rose from 32 to 58 percent.²⁷⁷

Case Study: Harnessing Unused Television Channels in Garrett County, Maryland

In 2011, less than 60 percent of the population in Garrett County could access broadband internet.²⁷⁸ Local officials decided to create their own answer to this problem. With local funds and a grant from the Appalachian Regional Commission, the county hired a private consultant with the goal of using local assets to bolster the county's connectivity. They ultimately decided to utilize unused television channels to connect high-speed internet to residents. After TV channels were switched from analog to digital in 2009, it was discovered that these unused, low-frequency airwaves, which are also known as white space, can extend broadband signals to remote areas by bypassing common obstructions such as trees, hills, and buildings.²⁷⁹ The county's innovative approach was two-pronged. To more exactly target the signal, the county identified a need for infrastructure with suitable height. Property owners willingly allowed officials to mount antennae on their homes, barns, silos, and even trees.²⁸⁰ From 2016-2017, these combined efforts expanded high-speed internet access to more than 150 businesses and homes, with additional expansion planned for subsequent years.²⁸¹

Case Study: Local Broadband Board in Letcher County, Kentucky

Letcher County, Kentucky has a higher-than-average unemployment rate.²⁸² To revitalize the local economy and get residents back to work, local officials have taken steps to overcome widespread lack of access to high-speed internet across hundreds of homes and businesses. In 2016, Letcher County established a voluntary broadband board with the goal of creating the county's own broadband network.²⁸³ Comprised of volunteers from the local community, the board's first task was to conduct a county-wide survey in order to understand the problem. Although AT&T provided the umbrella network to connect the region to the internet, the

company neglected to build the “last mile” infrastructure that would serve residents and businesses located outside of the major population centers.²⁸⁴ In response to pressure from the board, AT&T offered to provide bandwidth at a reduced rate on the condition that a local partner would build the last mile infrastructure; however, local providers were hesitant to take on the investment risk.²⁸⁵ In 2017, the board decided to move ahead on its own: first, by using a fixed wireless transmitter to broadcast a signal from the Whitesburg, the county seat, to the rural Linefork community, then by contracting with a company to run fiber optic cabling to people’s homes.²⁸⁶

Case Study: Expanding Smart Grid Infrastructure in Chattanooga, Tennessee

Broadband infrastructure is increasingly viewed as a core utility alongside water, sewer, and electricity.²⁸⁷ Utilities are increasingly optimizing rollout of smart grid infrastructure and broadband networks. Chattanooga’s municipal-owned utility, the Electric Power Board of Chattanooga (EPB), built a fiber optic network in its territory with one gigabit per second speed. The fiber optic network facilitated EPB’s smart grid rollout, which ensured that fallen trees during storms would not result in a power outage. Continuous power was a key requirement for Volkswagen to locate its advanced manufacturing plant in Chattanooga.²⁸⁸ The network cost \$369 million, and was paid for in part by a federal stimulus grant of \$112 million.²⁸⁹ However, the economic benefits of the smart grid and the fiber optic investments greatly outweigh the costs: The utility receives \$23.6 million in annual revenue from the investments.²⁹⁰ Meanwhile, according to one estimate, the community receives \$43.5 million in indirect paybacks from the additional infrastructure through improved regional productivity.²⁹¹

Policy 15: Build a Strong Foundation for Future Foreign Direct Investment

Opportunity

Working to attract foreign direct investment (FDI) is a common strategy to bring new jobs and capital into a state’s economy. FDI can be of particular value to Wyoming’s carbon tech industry since many research centers and innovative companies are based outside of the United States. To strengthen its carbon tech cluster, Wyoming could embrace a strategy focused on building relationships overseas that could generate future investment in the state. While the state has done well establishing a U.S. and Canadian research coalition, such a relationship is unlikely to result in companies relocating from Canada to Wyoming. Through a more strategic engagement of organizations and companies located outside of North America, state leaders could make locating in Wyoming an easy option for carbon tech firms looking to expand to the United States.

