ADDRESSING A CRITICAL NATIONAL NEED

PENN STATE UNIVERSITY:

LEADING THE DEVELOPMENT OF A
DOMESTIC CRITICAL MINERALS SUPPLY CHAIN

PennState

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EXECUTIVE SUMMARY

Critical minerals are vital to national security and domestic economic growth. These minerals are prevalent in essential components of everyday life, including our batteries, cellphones, automobiles, appliances, and electronic devices, to name a few. These resources also play a central role in countless defense and homeland security applications that are indispensable to our nation's defense readiness and will be crucial to the solar panels, wind turbines, and electric vehicles that will form the basis for a clean energy economy. Any disruption in the supply chain related to such minerals could have devastating impacts on our nation's ability to prosper domestically and combat security threats globally.

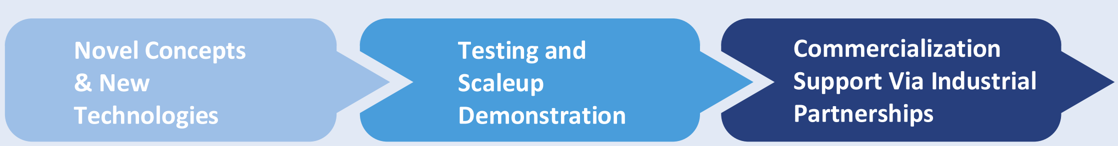
Our nation, however, has become almost completely dependent on offshore suppliers, primarily those in the People's Republic of China, for access to the critical minerals required to power our economy, defense, and daily lives. This reliance creates a massive vulnerability, one recognized by recent administrations of both political parties.

The United States must endeavor to develop its own supply of critical minerals, but faces challenges in sourcing, processing, and refining key minerals required to build a domestic supply chain. While the ability to obtain these commodities from primary domestic mineral deposits is an important component of our national strategy, the growing emphasis on utilizing secondary sources – including byproducts of coal mining and other forms of energy-based waste products – will be central to the development of a reliable domestic supply chain.

Coal byproducts, including, for example, acid mine drainage, are rich in critical minerals. Coal and its waste products will therefore play a crucial role in providing a secondary source of critical minerals. Utilizing acid mine drainage and other coal byproducts to source critical minerals will help Pennsylvania tackle the related challenges of environmental remediation and economic deterioration, while sourcing new supply chains for a more self-reliant U.S. economy.

WHY PENN STATE?

Penn State University – with its world-class faculty and facilities and established relationships with government and industry stakeholders – is perfectly positioned to lead the effort to establish a supply chain of key critical minerals extracted from domestic sources including energy-based waste products. In doing so, Penn State will be at the forefront of addressing a pressing national imperative while helping the Commonwealth overcome environmental and economic challenges that have plagued communities in Pennsylvania for generations.



I. INTRODUCTION

Critical minerals are vital to our national security and economic growth.[1] Any disruption in the supply chain related to such minerals could have destructive impacts in terms of domestic economic prosperity and global security concerns.

WHY ARE THESE MINERALS CLASSIFIED AS CRITICAL?

These minerals are classified as "critical" by the United States Department of the Interior because of their importance in everyday life. Many of today's critical minerals – such as cobalt, graphite, lithium, manganese, and rare earths – play a vital role in strengthening our national defense and ensuring access to the everyday essentials of modern life, including computers, cell phones, batteries, electric vehicles, and solar panels.


Cobalt


Lithium


Rare Earths


Manganese


Graphite

Examples of Critical Minerals Used in Advanced Technologies:


Solar Panels
Arsenic, Germanium, Indium, Tellurium


Battery Storage
Cobalt, Graphite, Lithium, Manganese


Wind Turbines
Aluminum, Rare Earth Elements


National Defense
Chromium, Gallium, Scandium


Aviation
Niobium, Tantalum, Vanadium

Despite their fundamental contribution to our economic and national security, the United States is dangerously dependent on foreign sources, including adversarial nations, for our supply of critical minerals. In particular, the People's Republic of China's dominance in the global critical mineral supply chain presents an acute threat to U.S. interests. China controls most of the global market for processing and refining several critical minerals, including cobalt, graphite, lithium, and rare earths.[2]

Ensuring that the United States has uninterrupted access to critical minerals is a national imperative. Disruptions to the supply chain resulting from global unrest or military tensions could ripple across the U.S. economy impacting every American.

