

**Testimony of Dr. Walter G. Copan**  
**Vice President for Research and Technology Transfer, Colorado School of**  
**Mines**  
**Before the Committee on Natural Resources, Subcommittee on Energy and**  
**Mineral Resources**

**June 14, 2023**

**Oral Testimony Summary**

Chairman Stauber, Ranking Member Ocasio-Cortez, members of the Committee and distinguished participants. It is a privilege to testify on this subject crucial to the future of U.S. mining and materials sector, impacting the future of energy, our economic competitiveness and national security. I have recently served our Nation as Director of the National Institute of Standards and Technology, and prior with two of the U.S. Department of Energy laboratories.

It is my honor currently to lead research and technology transfer at Colorado School of Mines, affectionately known as “Mines.” Mines is ranked in the top tier of U.S. research universities by the Carnegie R1 Classification and rated in the top 3 engineering programs in the nation overall. Mines is the number 1 rated university in the world for mineral and mining engineering, a comprehensive program with the nation’s only mineral economics and space resources majors. No other university in the world has this breadth.

I’m proud that this university can be an authoritative resource to Congress. Mining is critical to obtain the materials we rely upon for the products of our economy -- from buildings, roads, vehicles, energy systems, and industrial infrastructure to computers, the internet, mobile phones, and to new quantum devices just entering the market. Minerals underpin every sector within our economy.

As our nation and the world look to our shared energy future, for electric power and the environment, we are realizing the needs for mining and its products at an unprecedented scale. For example, over the next 20 – 25 years, it is estimated the world will need to mine and produce as much copper as has been done throughout all of human history.

There are 50 minerals and metals on the list of critical materials published by the U.S. Geological Survey – and copper isn’t even on that list. Of the 50 critical materials, 30 are primarily produced in China. The International Energy Agency estimates that by 2040 we will need 42 times the lithium produced in 2020, 25 times more graphite, 21 times as much cobalt. The list goes on – and America’s shortfall is staggering.

The U.S. is largely dependent on other nations for supply of key minerals and metals, a situation that will persist over the coming decades if we don’t act now. Trusted supply chain partnerships are essential. Major labor shortages are already being experienced in America’s mining sector, resulting in significant cost increases.

America needs a new relationship with mining, mineral and metal processing, extraction, and the circular economy. Colorado School of Mines has a compelling, new vision for the mine of the future. This industry must become attractive again, with positive relationships throughout society and minimized impacts on the environment, in order to attract new students and to retrain those within the workforce.

Colorado School of Mines is ranked number 1 in the world for mineral and mining engineering, but there is only one other U.S. university in the global top 25, tied for 17<sup>th</sup> with a Chinese university. China has invested strategically in the industry and its workforce - for decades. This past academic year, across the U.S., there were 600 enrollments in accredited undergraduate and graduate mining engineering and related programs. On the other side – China has over 1.4 million enrollments.

China currently has 38 universities devoted exclusively for Extractive Metallurgy and 38 others for Mineral Processing. The U.S. has none. Overall, today's accredited mining engineering programs in the U.S. produce less than 200 Bachelor of Science level graduates per year, with a current U.S. employment demand of well over 500 annually – and demand is growing.

There are many communities across Colorado and elsewhere throughout the country—and represented by this committee—proud of their mining industries and the partnership represented with their people, demonstrating real economic benefits and positive evidence of environmental stewardship. Key to the success of the Mining Schools Act will be **focus**.

This is a bill that incorporates many stakeholder recommendations. The use of \$10 million per year will need to be managed carefully with support from the advisory board. Most important will be establishing prestigious scholarships to attract new students into accredited mining and related undergraduate programs. Even more important than research and grad student education, we must first refill the pipeline of students into mineral and mining engineering programs. Industry must also effectively communicate current and future opportunities, and market new approaches, technologies and innovations to gain effective outcomes from the Mining Schools Act.

I'm excited about the Mining Schools Act of 2023. Thanks to this Committee for your important work toward securing the workforce and technology leadership for U.S. economic and national security. I look forward to answering questions you may have.

