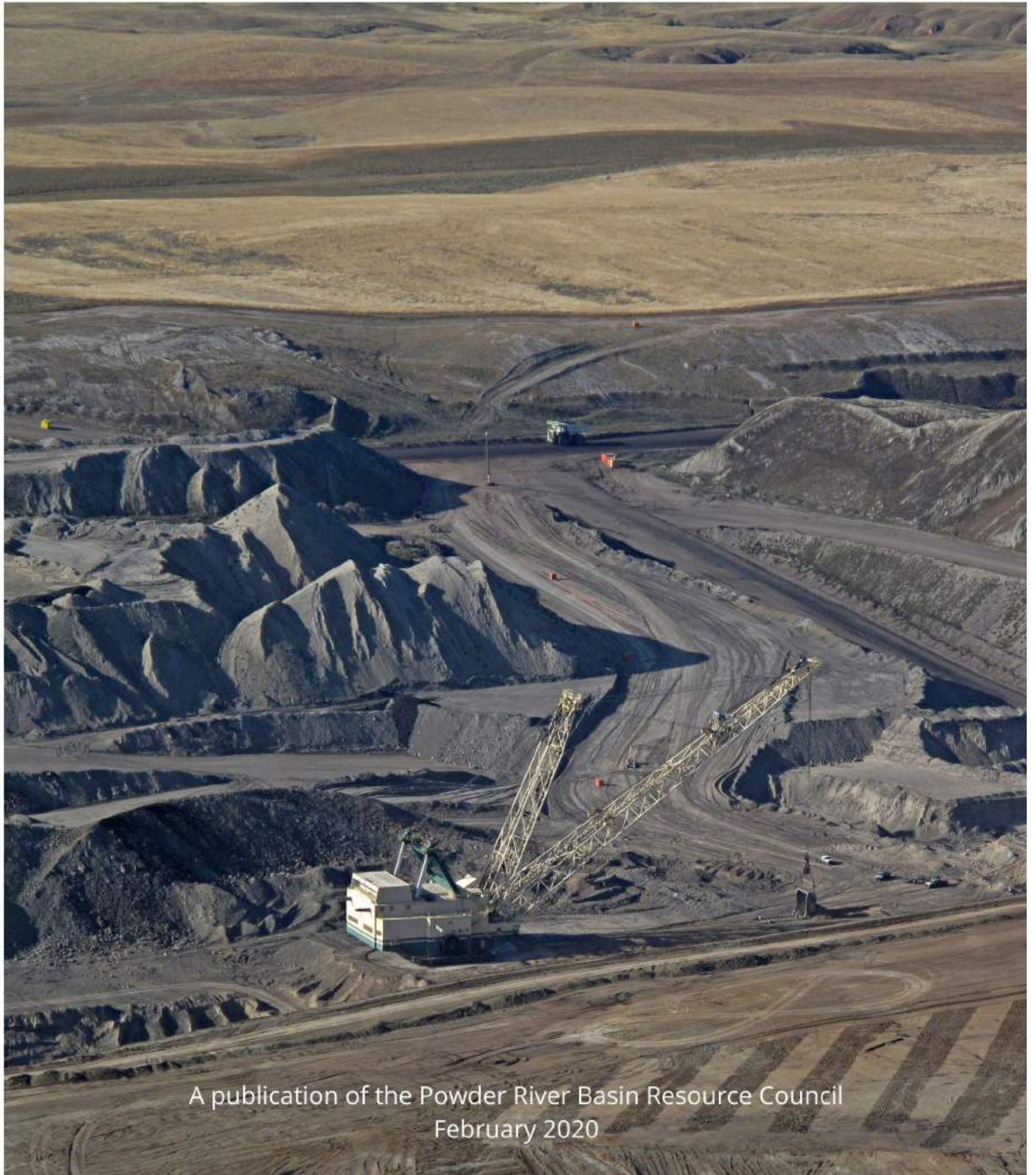


LESSONS FROM HISTORY:

Wyoming's 30 Years of Failed Coal Upgrading Projects



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POWDER RIVER BASIN

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Who We Are

Founded in 1973, Powder River Basin Resource Council is a citizen-based organization of individuals and affiliate groups dedicated to the stewardship of Wyoming's natural resources. Through member empowerment, strategic alliances, and a dedicated staff, we work to preserve Wyoming's unique quality of life and our precious air, land, and water quality.