As detailed in a 2021 report commissioned by the White House, the United States must secure a reliable and sustainable supply of critical minerals to ensure resilience across U.S. manufacturing and defense needs.[3] But this is not an easy task. Establishing new critical mineral projects is an extremely lengthy process burdened by a restrictive permitting environment; a reasonable industry benchmark for the development of a critical materials project is ten years.

To lessen this burden, exploring the potential of unconventional and secondary sources from remediation and reclamation such as acid-mine drainage and mining wastes has been identified as a national strategic priority.[4]

II. CHALLENGES FACING THE U.S. SUPPLY CHAIN

The United States' overreliance on imports of critical minerals (CMs) from foreign sources, including the dominance enjoyed by China over key minerals,[5] is due in large part to the lack of a reliable – and cost effective – domestic supply chain for sourcing and processing these commodities. This challenge is only going to grow. As much of the world transitions to clean energy, experts predict a surge in global demand for the key minerals in electric vehicles and battery storage. Analysts at the International Energy Agency predict lithium will see the fastest growth, with demand growing by over 40 times by 2040, followed by graphite, cobalt, and nickel, growing by 20-25 times.[6]

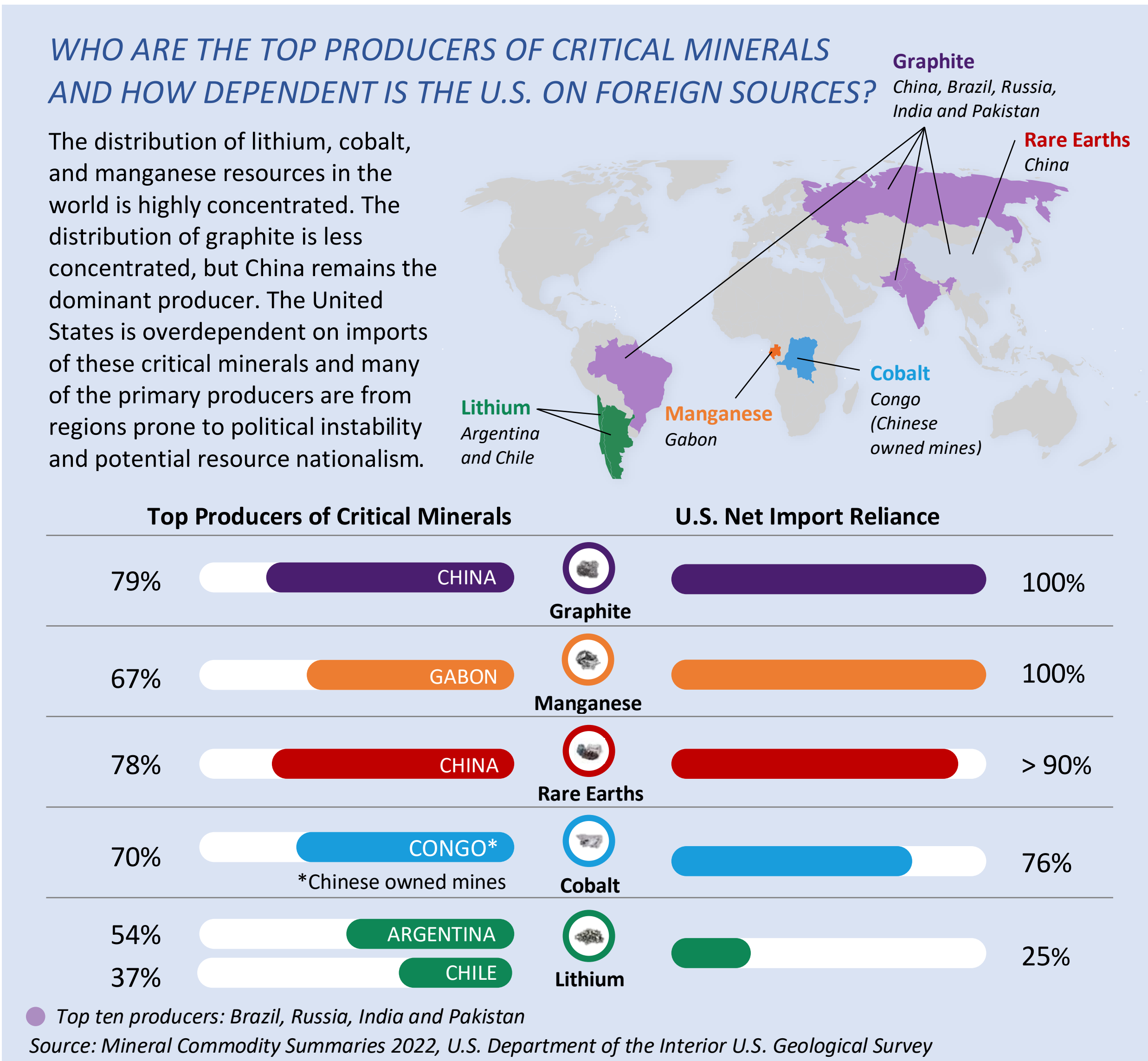
In April 2022, President Biden invoked the Defense Production Act to fund the mining, processing, and recycling of lithium, nickel, cobalt, graphite, and manganese, but the U.S. will continue to rely on foreign sources for these minerals for the foreseeable future in the absence of a commitment to building a domestic supply chain. Reducing dependence on China will continue to be a major challenge unless public policies change and public investments are made.