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**Vice President for Research and Technology Transfer, Colorado School of Mines**  
**Before the Committee on Natural Resources, Subcommittee on Energy and Mineral**  
**Resources**

**June 14, 2023**

**Detailed Statement**

Chairman Stauber, Ranking Member Ocasio-Cortez, members of the Committee and distinguished participants. It is a privilege to testify on this subject that is crucial to the future of U.S. energy, economic competitiveness, and national security interests. I have recently served our Nation as Director of the National Institute of Standards and Technology (NIST), and prior, with the National Renewable Energy Laboratory and the Brookhaven National Lab of our U.S. Department of Energy. My career journey in the private sector includes corporate leadership, research and development, innovation and intellectual property responsibilities, as well as an entrepreneur.

It is my honor currently to lead research and technology transfer at Colorado School of Mines, affectionately known as “Mines.” Mines is ranked in the top tier of U.S. research universities by the Carnegie R1 Classification, and it is rated in the top 3 engineering programs<sup>1</sup> overall in the nation. Mines is consistently ranked the number 1 university in the world for mineral and mining engineering<sup>2</sup>, and it offers this nation’s only degree program in mineral economics. With school sports teams known as the “Orediggers” and with 150 years of history of solving the world’s most pressing challenges, I believe the name “Colorado School of Mines” will proudly remain in service for a long time to come.

The key to university’s leadership in these fields and across science, technology, engineering, and mathematics domains over the past century and a half is the commitment to excellence in research and its interdisciplinary culture, the strong engagement with industry, and collaboration with government partners, particularly across the federal laboratory system. The university is located in Golden, the original capital of the Colorado territory when the mining sector and the metals and materials they produced dominated the economy.

I am proud that this university is an authoritative and trusted resource to Congress and policymakers on a broad range of topics connected with Science, Technology, Engineering and Mathematics. Mines is addressing all aspects of the mining and materials lifecycle – from initial community engagement, exploration, mineral economics, and mining - to minerals processing and extractive metallurgy, to metals and alloys processing and products - to closing the loop of the circular economy by product recycling. This knowledge base has also led to the first Space Resources interdisciplinary program globally.<sup>3</sup> No other university in the world has this technology breadth.

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<sup>1</sup> <https://minesnewsroom.com/news/mines-ranks-third-list-best-engineering-colleges>

<sup>2</sup> <https://www.topuniversities.com/university-rankings/university-subject-rankings/2023/mineral-mining-engineering>

<sup>3</sup> <https://space.mines.edu/>

**Role of the Mining Sector.** Mining is critical to obtain the materials we rely upon for the products of our economy and for America’s balance of trade -- from our buildings, roads, vehicles, machines and industrial and clean energy infrastructure to our computers, the internet, mobile phones, GPS and new quantum devices just entering the market. These and many more are products from the mining industry. Virtually every product we touch, and everything that surrounds us in this building in Washington D.C. is tied to materials originating from the mining sector and sourced from the earth.

**Massive New Demand for Mining and Materials.** As the nation and the world look to our shared energy future, needs for electric power, and to restore the environment, the world is waking up to the needs for mining and its products, particularly from hard rock and solution mining at a scale unprecedented in human history. Over the next 20 – 25 years, it is estimated the world will need to mine, extract, and produce as much copper as has been done throughout all human history on this planet.<sup>4</sup> The scale is massive – and how will we get there from here? There are 50 minerals and metals on the list of critical materials published by the U.S. government through the U.S. Geological Survey, for which this Committee has oversight. Copper isn’t even yet on that list.