Our mission is to preserve and enrich our agricultural heritage and rural lifestyle, conserve Wyoming's unique land, minerals, water, and clean air consistent with the responsible use of these resources to sustain the livelihoods of present and future generations; and educate and empower Wyoming's citizens to raise a coherent voice to affect the decisions that will impact our environment and lifestyle.

We are a nonprofit, 501c (3) tax-exempt organization.

Introduction: Purpose of research and definition of coal enhancement or upgrading

For over 30 years, many parties have invested time and effort in a myriad of projects seeking to upgrade Wyoming’s coal resources. Public money has funded a lot of this work, and to date, only one project has achieved any success. This report documents the history of coal upgrading failures, and the time and money spent in vain trying to increase coal’s market viability. In retrospect, it is clear that a better use of these resources would have been to apply them toward diversification of Wyoming’s economy and tax base.

The University of Wyoming’s Center for Energy Economics and Public Policy has acknowledged a pronounced, downward trend in coal production and associated tax revenues.²³ The recent spate of coal related bankruptcies in the state, and the uncollectable deficit they have left counties and school systems statewide, attest to the dangers of our failure to find viable economic alternatives to coal. This report is an effort to realistically review the state’s past priorities with respect to coal, and what those priorities have produced. The question before policy-makers is simple: do we continue to pump public monies into projects with limited success in an effort to stabilize our coal industry or do we instead shift efforts to helping our communities and our state transition into a new economic future? This report attempts to inform the answer to that question by looking at the past history of success with these projects.

“Upgrading” refers to projects that attempt either to enhance the value of coal as a fuel for electrical generation, or to create new, non-combustion uses for coal-derived products. Since the 1990s, Wyoming has seen many such projects proposed or attempted, and has backed many with public funds. These attempts have come in a variety of forms, but all sought to create value-added products from coal in order to increase its marketability.

Sadly, success rate of these attempts has been extremely low. Out of 16 coal upgrading projects studied for this report, only one has resulted in a successful product. Atlas Carbon has been making activated carbon, a substance used in filtration and industrial processes, from Powder River Basin coal since 2014.

FAILED WYOMING COAL ENHANCEMENT OR UPGRADING PROJECTS

<i>Evergreen Energy</i>	Coal Drying
<i>Amax</i>	Coal Drying (1990's) Belle <u>Aur</u>
<i>KFx</i>	Coal Drying
<i>White Energy</i>	Coal Drying & Briquetting
<i>Char Fuels</i>	Coal to liquid
<i>DKRW</i>	Coal to Liquid & Integrated Gas Combined Cycle
<i>Rocky Mountain 1</i>	Rawlins Underground Coal Gasification
<i>Encoal</i>	Gasification 1990
<i>Hoe Creek</i>	Underground Coal Gasification
<i>Williams Energy</i>	Underground Coal Gasification
<i>LINC Energy</i>	Underground Coal Gasification
<i>High Plains</i>	Above Ground Coal Gasification
<i>Hampshire Energy</i>	Synfuels
<i>Ciris</i>	In-situ Bio-conversion
<i>Luca/Patriot</i>	In Situ Bio-conversion

Beyond the fact that only one of these projects has produced a commercial-scale value-added product, each has posed inherent dangers in the form of environmental and social costs. And collectively, they have wasted hundreds of millions of dollars of public and private funds. Many of the ventures that have actually been built have left environmental liabilities in their wake, creating further externalized public costs. Maybe most harmful, the false hopes for Wyoming coal's market future they have created have led to complacency and inaction on efforts needed to economically diversify the state.

This analysis is based on a study of the following project types:

- Coal Drying (including Evergreen Energy, Amax, Kfx, and White Energy)
- Coal to Liquid Fuels (including Char Fuels, DKRW, Encoal, and Hampshire Energy)
- Above Ground Coal Gasification (High Plains Gasification)
- In-Situ Coal Gasification (including Hoe Creek, Rocky Mountain 1, Williams Energy, LINC Energy, Ciris, and Luca/Patriot).
- Coal-to-Carbon Products (including Atlas Carbon, Ramaco, and the Advanced Carbon Products Innovation Center (ACPIC)).

Although this research is not exhaustive, it covers the most prominent coal upgrading projects attempted to date in Wyoming.