Overdependence on Foreign Sources of Critical Minerals

China is the world's leading producer of many CMs but reliance on China's supply creates both national security and economic vulnerabilities. The possibility that Beijing could cut off access to critical minerals in the event of a conflict with the United States looms large in the minds of many military strategists.[7] There is precedent for such interruption; in 2010, China sharply reduced critical mineral exports to Japan over a maritime incident between the two countries, resulting in disruptions to global supply chains.[8] More recently, and more ominously, Beijing announced sanctions on two American defense contractors – Lockheed Martin Corporation (the maker of F-35 fighter jets) and Raytheon Technologies Corporation (the world's largest producer of guided missiles). These sanctions were in retaliation for a deal Washington approved to allow the two firms to provide maintenance services to Taiwan's missile defense system.[9] These sanctions are expected to curtail access to critical minerals for these firms.

Reliance on China also presents workforce and environmental concerns. Over 70% of the global cobalt supply is sourced from Chinese owned mines in the Democratic Republic of Congo.[10]

Estimates suggest that as many as 40,000 children – nearly 15% of the labor force – work in these mines.[11] An Amnesty International report detailed the brutal working conditions and health ramifications from chronic exposure to cobalt dust which can lead to potentially fatal lung disease called "hard metal lung disease."[12] Mining and extraction are associated with significant environmental risks, such as the release of toxins, deforestation, carbon output, and water contamination, all of which need to be addressed as part of sustainable development. There are also concerns about the enforcement of due diligence requirements to make these supply chains "cleaner" and "greener."[13]



The distribution of lithium, cobalt, and manganese resources in the world is highly concentrated. Between 2017 and 2020, over 90% of the lithium imported to the United States came from Argentina (54%) and Chile (37%). During this same time, Gabon produced 67% of the manganese imported to the United States. In terms of U.S. net import reliance on imports, 100%

of graphite and manganese, > 90% of rare earths, 76% of cobalt, and 25% of lithium was imported. The distribution of graphite is less concentrated, but China remains the dominant producer, accounting for 59% of production and 66% of exports globally in 2020.[14] Other top ten producers include Brazil, Russia, India, and Pakistan – regions prone to political instability and potential resource nationalism.[15]

A Challenging Environment for Primary Source Extraction

> *"The perceived high-risk profile of mining is a deterrent for investment. Exploration and assay risks, feasibility concerns, pricing risks, and potential political challenges all pose significant risk to the mining industry and have resulted in chronic underinvestment."*
>
> **– THE WILSON CENTER**

Traditionally, the U.S. market has focused on primary source extraction for the supply of critical minerals. Due to environmental and labor concerns, the mining industry is highly regulated, yet there is no single federal agency with authority over domestic mining. The legal framework for mining on federal public lands was enacted in 1872 – 150 years ago – and does not provide a comprehensive system to evaluate, permit, develop and reclaim mines.[16] Permitting and other legal restrictions on U.S. mining firms place them at a competitive disadvantage compared to Chinese competitors and provide a strong disincentive for the development of resources within the United States.[17] The Wilson Center, one of the nation's key non-partisan policy forums tackling global issues through independent research, summarized it this way: "The perceived high-risk profile of mining is a deterrent for investment. Exploration and assay risks, feasibility concerns, pricing risks, and potential political challenges all pose significant risk to the mining industry and have resulted in chronic underinvestment."[18]

Pivoting to Unconventional and Secondary Sources

In an effort to create and secure a domestic supply chain, the Biden Administration released the "Fundamental Principles for Domestic Mining Reform" which places a new emphasis on secondary/unconventional sources. A secondary source is the recovery of critical minerals from discarded end-use products, in essence a recycled mineral. An unconventional source includes minerals obtained from sources such as coal waste and coal spoils, capitalizing on the ash left behind from more than a century of coal mining to yield potential supplies of the metals needed to build tomorrow's technologies. Currently there is a limited domestic infrastructure and capacity to recover critical minerals from unconventional and secondary sources. However, the capacity to build such an infrastructure exists in the U.S., powered by the research conducted at Penn State University.