The critical materials include products for semiconductors, catalysts for hydrogen production and fuel cells, ingredients for energy storage systems such as lithium, cobalt and nickel, and the rare earth elements used for making countless products including the high-performance motors we will need for electric vehicles, solar cells and for wind turbines. Renewable energies and hydrogen are critical parts of our energy future, and we will be relying on other products from the mining industry to supply further energy sources including nuclear, as well as the materials needed to capture and transport carbon dioxide from industrial emissions and the atmosphere to stable geologic reservoirs and to be converted to other product uses. The scale of necessary changes to the mining and metals processing sector is immense. The International Energy Agency (IEA) estimates that by 2040 we will need 42 times the lithium we had produced in 2020, 25 times more graphite, 21 times as much cobalt. The list goes on – and America’s shortfall is staggering.

**Global Supply Chains and Risks.** Of the 50 critical materials on the list, 30 primarily are produced in one country – China. The U.S. is largely dependent on other nations for supply of key minerals and metals, and it will take a substantial investment on an unprecedented scale and speed involving trillions of dollars to access products to supply the energy transition and other industries from both domestic and imported sources. This demand is coming at the same time in which we have seen the effects of depleting the domestic mining sector, as well as major gaps in the ancillary industries for extraction, metals processing and high value product manufacturing. For the mining sector in the U.S. major labor shortages are being experienced, resulting in significant increases in labor costs, leading to projections for dramatic increases in product prices. The mining industry labor shortage is being called a war for talent. Unless America’s minerals and mining labor shortage is addressed, it’s projected that our products will be uncompetitive in domestic and global markets.<sup>5</sup>

Other nations, particularly China have expanded supply chain access globally, and China has the largest base in the world for critical materials manufacturing. China’s dominance has become a

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<sup>4</sup> <https://doi.org/10.1190/tle42040266.1> “Mining for Net Zero: The Impossible Task”

<sup>5</sup> <https://www.wsj.com/articles/war-for-talent-at-mines-could-drive-up-cost-of-energy-transition-30b927eb>

supply chain risk for the U.S. and our allies, and its impact is seen from the early-stage exploration and mining stages, through processing and all the way to final manufacturing. If an entity controls access to mining and minerals and processing, it may effectively control the high-end and value-add manufacturing sectors, as well.

**America needs a new relationship with mining.** America needs more of the products that can only come from the mining sector. We must also recognize that the volumes and time scales required to build capacity mean that our nation will not be able to do this alone. We will need to keep our trusted supply chain partners close. As we consider the proposed Mining Schools Act, we see clear evidence of many inputs that have already been received and integrated. This is a very ambitious bill. It starts with the comprehensive series of goals to begin the process of rebuilding the mining sector, and all this with a modest budget request of \$10 million per year. This is a move in the right direction, a good start -- but it's a small investment considering the massive challenges America faces.

The opportunity we have before us is to consider first how we engage and inspire the next generation of leaders for the mining and critical materials sectors with a purpose and passion for the future of the planet, for people and communities, and our energy future.<sup>6</sup> America needs a new compact regarding natural resources and where these are obtained - both within our nation and from others. Industry will accelerate its fundamental changes principally as we bring in a whole new generation to participate in re-imagining and transforming the sector.<sup>7</sup>

The vision Colorado School of Mines is advancing for the Mine of the Future considers the technological opportunities for efficiency in total mining to utilize every bit of value from minerals and products of the earth, and for stewardship of water and materials of production. Our vision must inspire the next generation by including the totality of working in partnership and transparency with communities toward sustainable pathways. The vision must include planning for the total life cycle of the mining operation to its closure and return to nature. Our vision includes design for product durability and ultimately for product reuse and recycling, closing the cycle of the circular economy for mining. This brings a fully interdisciplinary approach involving not only mining engineering and technology components, but all aspects of hydrology and the geosciences, the humanities and particularly social interactions and communications underpinned by trusted data. This involves economics and business in ways that engender a new foundation of mutual trust, respect and acceptance with information sharing that is both trusted and trustworthy, and with environmental social and governance (ESG) communications and reporting that is credible, trustworthy and independently validated.