COAL DRYING

Wyoming produces around 40% of the thermal coal used in United States power plants. The high rate of production currently seen in the Powder River Basin started in 1990, when sulfur emissions from power plants were limited by the Clean Air Act in response to acid rain.¹ According to the Wyoming State Geological Survey, because coal from the Powder River Basin (PRB) is generally low in sulfur content “Wyoming coal does not require the cleaning and processing needed for much of the coal in the eastern United States.”² While this low-sulfur subbituminous coal has helped it gain and retain a large market share in thermal power generation, Wyoming’s coal contains around 30% moisture,³ which reduces its thermal output, making it more expensive to ship (in dollars per million Btu). Throughout the '80s, '90s, and early 2000s, coal drying projects were repeatedly touted as the solution to this issue, but not one was commercially successful.



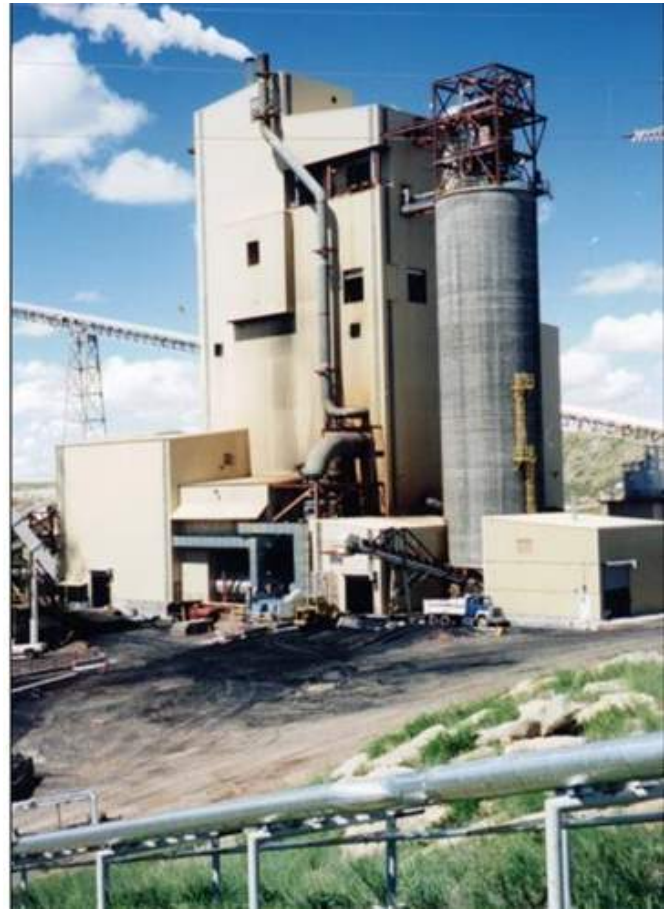
The Eagle Butte Mine in Campbell County was the site of the proposed Amax coal drying project in the 1980s.

In the 1980s, the company KFx developed a coal drying project using pressurized steam to dewater PRB coal and increase its heating value. By promoting the unproven advantages of this technology, KFx was able to secure multiple rounds of public and private funding. A plant was built to make enough dried product for utility test burns, but the process was costly, and

the product was susceptible to spontaneous combustion once the coal was dried. The project was ultimately abandoned after repeated budget shortfalls and cumulative expenditures of over \$95 million.⁴

In the late 1980s, the Amax Coal Dryer Project sought to reduce moisture without increasing the reactive characteristics of Powder River Basin (PRB) coal, using a fluidized bed drying technology. Although there were initial reports of success, the final report on the project prepared for the U.S. Department of Energy (DOE) found that around 80% of the end product was unmarketable because of its fine particulate size.⁵ Instead of meeting the stated goal to “expand the marketability of Powder River Basin Coals,” the process instead created an unmarketable product that was dusty and highly reactive. The project was shut down within a few years. We have been unable to find documentation of how many millions of dollars were spent on this project, but the DOE was a public partner in the project.

In later years, other companies undertaking coal drying projects included White Energy, which abandoned the project in the permitting stage, and Evergreen Energy,⁶ a successor to KFx which filed for Chapter 7 bankruptcy. Over the years, many similar endeavors have also ended in failure. In each instance, media coverage surrounding the projects was optimistic, and in each instance the project ended with no marketable product, and often with no physical facilities ever being built. Throughout these 30 years, the constant enemies of coal upgrading projects have been economics and product quality. Despite repeated attempts and well over \$100,000,000 spent, coal drying remains technically and commercially out of reach as a mechanism for improving the marketability of PRB coal.