Creating a Domestic Supply Chain

Considerable investment would be needed to build out critical minerals supply chains in the United States. Supply chains for critical minerals generally follow a linear path containing five key stages:

KEY STAGES OF CRITICAL MINERALS SUPPLY CHAINS

Stage	Description	PennState EXPERTISE
1 Material characterization & production	Potential sources, abundances, and accessibility of feedstock materials are identified and studied. Then critical minerals are extracted. Typically, in traditional mining, materials are crushed into a smaller size for easier separation.	Established
2 Material processing, refining & alloying	Critical minerals feedstock materials are separated, smelted or refined to produce purified powders, metals, alloys, or other materials. Further processing, such as cutting and polishing is used to create a final material.	Established
3 Manufacturing	Processed materials are used in the making of a wide range of products in areas such as defense, transportation, energy and electronics.	Emerging
4 Use	Manufactured products are distributed and sold for use by others, such as consumers and industry.	Established
5 End of life, reuse & recycling	Products are discarded, reused, or collected for recycling.	Emerging/ Industry Partners

Source: GAO analysis of stakeholder information.

After decades of near dormancy, building out domestic critical minerals supply chains without domestic sources of raw minerals and existing projects in the pipeline will face a range of political and stakeholder challenges. Unconventional and secondary sources could help the U.S. address these hurdles by expediting the establishment of a reliable domestic stockpile of key critical minerals. Penn State has the expertise necessary to advise industry on locating, mining, characterizing, processing, and utilizing critical minerals.[19] However, more research is needed, especially to develop greener processes for extraction, separation, and reduction.

III. PENNSYLVANIA'S ROLE IN CREATING DOMESTIC CAPACITY

Pennsylvania's unique geological characteristics and location in the Appalachian basin make the Commonwealth an integral part of the national strategy to accelerate production from unconventional and secondary sources. Pennsylvania presents opportunities for the domestic production of cobalt, manganese, and lithium from secondary materials left by past industrial activities in the Commonwealth.

History of Coal Mining

Pennsylvania's unparalleled potential for unconventional and secondary source extraction is a product of the Commonwealth's long history with coal mining. From the 1870s to the 1930s, Pennsylvania was the nation's leading coal producer. By World War I, some 330,000 coal miners were working in the state and in 1918 the industry produced 227 million tons of coal.[20] Through the late 1970s, Pennsylvania produced a third of all coal mined in the entire country.[21] Today, the Commonwealth produces 6% of U.S. coal, the third largest state producer behind Wyoming (42%) and West Virginia (12%).[22] While the economic benefits to the state and the communities that relied on coal mining were substantial, they came at great long-term cost. Coal production in the Commonwealth declined significantly after World War II leaving many communities economically devastated. In too many cases, these communities are still working to overcome these economic challenges. The most prominent legacy of this era is the environmental degradation that is still on display across the Commonwealth. Building greater domestic capacity to extract critical minerals from coal waste will revitalize these communities from both an economic and environmental perspective.

> *Extracting critical minerals from energy-based waste products is a win-win-win for Pennsylvania and the nation. Doing so will clean up the Commonwealth's environment, revitalize communities, and address a national imperative to reduce overdependence on foreign sources.*

Pennsylvania's Environmental Legacy

The decline of the coal mining industry left behind 184,000 acres of abandoned mine lands, including over 9,500 acres of coal refuse piles across the western and northeastern parts of the state.[23] This legacy includes some of the largest coal ash waste sites in the country.[24] The total volume of coal waste in Pennsylvania is estimated between 200 million cubic yards and 8 billion cubic yards.[25]

Additionally, coal-mining operations resulted in acid mine drainage that caused widespread pollution of streams and negatively impacted wildlife. Today there are over 5,500 miles of streams in the state with impaired water quality because of runoff from these long-shuttered mines. Untreated, acid runoff can persist for thousands of years.[26] Utilizing acid mine drainage to source critical minerals will help Pennsylvania tackle the challenges of environmental remediation and revitalize forgotten communities, while sourcing new supply chains for a clean energy future and enhancing national security.