**The Mining Industry's Legacy Image.** The mining industry has been one of the pivotal engines of economic growth and prosperity in the United States. Together with the growth and wealth creation during the 19th century and later, we also saw concurrent destruction of ecosystems and waterways, and history has taught many lessons – including about the uneven distribution of wealth that disproportionately affected certain communities. We have since seen a decline of not only participants in the U.S. workforce trained in mining, mineral engineering and processing, but

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<sup>6</sup> <https://www.wsj.com/articles/a-dirty-job-that-few-want-mining-companies-struggle-to-hire-for-the-energy-transition>

<sup>7</sup> <https://www.csis.org/analysis/united-states-needs-shift-perspective-mining>

also the refining and use of metals and metallic systems throughout the manufacturing sectors. The United States has gone through an era of offshoring and globalization in many supply chains, including those related to mining and critical materials. How much capacity can we re-shore?

We will not be able to attract students into programs envisioned by the Mining Schools Act unless we have the minerals industry, industry associations, energy, materials and products companies delivering a new, optimistic and responsible message. The marketing and communications of the industry about the jobs and sector of the future must be a priority.<sup>8</sup> Prospective students should come to understand the importance of their talents to be deployed in these sectors – and the chance to make a real difference. Communications within universities and community colleges, supported by messages from relevant government agencies can help raise the profile of exciting job opportunities arising. The essential role that innovation and entrepreneurship plays in these industries must also be made increasingly visible to prospective students and those providing them guidance.

China has invested strategically to build manufacturing capacity, supply chain partnerships for raw materials and finished products and workforce. In many instances, China receives raw mineral ores produced in developing and developed nations from around the world and refines them into finished materials for sale on world markets. The standards for environmental performance, energy intensity, labor and human rights that are practiced in certain regions do not conform with those high standards from North America, Western Europe and elsewhere. Standards and systems for accounting and enabling supply chain transparency and mineral traceability are essential as we continue to trade with China and other nations.

**Higher Education and Workforce.** Colorado School of Mines is ranked number 1 in the world for mineral and mining engineering<sup>9</sup>, but there is only one other U.S. university in the global top 25, tied for 17<sup>th</sup> place with a Chinese university. The U.S. has 14 universities with 17 accredited degree programs that include mining and mineral engineering. China has invested strategically in the industry - and its workforce. This past academic year, across the United States, there were 600 enrollments in accredited undergraduate and graduate mining engineering and related programs. China had over 1.4 million enrollments. Overall, today's accredited mining engineering programs in the U.S. produce less than 200 Bachelor of Science level graduates per year, with a current U.S. employment demand of well over 500 annually – and demand is growing. Other nations that have been reliable trading partners with the U.S., including Canada, Australia, Europe, and Latin American countries have also been experiencing shortages of production capacity as well as labor, as we are experiencing this rapid rise in demand and related costs.

China currently has 38 universities with schools providing undergraduate and graduate levels education and research devoted exclusively to Extractive Metallurgy. There are 38 other separate schools devoted to Mineral Processing. One of the largest is Central South University, with specific BS, MS and PhD degrees in Mineral Processing Engineering and 1000 undergraduate and 500 graduate students currently enrolled. The U.S. has none – no such dedicated schools nor

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<sup>8</sup> <https://www.northernminer.com/global-mining-symposium/global-mining-symposium-mcewen-calls-for-uber-moment-in-mining-industry/1003855620/>

<sup>9</sup> <https://www.topuniversities.com/university-rankings/university-subject-rankings/2023/mineral-mining-engineering>

degree programs. Colorado School of Mines offers a comprehensive degree program with concentrations in all these areas, but not the entire degree programs as the Chinese universities have been building. 40 years ago, we had many – both at Colorado School of Mines and at other U.S. universities. Canada faces similar workforce challenges as the U.S.<sup>10</sup>

Chinese programs are rigorous, competitive, and increasingly delivering graduates that are highly skilled with a breadth and depth of knowledge. China has a plan. They have seen the combination of workforce, supply chain dominance and manufacturing price control as strategically essential. Currently, Chinese entities including their universities are filing the most patents in the world in mining mineral engineering and metals processing.<sup>11</sup>