The Encoal facility at the Buckskin Mine never produced a commercial product. (Source DOE)

COAL TO LIQUIDS & COAL GASIFICATION

Coal-to-liquid projects in Wyoming have aimed to utilize gasification techniques to produce a synthetic gas (which may include hydrogen, carbon monoxide, methane, and light hydrocarbons) from which liquid fuels such as gasoline and diesel fuel can then be produced. Only one of these projects, Encoal, was constructed, in 1992, at a noncommercial demonstration scale. It developed a mild gasification process that made both solid and liquid products. While the liquid product worked as a low-quality substitute for fuel oil, the companion solid product was dusty and prone to spontaneous combustion. Without both product streams, the Encoal technology was uneconomical.

Then, in 2010 another demonstration-scale project was proposed, using a high-pressure gasifier designed for higher altitudes with PRB coal as the feedstock. The \$100 million High Plains Gasification Research Facility,¹⁰ a collaboration between General Electric (GE) and the State of Wyoming, sought to develop technologies to produce cleaner fuels like hydrogen while capturing carbon dioxide from the plant exhaust to inhibit greenhouse gas emissions. GE withdrew its proposal in 2011, citing the lack of clear federal policy on climate change. A GE spokesman said, "When government policy and economic realities are aligned in the U.S., we plan to be a leader in cleaner coal technologies." Wyoming Governor Matt Mead saw this withdrawal as, "... a real-world example of the local impact of the federal government's failure to

provide a policy path forward for energy use in America." Not all of Wyoming's \$40 million investment in the project could be recovered, leaving the state with stranded assets in a project that was never built.

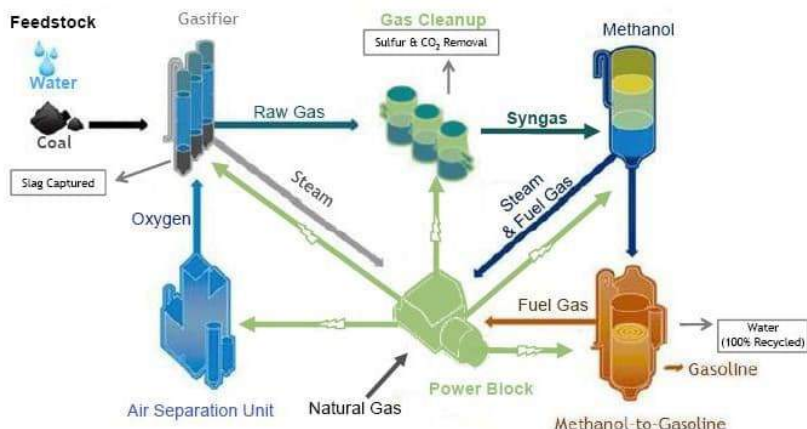
In retrospect, the fracking revolution and the persistent abundance of natural gas and crude oil have since dashed the dream that coal-to-liquids or coal gasification technology will prove viable in the foreseeable future.

Other coal-to-liquids projects have met similar fates, some after receiving public subsidies. Despite acquiring large amounts of funding from a variety of federal, state and private sources, they were abandoned before they were ever built.

Examples include the Hampshire Energy Synfuels Plant,¹¹ an Integrated Gasification Combined Cycle and liquid fuels plant planned by DKRW,¹² and a coal-to-liquids project proposed by the company Char Fuels that was to be built next to the Dave Johnston generating plant in Glenrock.¹³



Two concrete pads were the extent of construction at the DKRW site.



2012 diagram of the DKRW process.
(Source NETL/DOE, photo courtesy of Wyofile.)

IN-SITU COAL GASIFICATION

In Wyoming, several coal gasification proposals have sought to convert low-rank coal into syngas and/or methane either thermally or biologically. Thermal conversion, known as underground coal gasification (UCG), supplies heat and oxygen to the coal seam to initiate partial combustion and pyrolysis. This generates a variety of organic compounds, some of which are hazardous. The process is subject to the uncertainty of underground geology and is difficult to control from the surface. The underground technologies posed thus far present insurmountable technical and

environmental challenges. Attempted thermal conversion projects have left behind a series of environmental disasters for the state and federal governments to handle without ever producing a marketable product.

Some UCG projects were never even built, but they still cost taxpayers millions of dollars in subsidies. None of the projects that *were* built produced a marketable product, but some still caused environmental damage. Numerous UCG projects have been abandoned, leaving behind environmental contamination that cost state and federal governments additional millions of dollars to clean up.