Pennsylvania's coal mining legacy is also shared with other Appalachian basin states such as neighboring West Virginia, Kentucky, and Tennessee. Government officials, local leaders, business leaders, and academic institutions have acknowledged the potential for critical minerals sourced from unconventional and secondary sources like coal wastes to transform the region economically and environmentally.[27] Pennsylvania, as in decades and centuries past, can lead the region through this economic revitalization, with Penn State University pioneering Appalachia's clean energy future.

Mineral Concentrations in Appalachian Basin: Lithium, Cobalt, Manganese

Penn State's Center for Critical Minerals conducted a study in 2021, sponsored by the U.S. Department of Energy (DOE), assessing secondary cobalt and manganese resources in Pennsylvania from mine reclamation and remediation. The preliminary findings of the study estimated that coal refuse in the state contains approximately 52,000 metric tons of cobalt and over half a million metric tons of manganese. Additionally, the Center found that acid mine drainage was discharging an estimated 60 metric tons of cobalt and 5,500 metric tons of manganese in Pennsylvania waterways each year.[28]

The Marcellus Shale, which has been identified as the largest natural gas field in the country, extends through much of Pennsylvania stretching from the southwest through the northeastern parts of the state. As of 2020, there were over 20,000 estimated natural gas wells resulting from the development of hydraulic fracturing making Pennsylvania the second largest producer of natural gas in the nation behind Texas.[29] A recent University of Houston study found highly concentrated lithium in the water produced as a byproduct during the extraction of oil and natural gas in the Marcellus Shale,[30] and a local processing company will be purchasing the produced water to extract the lithium.[31] This type of research and demonstration is critical given that at present the U.S. has only one lithium mine located in Nevada.

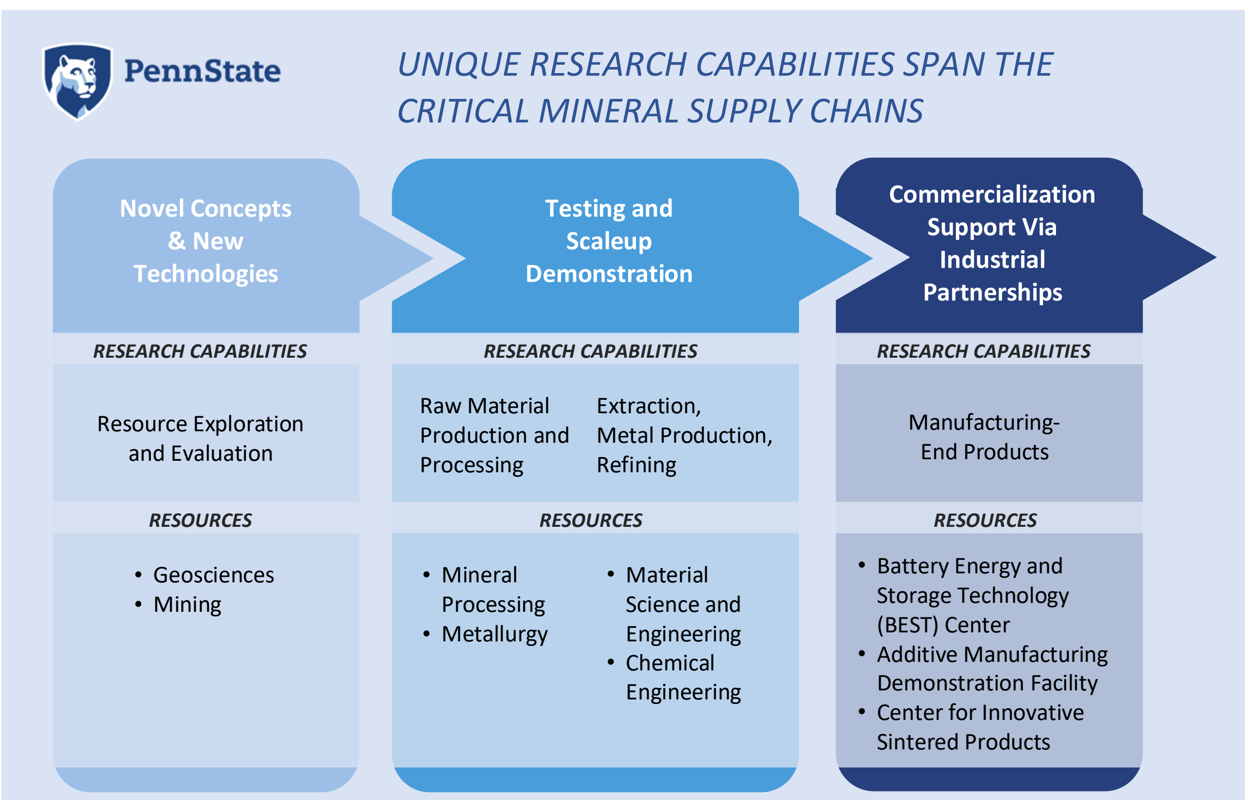
Situated in the central part of the Commonwealth is the Mercer Clay bed which has historically produced feedstocks for the refractory industry. Penn State faculty researchers pioneered the investigation into the clay bed and located lithium content directly below the overlying Mercer coal.[32] A recently completed geological study determined lithium contents that exceed 1,000 ppm leading Penn State researchers to further characterized the Mercer "underclay" as a viable feedstock for lithium.[33]