Solution

Wyoming could build its reputation as a global leader in carbon tech by establishing more formal relationships with potential international trade partners. While many states establish overseas trade offices to establish relationships with other countries, a better solution for Wyoming could be to forge innovation partnerships with key countries that are active in carbon tech innovation, like Germany and Japan. These innovation partnerships can begin as research collaborations and can grow into more robust trade relationships (*see case study*). The state has taken a significant step toward this type of relationship by engaging with the Japan Coal Energy Center and Kawasaki Heavy Industries to test new carbon capture technologies at the ITC.²⁹²

State leaders can also build relationships with international carbon tech clusters, innovation centers, and industry organizations, such as the Graphene Flagship, the European Man-Made Fibres Association, the European Composites Industry Association, the Japan Chemical Fibers Association, the China Innovation Alliance of the Graphene Industry, and the Activated Carbon Producers Association.²⁹³ Wyoming could leverage relationships with these organizations to highlight its carbon tech cluster assets and attract foreign firms as they look to expand to North America.

The state could also look to recruit specific companies based overseas to establish a facility in Wyoming. Some examples are: Jacobi Carbons (Sweden), Donau Carbon (Germany), CarboTech (Germany), Nippon Steel & Sumikin Materials (Japan), CealTech (Norway), Haydale (United Kingdom), XFNANO (China), and Graphenea (Spain).

START CALL-OUT BOX

Best Practices for FDI and Exporting Programs

The U.S. Department of Commerce commissioned an extensive study of the most successful FDI and exporting programs around the country and found that state leaders of these programs share several key practices.²⁹⁴ The report found that they:

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

END CALL-OUT BOX

Key Players

University of Wyoming, Wyoming Business Council, Carbon Tech Cluster Partnership (*see Policy 12*)

Case Study: Massachusetts-Israel Innovation Partnership

The Massachusetts-Israel Innovation Partnership offers an innovative model for facilitating global connections. Launched in 2011 after the governor's mission to Israel, the partnership grew from an industry research collaborative to a joint FDI partnership. Major Israeli companies have expanded operations into Massachusetts, and domestic firms have invested in Israeli intellectual property and R&D.²⁹⁵ As of 2015, more than 200 Israeli-founded companies have made a home in Massachusetts; altogether, these firms accounted for \$9 billion in direct revenue, \$18 billion in total economic impact, and 4 percent of the state's GDP, as well as 9,000 direct jobs and 27,000 indirect and induced jobs.²⁹⁶

Local Market

Policy 16: Create Incentives to Drive Demand for Wyoming's Carbon Tech Products

Opportunity

The Wyoming carbon tech industry has an incredible opportunity to supply in-state industries with its products. The state has committed billions of dollars to its ambitious goals, including the construction of top-notch schools and the expansion of its irrigation infrastructure.²⁹⁷ Simultaneously, Wyoming's existing infrastructure—such as roads, bridges, and dams—are aging and will require hundreds of millions of dollars to modernize or repair.²⁹⁸ When it comes to road repair alone, in 2017, the Wyoming Department of Transportation forecasted spending \$331 million on highway improvement.²⁹⁹ Much of this work will be done by private contractors who competitively bid for these construction contracts. This presents an unparalleled opportunity to deploy Wyoming-made carbon tech products: Advanced concrete technology and other building materials utilize carbon dioxide captured from the air and new carbon tech construction materials are in the development pipeline.³⁰⁰ Taken together, these industries represent potentially large and lucrative local markets for Wyoming carbon tech products—ones Wyoming can harness to grow its budding carbon tech industry.

Solution

Wyoming could institute a set of policies that enhance opportunities for local companies to win contracts with both state and private developers to stimulate purchases of carbon tech products manufactured in-state. On state contracts, Wyoming could award bid preferences to those contractors who commit to purchase locally manufactured carbon tech goods in their project, such as using cement manufactured with carbon captured for highway repair. Wyoming could institute a similar policy to Montana's local food geographic preference policy within its purchasing and procurement code to drive institutional demand for carbon tech products made in the state (*see case study*). The state could also notify bidders and facilitate the bidding process on state contracts for purchasing Wyoming-made carbon tech products, similar to how it currently does with state contracts for technology companies (*see case study*).