**Foreign Talent.** The universities of the United States have educated talent not only for this country but for those from other nations who have come here to study and seek opportunity. Additionally, other nations have been expanding capacity and quality in education and have benchmarked the U.S. higher education system and research enterprise. Colorado School of Mines is currently called upon by nations with important natural resources around the world to establish mining engineering and related programs. These schools are intended to enable those nations' economies to succeed not only in natural resource production, but also to be able to enjoy the value-add of upgraded materials and finished products that can be processed in the future within their own nations. Should America close its borders to educate foreign talent? Clearly, no. Some of the foreign students will come and stay in the U.S., while others will return to their home nations as friends and colleagues of the U.S.

**Why have U.S. Mining Engineering related programs declined?** This appears to be a combination of important factors. The number of companies who are actively recruiting and communicating with students in these areas has not kept pace as industries have globalized, the marketing of the desirability of careers in the sector has lagged, and the image of the industry itself has needed a facelift. The bright students at our universities have many choices, and unless they understand the attractiveness of a career in the mining and resources sector, they will choose alternatives. Unless we reposition mining engineering and related fields as exciting, attractive, rewarding and impactful, with a call to duty to save our planet and economic prosperity – our students and future leaders will continue to look at other opportunities.

**More about the Mine of the Future.** Colorado School of Mines has a compelling new vision for the mine of the future. This is a holistic view that begins not with technology and workforce - but starts with communities and a visible respect for the planet and its resources. The mining industry of the future must become the exemplar of industries, where people want to work, contributing with patriotism to the nation, and with the knowledge of creating positive impact and a sustainable future. Without the engagement of the people and an acceptance that mining can and must deliver **a net positive impact for all stakeholders** concerned and for the effective stewardship of the planet's resources, the mining sector will struggle. Instead, the industry will need to address massive opportunities for growth and impact for the future of energy - and must deliver the materials needed for advancement of human civilization.

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<sup>10</sup> <https://mihr.ca/wp-content/uploads/2023/03/Mihr-Workplace-EN-2023.pdf>

<sup>11</sup> <https://www.nationaldefensemagazine.org/articles/2019/3/21/viewpoint-china-solidifies-dominance-in-rare-earth-processing>

The future of mining is linked with applications of robotics and industrial controls, automation, global positioning drones, the Internet of Things, development and applications of artificial intelligence and machine learning, advanced communications strategies, including those for GPS-denied environments. There are exciting and challenging opportunities in mineral processing and separations, novel strategies for using membrane systems for water and resource recovery, and an amazing array of downstream applications in products touching every sector of the economy - including energy. The chance to inspire the students of the future with a vision for these possibilities and their impacts is exciting. The message behind the Mining Schools Act is a message of hope, of possibilities, and of opportunities to make a difference, for the future of America and the world, and to build partnerships with like-minded nations, our allies and friends.

**What will be most impactful from the proposed legislation?** I personally believe it critical that we initially establish a prestigious scholarship program at America's established and accredited programs in mining and mineral engineering and directly related disciplines. This will build a top-level cadre of students ready to go forward into industry and into advanced degree programs within the mining related sectors. Unless we overcome current perceptions of mining as a less attractive career path than others, we will continue to be challenged to meet the workforce demands of today and the years to come. Because today's mining engineering and related programs in the U.S. produce less than 200 B.S.-level graduates per year, we need to fill the pipeline of undergrads and associate-level students in these disciplines. An initial focus on graduate programs and academic research could divert precious limited resources from filling the pipeline -- and may risk the program's effectiveness overall.

There are many communities across Colorado—and represented by this committee—proud of their mining industries and the partnership represented with their people, demonstrating real economic benefits and positive evidence of environmental stewardship regionally and beyond. Key to the success of the Mining Schools Act will be maintaining clear **focus**. This is a bill that incorporates many stakeholder recommendations. I believe that many states across the country, including those represented on this Committee, would like to see their universities benefit and grow, and build the mining workforce through educational programs and research. \$10 million, if evenly divided to just 17 accredited programs, would provide \$588,000 per mining school program. Typical graduate student tuition, stipend and expenses can total between \$80,000 - \$100,000 per student – not counting the rest of the research costs. Graduate research programs are the more expensive components of this legislative proposal.