Pennsylvania's Comparative Economic Advantages

In addition to the Commonwealth's geologic and geographic assets, Pennsylvania is also an emerging leader for energy sector jobs in renewable and clean energy. A June 2022 Department of Energy report ranked Pennsylvania second in the nation for job growth in the transmission, distribution, and storage sector.[34] This is a critical advantage and opportunity to create a complete supply chain from extraction to commercialization utilizing Pennsylvania's highly trained workforce and abundant resources. A domestic supply chain will serve our national security and environmental interests, while creating jobs in economically distressed areas.

IV. PENN STATE'S EXPERTISE IN CRITICAL MINERALS R&D

Penn State has a long and established history in mining engineering and mineral science. Penn State is home to the nation's premiere university-led center devoted exclusively to critical minerals research, and the faculty bring a breadth of expertise that spans every phase of the domestic supply chain from material characterization to extraction, manufacturing, and end use. Penn State is an R1 institution with strong research infrastructure systems in place to support large scale projects. The University also consistently ranks in the top five of all universities nationwide in the number of undergraduate degrees in STEM fields awarded, ranking #1 in 2019-2020 with 6,473 undergraduate STEM degrees conferred.[35] Collectively, these highly skilled graduates create the workforce necessary to meet the demands of tomorrow.



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MINING & MINERAL SCIENCE ENGINEERING BY THE NUMBERS

*THE **PREMIERE** UNIVERSITY-LED CENTER DEVOTED EXCLUSIVELY TO CRITICAL MINERALS RESEARCH.*

R1 INSTITUTION

with strong research infrastructure systems in place to support large scale projects.

TOP **5** — *Consistent ranking of all universities nationwide for the number of undergraduate degrees in STEM fields awarded.*

 # 1 — *2019-2020 undergraduate STEM degrees conferred (6,473)*

4th NATIONALLY — *In total and federally financed higher education research and development*

2nd NATIONALLY — *In total and federally financed research and development expenditures in metallurgical and materials engineering.*

1st NATIONALLY — *By scholarly output in "Coal Deposits; Methane; Coal Mines"*

7th NATIONALLY — *By scholarly output in "Mines; Mining; Models"*

18th NATIONALLY — *By scholarly output in "Tailings; Mines; Mining"*

1 OF 5 — *Institutions in the top-20 across all three mining discipline areas*

Unique and Distinguished History in Mining and Mineral Science

The College of Earth and Mineral Sciences was founded in 1890 as the Department of Mining Engineering. The first Bachelor of Science in Mining Geology was awarded in 1912 followed by the first Master of Science in Mining Geology in 1913.[36] By 1930, the Department had become the School of Mineral Industries to support the mining industry with a view towards the inclusion of other disciplines than mining engineering.[37] The College of Earth and Mineral Sciences today maintains an interdisciplinary focus on earth, energy, and materials sciences and engineering with departments of energy and mineral engineering, geography, geosciences, materials science and engineering, and meteorology and atmospheric science.[38]

Dr. Lee Kump, Dean of the College of Earth and Mineral Sciences, was elected to the National Academy of Sciences (NAS) in May 2022. NAS is a private, nonprofit institution established in 1863 to recognize achievement in science by election to membership and provide scientific and engineering policy advice to the federal government. Dr. Kump is the sixth member from the College of Earth and Mineral Sciences to join NAS.

In 1952, Dr. Edward Steidle, the first Dean of the School of Mineral Industries, and the man responsible for the shift toward an all-inclusive program that would go on to become today's College of Earth and Mineral Sciences wrote:

> "*By the year 2000, we will not be wasting our coal ash, in which geochemists have shown there is a notable concentration of rare elements, such as germanium and rare earths. We will be recovering those elements, which by then will be critical materials in our economy… American industry will be faced not only with a lack of raw materials at home, but also with the difficulty of obtaining supplies abroad.*"

Center for Critical Minerals (C^{2}M)

Dr. Steidle's forward-thinking vision, and anticipation of the challenges that now confront the United States in its transition to a clean energy economy, laid the foundation for Penn State's Center for Critical Minerals (C^{2}M) established in 2019.[39] C^{2}M is the only university-led center in the nation focusing exclusively on critical minerals research and secondary and unconventional sources.