Key Players

Wyoming General Services Division, Wyoming Business Council, Wyoming Legislature, Wyoming Governor, Wyoming Contractor's Association

Case Study: Montana Local Food Geographic Preference

Montana took an innovative purchasing approach to create jobs and support its agricultural industry. In 2007, the Montana Legislature passed a geographic preference policy to encourage public agencies to buy their food from in-state farms and farmers. Under the Montana Procurement Act, public institutions are able to prioritize "local" over "lowest bid" when it comes to awarding food contracts.³⁰¹ Items produced in Montana are defined as food that is "planted, cultivated, grown, harvested, raised, collected, or manufactured" in the state.³⁰²

Case Study: Wyoming In-State Technology Company Preference Assistance

In 2018, Governor Mead issued an executive order to encourage bids on government contracts from in-state technology companies as part of an effort to diversify Wyoming's economy.³⁰³ Under this policy, the state alerts local technology companies of competitive Requests For Proposals (RFPs) and assists them with the bid process, including becoming certified as a resident bidder, so that the company can qualify for the state's 5 percent resident preference on all construction projects, equipment purchases, and other bids.³⁰⁴

Policy 17: Unleash Wyoming's Wind Market

Opportunity

Wyoming's wind industry is a potentially large and lucrative purchaser of Wyoming carbon tech products. Wyoming carbon tech manufacturers could benefit from selling their products to the manufacturers of wind turbine components and transmission lines to be used for in-state wind projects. To fully harness this potential, Wyoming could consider policies to foster its wind industry. Despite its enormous wind resource, Wyoming lags far behind its neighboring states in harnessing this resource, in part because of the state's lack of property, sales, and purchase tax incentives for the wind industry.³⁰⁵ In addition, Wyoming is the only state to leverage a generation tax on each wind project.³⁰⁶ Given the long lead time for wind generation and transmission projects, state leaders must adopt a forward-thinking mindset and begin removing barriers. This could help create a local market that is able to support Wyoming carbon tech companies when they are ready to go to market with their products.

Solution

To truly tap into the potential of the Wyoming carbon tech industry, the state could increase its competitiveness and send a clear market signal that Wyoming is open for wind business. The state could follow Iowa's lead by establishing an office within the Wyoming Infrastructure Authority dedicated to supporting energy independence and capitalizing on Wyoming's prodigious wind resource, thus providing the dedicated leadership and stability necessary to coax wind developers to make investments in Wyoming wind (*see case study*). Additionally, Wyoming could tailor its tax incentives to make the state attractive for wind developers—doing so would remove risk and make the state regionally competitive. North Dakota took this approach to great success (*see case study*). Both of these approaches will send a strong and clear message to wind developers—and the carbon tech manufacturers who will supply them with key components—that Wyoming welcomes their business.

Key Players

Wyoming Infrastructure Authority, Wyoming Legislature

Case Study: Stability Leads to Prosperity in Iowa

Like Wyoming, Iowa has vast amounts of land and a robust wind energy resource. In 2006, this Midwest state leveraged its assets by establishing the Iowa Power Fund, which underwrote funding for alternative energy research and development, including wind energy.³⁰⁷ The state also initiated an Office of Energy Independence to coordinate these efforts.³⁰⁸ Finally, the state legislature instituted an in-state market for wind, ensuring there would be demand. Together, these policies created the regulatory certainty, strong leadership, and business climate that were necessary to generate impressive results: The wind industry supports over 7,000 Iowan jobs and

provides approximately \$20-25 million in lease payments to Iowans who host wind turbines on their land.³⁰⁹ This growth prompted the CEO for MidAmerican Energy Company, a key player in Iowa power, to remark that the stability of the regulatory, legislative, and executive branches in Iowa empowered energy providers to feel confident in making long-term investments.³¹⁰