In Rawlins, the "Rocky Mountain 1," a UCG joint venture project between DOE, Amoco, GRI, and EPRI reported initial success in producing gas from coal seams.⁷ Unfortunately, the process used led to environmental contamination and surface leaks from inadequately capped wells.⁸ To make matters worse, the gas produced was not a salable product. Analysis from Western Research Institute concluded that the gas

would require additional cleaning before it would be saleable,⁹ and that cleaning would be difficult and expensive because of the large variation in particle size present in samples from Rocky Mountain 1.

Lawrence Livermore National Laboratory's Hoe Creek UCG test project in Campbell County did nothing to improve the marketability of coal gasification, but it did leave behind groundwater contamination that took decades to clean up at significant taxpayer expense. According to a report on the project from Purdue University, "[a]t Hoe Creek, WY, U.S., the site of several UCG pilot tests, improper site selection and over-pressurization of the reactor drove a plume containing benzene, volatile organic carbons, and other contaminants into fresh-water aquifers."¹⁴ The project area had severe enough environmental degradation to qualify as a superfund site.¹⁵



The Linc Energy site in Campbell County was abandoned.

Williams Energy's UCG project near Rawlins¹⁶ resulted in similar environmental damage. According to a book¹⁷ written on UCG, tests conducted at the Rawlins facility resulted in benzene contamination "due to poor well linkage and operation of the UCG reactor above hydrostatic pressures." Benzene contamination occurred in groundwater within the coal seam, as well as in sandstone layers both above and below the test area.

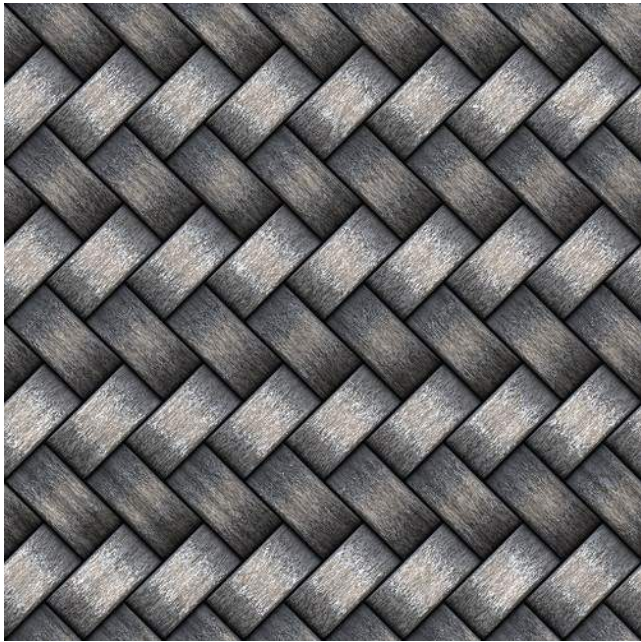
LINC Energy proposed a UCG pilot project in southern Campbell County. After years of permitting effort in Wyoming, the company was fined \$4.5 million for damage caused by a similar project in Australia. LINC was charged with five counts of willfully and unlawfully causing serious environmental harm between 2007 and 2013 near Chinchilla in Queensland, Australia by mismanaging the underground burning of coal seams. LINC was subsequently liquidated and its U.S. subsidiaries filed for Chapter 11 bankruptcy, leaving the Wyoming site abandoned and subject to reclamation bond forfeiture.

Like UCG, biological gasification also occurs in-situ. But rather than using heat it employs microbes to break the coal seam down into recoverable gas – mostly methane. Notable proponents of this technology were Luca/Patriot and Ciris. In spite of establishing a favorable regulatory framework with first-in-the-nation laws passed in Wyoming, neither venture succeeded in commercializing the process. Like UCG, it proved difficult to control and expensive to monitor. And like all the coal gasification technologies discussed above, it could not remotely compete economically with conventional sources of natural gas.

COAL TO ACTIVATED CARBON

Processing coal to make activated carbon for filtration and industrial purposes is the one commercially successful coal-upgrading project undertaken in the Powder River Basin. Atlas Carbon processes coal to create activated carbon, which has demand on the open market.¹⁸ In doing so, they are providing jobs to Wyoming people and repurposing an abundantly occurring resource. The activated carbon is used for filtration, most notably to clean mercury and other contaminants from power plant flue gas.

By all indications Atlas is a stable company that will likely continue to provide good jobs to local people well into the future. Still, it uses only a tiny amount of coal because there is limited market



Petroleum-based carbon fiber.