Undergrad scholarships can make a real difference – and can open possibilities for students to pursue majors and coursework relevant to the mining sector. Undergrad research experiences result in students who are trained in the science and engineering method, and who will gain valuable insights to the needs of the industry sector. Research experiences and fieldwork offered at the undergraduate level can help students establish a practical grounding and an excitement for career possibilities.

We also need to be realistic. Building and augmenting quality programs of mining engineering, minerals processing and metallurgical refining at the universities who currently do not have accredited programs will take time. This may also involve a new level of partnership with



universities having such approved curricula, as well as with industry players who are looking for specific talents and experience. It is relatively easy to establish a new research project that will train several students, but it takes longer, significantly longer to develop and approve a new course of study for inclusion in curriculum, and substantially longer yet to establish whole new degree programs and have them properly structured and ultimately accredited. Building workforce through attracting students to our currently accredited mining programs across the U.S. and building new courses and accredited degree programs at community colleges, colleges and universities committed to this industry will take time.

Industry has an essential role to play toward effective outcomes. The mining sector is a global business. Mining graduates of universities in the United States and abroad could see their career trajectories taking them to far-flung, exciting, and often remote parts of the world. People entering these fields need to first have an experience of what the mining sector and its related industries offer. Hence a strong partnership with industry offering internships, co-ops, hands-on experiences, field sessions as well as apprenticeships will be a necessary part of the equation for change. Programs of workforce retraining include certificate and online programs that allow efficient use of resource and time in bringing qualified people into the sector and preparing them for productive new careers.

Among the strongest predictors of having people enter the mining sector for a career path involves their family circumstances, where the students grew up, and the mentorship and early learning experiences they received. Students that come from a family heritage of mining, but who also resonate with the vision of the Mine of the Future as something entirely new and exciting will surely be part of the story. We, however, cannot and should not tell our next generation that they are entering into the same kind of business and for the same purposes as their grandfather may have done. We must appeal to, and create opportunities for, a broad spectrum of students, particularly those who have not considered a career in mining and are motivated to solve some of the most significant challenges of our times.

The future of mining has a new mission, and it needs to tell a new story, inspire a new purpose, and be pursued with a new ethos. Companies recruiting students to enter the sector must demonstrate a deep commitment to environmental, social and governance principles and engender trust through their sustained actions and investments. Indeed, it will be the new talent entering the sector that will help drive the changes so needed for a vibrant U.S. mining and mineral resource industry.

The United States no longer has a Bureau of Mines. Hence, the work that this Committee does with the Department of Energy, U.S. Geological Survey, and others including the Department of Defense to stimulate the necessary other interagency collaborations is essential for the strategic future of the mining and materials sectors of America.

The federal government in the United States does have examples of legislation passed and implemented with good intent - but resulting in less than satisfactory outcomes. In trying to accommodate all stakeholders, some legislation may never result in the nation achieving critical mass of workforce capacity, and hence remain unable to reach the desired goals. We need to recognize that this Mining Schools Act of 2023 is indeed trying to accomplish much, and that the

use of the limited funding of \$10 million per year as proposed will need to be managed carefully with the support of the advisory board to result in impactful outcomes.

The opportunity we have before us is to look first at how we engage and inspire the next generation of leaders for the mining and critical materials sectors, with a purpose and passion for the future of the planet, for people and communities, and our energy future.

Together with many colleagues in research, education, and industry around the country, I'm excited about the Mining Schools Act of 2023. I include with this testimony the text of a letter of support for its companion bill in the Senate.

Thanks to Chairman Stauber, Ranking Member Ocasio-Cortez, and all who have worked on this bill. We are grateful for the leadership of this Committee in your work to address these critical matters toward securing the workforce and technology leadership for U.S. economic and national security. I look forward to answering questions you may have.