Case Study: Tax Incentives Promote Growth in North Dakota

North Dakota is well-known for its vast oil and gas deposits. The state has also established a variety of incentives to spur forward development of its expansive wind resources. Wind easements allow property owners to lease potential wind development sites without incurring property tax increases associated with the development.³¹¹ Corporate income tax credits help offset the cost of acquiring and installing wind systems.³¹² All facilities that generate electricity are exempt from sales and use taxes, including wind.³¹³ These incentives have helped North Dakota attract \$5.8 billion in wind project capital investments through 2017 and have enabled it to install twice the amount of wind energy capacity as Wyoming.³¹⁴

Call to Action

Wyoming's emerging carbon tech cluster is a solid foundation upon which the state can grow its economy, support 2,600 jobs, and become a leader in the production and deployment of advanced energy technology. The policies recommended in this report are complementary and intended to help Wyoming manufacture products within the state, foster entrepreneurship for technological advances, fund innovation with accessible capital, equip workers with needed skills, and grow demand for carbon tech.

START QUOTE BOX

Wyoming has the opportunity to support over 2,600 direct, indirect, and induced jobs in the carbon tech industry. This cluster is well positioned to serve a significant portion of national demand, especially considering its vast coal and carbon resources, extraordinary R&D assets, favorable business environment, high quality of life, and commitment to economic diversification.

END QUOTE BOX

To fully realize Wyoming's potential in the carbon tech industry and position the state for continued growth, policymakers will need to make a concerted effort to seize the opportunity presented by increasing global demand. Strong leadership plays an important role in promoting Wyoming's competitive advantage in the industry and creating quality jobs. State and local economic development depend on the collective work of many partners across government, universities, industry, and other stakeholders. This report recommends actions that each group can take to support the carbon tech industry. As an effective and critical first step, Wyoming's leaders could establish a public-private partnership to drive forward a strategic and comprehensive plan to propel Wyoming's carbon tech cluster forward. Continued collaboration is necessary to address barriers to cluster growth and demonstrate that the state is ripe for investment.

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

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

START CALL-OUT BOX

Growing the Carbon Tech Cluster, Growing Jobs

The American Jobs Project

- Foster a Commercialization Culture at the University of Wyoming
- Develop a Statewide Mentorship Network
- Create a Wyoming-Driven Innovation Engine
- Simplify Access to Sources of Capital
- Establish a Technology Maturation Loan Fund to Fill Financing Gaps
- Appoint a Foundation Liaison to Increase Funding for Business Competitions
- Establish a Fund of Funds
- Increase Apprenticeships for High School Students
- Retain Wyoming's Brightest Students
- Improve Soft Skills Training for High School Students
- Formalize Industry-Led Job Training Programs for Carbon Tech
- Build a Comprehensive Carbon Tech Cluster Partnership
- Broadcast Wyoming's Business Assets
- Leverage the High-Speed Internet Opportunity in Local Communities
- Build a Strong Foundation for Future Foreign Direct Investment
- Create Incentives to Drive Demand for Wyoming's Carbon Tech Products
- Unleash Wyoming's Wind Market