Dr. Sarma V. Pisupati, Professor of Energy and Mineral Engineering and Chemical Engineering, and a Fellow of the American Chemical Society, serves as the Director of C^{2}M. A nationally recognized expert in unconventional and secondary sources, Dr. Pisupati has testified before various committees of the Pennsylvania General Assembly on the importance of scaling technology to recover critical minerals from mine drainage and coal refuse.[40]

"The need is urgent, and Penn State is ready and able to help."

– DR. SARMA PISUPATI, DIRECTOR OF CENTER FOR CRITICAL MINERALS

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C^{2}M is supported by faculty across the entire breadth of Penn State's science and engineering infrastructure. Center affiliated faculty span the College of Earth and Mineral Sciences, the Eberly College of Science, and the College of Engineering, allowing the Center to utilize faculty expertise and talent in additional fields such as Chemistry, Chemical Engineering, and Environmental Engineering to inform and guide its CM research and development. C^{2}M also partners and collaborates with the university's Materials Research Institute which houses the Materials Characterization Lab, a key component in mineral characterization research.

Faculty Expertise Leveraging Unconventional and Secondary Sources

C^2M's affiliated faculty researchers are pioneering novel approaches to extract critical minerals from the Commonwealth's abundant unconventional and secondary sources. The University has already registered intellectual property patents for extraction processes for critical minerals from waste streams, fly ash, and acid mine drainage;[41] and lithium from secondary clay beds.[42] The Center's interdisciplinary approach has also resulted in breakthroughs in chemistry research in the use of bacterial protein that can sense and extract critical minerals from secondary sources such as mine wastes in environmentally safe ways.[43] Center affiliated faculty have several additional patents for the recovery and processing of critical minerals that are pending approval or have since been issued.[44]

The Center's groundbreaking research in environmentally safe extraction, processing, and recycling from secondary sources such as mine waste and acid mine drainage has made Penn State a recognized regional and national leader in the field by the federal government. Penn State was chosen by the Department of Energy as the lead institution for the Consortium to Assess Northern Appalachia Resource Yield (CANARY) of carbon ore, rare earth element, and critical mineral (CORE-CM) for Advanced Materials. Comprised of university, private industry, state, local, and federal government personnel, the consortium will evaluate the CORE-CM production potential of the Northern Appalachian (NA) basin covering Maryland, Ohio, Pennsylvania, and West Virginia. The $1.2 million project began in 2021 and will conclude in September 2023, providing a complete value chain basinal assessment of the Northern Appalachian region for future commercial development.[45]

Faculty Expertise with Carbon Products, Specifically Graphite

Graphite is critical for battery production, yet the United States imports 100% of its natural graphite. There is an opportunity to develop synthetic graphite in Pennsylvania, using the Commonwealth's rich supplies of carbon ore. Penn State faculty have seven decades of history in carbon research, and they have the research capacity to produce synthetic graphite using these local sources. Besides decreasing our nation's reliance on foreign providers, many electric vehicle automakers prefer synthetic graphite, citing its superior fast charge turnaround and battery longevity.[46]

Experience Leading Government Funded CM Research and Consortia

Other academic institutions recognize Penn State's thought leadership in the field of critical minerals and Penn State is well-connected with faculty in this discipline across the country. For example, C^2M has a Memorandum of Understanding with the Colorado School of Mines and collaborations with other leading institutions, including Virginia Tech, the University of Kentucky, Ohio State University, and the University of Arizona.

Penn State faculty researchers from the Materials Research Institute, Departments of Chemistry and Chemical Engineering, and Institutes of Energy and the Environment are also currently leading several additional multi-year large award projects at the Department of Energy and National Science Foundation. These projects include the discovery of new separation mechanisms, materials, and processes to recover critical minerals from fertilizer waste streams; and the recycling and separation of critical minerals such as lithium, cobalt, and aluminum using porous materials.[47] These projects represent over $2.3 million in additional federal funding awarded to Penn State in critical minerals research since 2020.