(Source: "Carbon Fiber" by Filter Forge is licensed under CC BY 2.0 .)

demand for activated carbon products. Atlas certainly deserves credit for its innovation and job creation, but its model is not scalable to the point of appreciably slowing the current decline in overall demand for Wyoming coal.

COAL TO CARBON FIBER & OTHER CARBON PRODUCTS

Most upgrading efforts have primarily focused on improving coal for its established use of electrical generation or creating other combustible fuels from the feedstock. Recently, however, another track to add value to PRB coal has emerged. The focus of this new area of coal upgrading research is carbon fiber.

There is no shortage of carbon fiber on the market today. It is being made successfully from several feed stocks, with around 90% being sourced from polyacrylonitrile (PAN),¹⁹ a substance derived from petroleum. PAN-based carbon fiber dominates the overall carbon fiber market. It is widely applicable in aerospace & defense, automotive, sports & recreation, wind energy, and

other industries. PAN-based carbon fiber has high strength and is very cost-effective in comparison to other types of carbon fibers.²⁵

Despite these attributes, research into coal as an alternative source of carbon fiber emerged around 2015. Several coal-to-carbon upgrading projects have been proposed in the Rocky Mountain West. Just as Wyoming placed its hopes on UCG and coal drying projects in the past, these new projects are being hailed as the answer to coal's declining market share in recent years, even though PAN-based fiber is widely available and economic. A publicly funded carbon research facility – the Advanced Carbon Products Innovation Center - is currently planned for the Fort Union mine site north of Gillette. In Sheridan County, Ramaco Carbon has proposed a carbon products research center called the iCAM. Ramaco was recently awarded a substantial DOE grant and is actively seeking other public financing for its project. Just this legislative session, lawmakers are adding in carbon products to the laundry list of energy projects that can be financed with Wyoming Energy Authority bond authority through House Bill 3.

Still in its infancy, coal-to-carbon-fiber technology faces an uphill battle to compete with petroleum-based carbon on price and product strength. Moreover, even if the technology were to become competitive in the future, the world market for carbon fiber could theoretically be served from one single, small coal mine. Global demand for carbon fiber, while steadily growing, is only expected to reach 120,000 metric tons in 2022.²⁶ Assuming even half the fixed carbon in PRB coal could be converted to carbon fiber, a single one-million-ton-per-year coal mine would suffice (Wyoming produced over 304 million tons in 2018). Claims that coal-based carbon fiber will supplant PAN-based fiber are unfounded at present and claims that coal-to-carbon will save Wyoming's coal industry are simply not credible.

The Risks of Public Investment in Coal Technology

It is difficult to estimate how much money has been invested in coal upgrading projects that were either never built, yielded no commercially viable products or caused contamination that is still being cleaned up. Most of these projects have been funded through a mix of private, state, and federal sources,

but readily accessible information is in short supply. Much of the information that we were able to obtain came from historic newspaper articles.

Although the precise investment is unknown, clearly these projects have cost Wyoming and U.S. taxpayers considerable money. KFx received an \$11.7 million loan and the company Char Fuel received an \$8 million loan, both from the state of Wyoming. As a direct partnership between GE and Wyoming, the High Plains Gasification Center would have received \$40 million from the state, had it been built. At least \$1.5 million in indirect funding was granted to DKRW by the state of Wyoming in 2007, and DKRW was in line to receive a sizeable loan from the DOE.²¹ We also found that the state of Wyoming set aside \$30 million for coal upgrading projects in 1987 and has since regularly set aside more money. In 2019, Governor Gordon requested another \$10 million in appropriations for coal upgrading.

While the monetary costs of these projects are significant and should be carefully tracked, the opportunity costs cause even greater concern. The greatest risk from continuing to collaborate with, promote, and fund coal upgrading projects is the lost time and public energy that instead could be spent planning for our future and making real changes in our state's economy. The coal market is rapidly declining outside of Wyoming, and Wyoming needs to figure out how to change with it into a more sustainable future. Time and money spent now trying to save coal is time and money that could be invested in systemic changes to Wyoming's tax system and our economic base.

For the state going forward, it is essential that Wyoming leaders are honest about the permanent changes occurring in our energy sector and the fact that coal is not going to make a miraculous comeback.

It is time for us to invest in transitioning away from coal dependency and pursue economic diversification in earnest. We can work together to diversify our economy and tax base but time is running out for us to act. We can no longer chase every shiny new possibility for coal as if it were the silver bullet, while failing to act on real solutions.



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