END CALL-OUT BOX

Appendix 1: Economic Impacts, Jobs Estimates, and Modeling Methodology

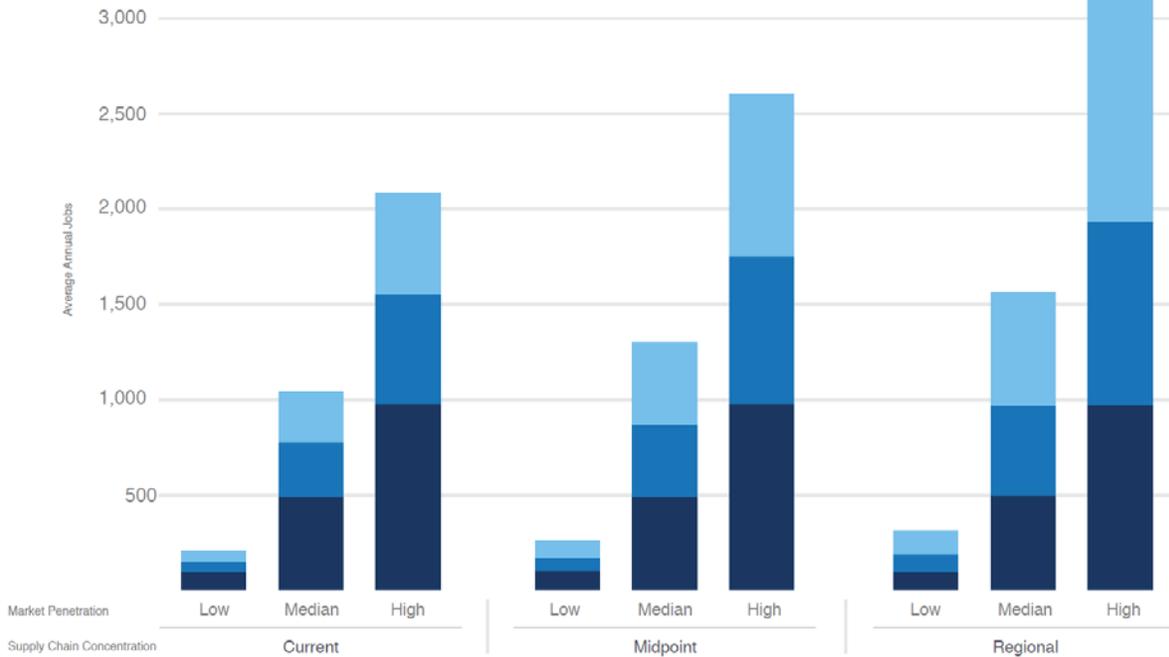
From 2018 through 2035, Wyoming's carbon tech industry could support an annual average of 2,600 direct jobs from manufacturing, indirect jobs from suppliers, and induced jobs from spending in the local economy.

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

To estimate jobs potential for the carbon tech industry in Wyoming, we utilize several reputable tools, analyses, and projections to determine global and national estimates of future demand, the current estimated state market penetration for carbon tech businesses, and industry benchmarks for wages and profits. We use these inputs to generate multiple industry growth scenarios based on varying levels of market penetration and supply chain concentration. Each scenario shows the average number of jobs that the in-state manufacturing industry could support annually from 2018 through 2035. The actual number of jobs in any given year could vary significantly from the average, and the annual average is intended to be a target over the analysis timeline.

We suggest that the High market penetration and the Midpoint supply chain concentration are realistic goals for Wyoming. If Wyoming can grow its market share and build a supply chain to these levels, the industry could support an annual average of 2,600 direct, indirect, and induced jobs from 2018 through 2035. Thus, the carbon tech industry could serve as a vehicle for future state economic growth while creating quality jobs for Wyoming's residents.

AVERAGE ANNUAL JOBS IN WYOMING'S CARBON TECH INDUSTRY BY MARKET PENETRATION AND SUPPLY CHAIN CONCENTRATION, 2018-2035



START CALL-OUT BOX

Definitions

Market Penetration

Amount of sales of a product as a percentage of the total sales volume for that product in a defined market.

Supply Chain Concentration

The level at which target industries could meet supply chain needs from in-state companies.

Direct Jobs

Jobs created or sustained due to direct increases in sales to companies in the target state industry.

Indirect Jobs

Jobs created or sustained due to higher demand for equipment, materials, and services from supplying industries that support the target state industry.

Induced Jobs

Jobs created or sustained due to increased local spending by employees of the target state industry and its supplying industries.

Multiplier Effect

Refers to when the economic impact generated is larger than the initial investment due to cascading spending from target state industry to its supplying industries and workforce to products and services in the local economy.