Penn State also has distinguished alumni working in the field of critical minerals research and development. Christina Lopano, Ph.D., received her doctoral degree from Penn State in Geosciences[48] and is currently a research scientist at the National Energy Technology Laboratory (NETL).[49] In 2021, she received the Secretary of Energy's annual Excellence Award in recognition of her research achievements in innovative recovery methods of critical minerals from coal waste streams.[50] NETL has three facilities in the United States, one located in Pittsburgh[51] near several of PSU's Commonwealth Commonwealth campuses. As one of the DOE's 18 National Laboratories, NETL is a major federal research facility with research programs in critical minerals sustainability, materials engineering and manufacturing, and geological and environmental systems.[52]

The University is also a partner in the Critical Materials Institute (CMI) at Ames National Laboratory, an interdisciplinary team of national laboratories, universities, and industry partners, designated as an Energy Innovation Hub by DOE.[53] Established in 2013, CMI aims to develop a resilient and secure supply chain of critical minerals for clean energy technologies through cross-cutting research, diversifying supply, developing substitutes, and driving reuse and recycling.[54]

Collaborations with Industry

C^2M works with a variety of regional and national industry partners, from established corporations to startups, to develop and test novel extraction, separation, and recovery methods with the goal of providing concept to commercialization support. Affiliated researchers and faculty have registered multiple patents proving the Center's capabilities to produce viable methods. Penn State also hosts the Power and Mineral Industrial Stakeholder Group (PMISG), a coalition of national and regional stakeholders from industry, government, and academia to advance the national dialogue regarding the critical mineral supply chain and further federal, state, and industry investment.

Importantly, PSU is home to Innovation Park, which offers 118-acres of office, manufacturing, and research space, and the support services needed to transfer knowledge from the University to the marketplace. The network of resources available at Innovation Park supports early-stage entrepreneurs and established businesses alike.

V. REGIONAL BENEFITS FROM INVESTMENT IN CRITICAL MINERALS

Recent legislation at the federal level, including the Bipartisan Infrastructure Law, the CHIPS and Science Act, and the Inflation Reduction Act, has ensured billions of dollars in federal funding will be available for both critical minerals R&D and other renewable and clean energy technologies that rely on critical minerals. Pennsylvania is already aggressively pursuing additional growth in the energy storage sector to capitalize on its accomplishments.[55] With additional state and federal funding, Pennsylvania is poised to be a national leader in creating the domestic supply chain of critical minerals.

C^2M's Significant Research Activities in Appalachia

The C^2M has significant research activities in the Appalachian counties of Pennsylvania. Penn State's campus at University Park is located in an eight-county region in Pennsylvania, where six of the counties suffer from substantially higher poverty rates and lower incomes than the national average.

> *"Extracting critical minerals from coal sequences and coal waste has the potential to bolster the state's economy and provide new employment in mining regions."*

– DR. LEE KUMP, JOHN LEONE DEAN IN THE COLLEGE OF EARTH AND MINERAL SCIENCES

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Achieving Economic Regional Development through R&D

According to Fiscal Year 2022 Appalachian Region Commission data, this region has sixteen economically distressed areas. The best strategies to achieve economic improvements in this region involve: (1) community engagement in the development process; and (2) prioritizing members of these impacted communities regarding workforce development opportunities associated with projects under development. Communities in the region around Penn State can benefit from high-paying production jobs and expansion of the local tax base.

Alignment with Biden Administration's Justice 40 Program

Established through an executive order President Biden signed during his first week in office, Justice40 requires that 40% of the overall benefits of federal activities in areas such as climate change mitigation and environmental protection flow to disadvantaged communities.

Reclamation of Degraded Mines and Restoration of Streams

Penn State has a long track record of industry support in integrating mineral recovery with abandoned mine reclamation. Acid mine drainage and similar approaches to source critical minerals will help Pennsylvania tackle the challenges of environmental remediation while sourcing new supply chains for a clean energy future.

VI. CONCLUSION

The U.S. must secure reliable and sustainable supplies of critical minerals to ensure resilience across U.S. manufacturing and defense needs while doing so in a manner consistent with America's environmental values. **Penn State University is perfectly positioned to lead the creation of a new business sector focusing on unconventional and secondary sources as a vital component of the future domestic critical mineral supply chain.**

Penn State is uniquely qualified to leverage our nation's considerable unconventional and secondary sources from coal and other mine wastes to help create a diverse and resilient domestic critical mineral supply that supports the creation of new jobs, furthers environmental stewardship, and advances the development of an independent energy future. It is crucial that Penn State's expertise and the Commonwealth of Pennsylvania's potential are at the forefront of the national conversation as it relates to critical minerals.

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