END CALL-OUT BOX

Modeling Approach

We utilize IMPLAN, a proprietary model maintained by the Minnesota IMPLAN Group, and its 2013 data package to conduct our regional economic analysis. IMPLAN uses average expenditure data to estimate how industry spending cascades throughout the economy to suppliers and consumer-facing industries. IMPLAN tracks multiple rounds of indirect and induced spending impacts until that spending “leaks” out of the selected regional economy, as determined by local purchasing coefficients built into the model.

Drawing from reputable sources, we develop multiple scenarios in which Wyoming could grow its carbon tech industry. Each scenario represents varying levels of market penetration and supply chain concentration, which generate different inputs for the IMPLAN model.

Market penetration is shown at three levels (Low, Median, High), with the lower bound being Wyoming’s current estimated market share and the upper bound being an aggressive increase that approaches current regional market share for carbon tech. Another level represents the median between both bounds. We use the Bureau of Labor Statistics’ (BLS) Quarterly Census of Employment and Wages (QCEW), supply chain research, and IBISWorld data to estimate market share as a function of establishments, wages, and revenue.

Three supply chain concentration levels (Current, Midpoint, Regional) are presented to identify the impacts of growing Wyoming’s supply chain. The lower bound uses the current state economy, demonstrating the effect of merely maintaining the present level of supply chain concentration. The upper bound uses the Rockies Region (MT, ID, WY, UT, and CO) as the model to represent the impacts of Wyoming having as complete of a carbon tech supply chain as is available in the selected states. Another level gives the midpoint between both bounds.

It is important to note that we do not include any financial impacts associated with the construction of new facilities that may result from an increased number of carbon tech firms locating in the Wyoming economy during the analysis timeline, nor do we include jobs associated with carbon capture technology, geologic sequestration projects, enhanced oil recovery, or carbon-derived value-added products that do not have advanced energy applications. These could all be significant sources of job creation, and may warrant further analysis.

Model Inputs

We define carbon tech as manufactured products made by converting carbon dioxide and fossil fuels, like coal, into valuable materials. Many different processes are used to convert these carbon sources into value-added products, and we focus on materials with advanced energy applications. Our analysis utilizes the North American Industry Classification System (NAICS) codes, the basis for most macroeconomic analysis and reporting. To estimate the economic impacts of carbon tech, we look at several associated technologies:

- Carbon Foam
- Carbon Matrix Composites
- Activated Carbon
- Carbon Fiber
- Graphene, Nanotubes, and Fullerenes

Estimates of market demand for carbon tech are taken from BCC Research, Grandview Research, and IBISWorld reports. Annual demand for our analysis timeline is derived from the current estimates and compound annual growth rates through 2035. We assume that the rates stay constant through 2035 since they do not project further into the future.

Estimates of average wages are taken from IBISWorld, IMPLAN, and BLS QCEW. Owner income is also derived from IBISWorld and IMPLAN wherever possible.

The current market penetration of Wyoming's carbon tech industry is estimated as a function of current estimated employment and firms. IBISWorld's ratio for employment per unit of revenue and the current concentration of firms in Wyoming, as well as QCEW employment and firms data, are applied to Grand View Research, IBISWorld, and BCC's market demand totals to estimate current employment and revenues.

Model Outputs

Once the data is prepared for input into IMPLAN, we run the model for each scenario and generate the following direct, indirect, and induced estimates for Wyoming's carbon tech industry: employment, labor income, GDP, total economic output, state/local tax revenue, and federal tax revenue. Only employment outcomes are given in this report. Additional output estimates are available by request.

We present employment as an average of annual jobs sustained. These outcomes are based on the total job-years, or one full-time equivalent job sustained for one year, that exist within the timeframe of our analysis. Jobs in any given year can vary greatly within the timeframe. Additionally, job losses in industries that compete with those in our analysis are not evaluated. Models do not perfectly predict behavior, so job estimates could vary based on the reality of what is purchased locally and the impact of foreign and domestic competition. The estimates presented in this report are highly dependent on sustained local action towards developing and maintaining the target state industry.

Appendix 2: References for Infographics

Percent Change in Regional State Population, 2016 to 2017

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