POLICY PAPER

Global Energy Supply Chains: Addressing A Dramatically Changed U.S. Energy Landscape

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Melanie Kenderdine
Principal, Executive Vice President
Energy Futures Initiative
makenderdine@energyfuturesinitiative.org

Brian DaRin
Project Manager
Energy Futures Initiative
bsdarin@energyfuturesinitiative.org

900 17th Street NW, Suite 1100, Washington, DC 20006

ENERGY FUTURES INITIATIVE

About the Authors

Melanie Kenderdine

Melanie Kenderdine joined former Secretary of Energy Ernest J. Moniz and fellow Principal Joseph S. Hezir in founding the Energy Futures Initiative (EFI), a non-profit organization dedicated to driving innovation in energy technology, policy, and business models.

Kenderdine worked in the Administration of President Barack Obama at the Department of Energy (DOE) from May 2013 to January 2017. She served concurrently as Energy Counselor to the Secretary and as the Director of DOE's Office of Energy Policy and Systems Analysis. Her 100-person office was responsible for analysis and policy development in areas that included: DOE's role in the annual review of the Renewable Fuel Standard Program requirements, energy innovation, and climate change. Her office produced two installments of the Quadrennial Energy Review and helped conceive and develop the Energy Security Principles adopted by G-7 leaders in 2014. In her capacity as Energy Counselor to the Secretary, Kenderdine helped create Mission Innovation, now a 24-country/European Union initiative that supports transformational clean energy RD&D; North American grid integration and security; and the modernization of the Strategic Petroleum Reserve.

Prior to her service at DOE, Kenderdine helped establish the MIT Energy Initiative (MITEI) and served there as Executive Director. During her six-year tenure at MITEI, she managed large research and administrative staff, was a key contributor of MIT's Future of Natural Gas Study, the MITEI Symposium Report on Alternative Fuels and Vehicles, and edited the MIT Future of the Electric Grid study. Kenderdine also started the C3E Symposium series, a joint MIT-DOE program to support the careers of women in clean energy with cash prizes; she still serves as a DOE C3E Ambassador.

Before joining MITEI, she was Vice President of Washington Operations for the Gas Technology Institute (GTI) from 2001 to 2007. While at GTI, Kenderdine established a separate not-for-profit company, the Research Partnership to Secure Energy for America (RPSEA). As RPSEA's first CEO, she transformed it from an MOU between GTI and one university to an industry/academic unconventional natural gas research consortium of 26 universities and 30 industry partners. Concurrently, she was a key architect of the Royalty Trust Fund, the only federal trust fund dedicated to energy R&D.

From 1993 to 2001, Kenderdine was an appointee in President Bill Clinton's administration, where she served in several key posts at DOE, including Senior Policy Advisor to the Secretary, Bill Richardson, Director of the Office of Policy, and Deputy Assistant Secretary for Congressional and Intergovernmental Affairs.

She was a primary architect of the SPR oil exchange of 2000, the creation of the Northeast Home Heating Oil Reserve, and the return of the Naval Oil Shale Reserve No. 2 to the Ute tribe in Utah, the largest land transfer back to Native Americans in the lower 48 in over 100 years. Prior to joining DOE, Kenderdine was Chief of Staff and Legislative Director for then-New Mexico Congressman Richardson.

She is a graduate of the University of New Mexico, has homes in New Mexico and Hawaii, and is an avid global traveler and enthusiast of fly fishing.

Brian DaRin

Brian DaRin is a Project Manager at the Energy Futures Initiative (EFI). He has over 25 years of international affairs and policy experience in energy, monetary, trade, technology, and other economic issues. DaRin came to EFI following a distinguished diplomatic career with the U.S. Department of State. He served at United States missions to Japan, China, Hong Kong, Afghanistan, Belize, and Mongolia with the Department of State and the U.S. Agency for International Development (USAID).

Domestically, DaRin directed the approval of billions of dollars in critical energy infrastructure as head of Presidential pipeline permitting for hydrocarbons. DaRin also served as co-chair of the Defense Logistics Agency's Materials Impacts Committee, a representative for the Department of State at the National Petroleum Council, and a representative for the National Security Council's National Emergency Grid Planning and Strategic Minerals Committees.

At the U.S. Consulate General Osaka-Kobe, DaRin was the political-economic section chief where he advised senior U.S. officials on developments in Japan's energy sector and burgeoning gas importation needs. At Embassy Kabul, DaRin was head of energy and minerals development. While at the Department of State, in addition to a focus on energy-related policy issues, DaRin specialized in international monetary affairs, political-military affairs, and other national security issues. With USAID Mongolia, DaRin established the first U.S. Trade Linkage Office and drafted the first Country Commercial Guide to Mongolia.

DaRin has a Master of Business Administration in international management with a focus in international finance and Mandarin from the Thunderbird School of Global Management. He also holds a Bachelor of Arts in English and Fine Arts with a minor in Economics from the Virginia Military Institute.

The Energy Futures Initiative advances technically grounded solutions to climate change through evidence-based analysis, thought leadership, and coalition-building. Under the leadership of Ernest J. Moniz, the 13th U.S. Secretary of Energy, EFI conducts rigorous research to accelerate the transition to a low-carbon economy through innovation in technology, policy, and business models. EFI maintains editorial independence from its public and private sponsors.

Abstract

The Russian invasion of Ukraine has raised critical concerns about the ongoing security of conventional U.S. energy supply chains, underscoring their geostrategic importance to the United States, its allies, and its trading partners. At the same time, there are also relatively new and growing supply chain issues and concerns associated with the metals and minerals needed for clean energy technologies.

Net zero policies are also driving concerns about the full range of emissions for both conventional and clean energy supply chains, ranging from production to pipelines and other transport of energy supplies, processing, international shipping, mining, component manufacturing, and end uses. These concerns and associated policies, such as the EU's carbon border adjustment policy, could have major impacts on both conventional and clean energy supply chains.

This paper provides background on both conventional and clean energy supply chains in the context of today's changed U.S. energy profile, current and ongoing energy security concerns, and climate change impacts. The paper includes a specific focus on the role of the Department of Energy as the federal agency with primary responsibility for addressing both the security of, and emissions from, conventional and clean energy supply chains.

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1. The Establishment of the Department of Energy

During the Arab Oil Embargo of 1973-74, for five months, oil-producing nations in the Middle East ceased oil exports to many countries including the U.S. The embargo resulted in long lines at gas stations, slowed the prosperity of the post-WWII West[i], and raised a range of threats to global energy security. At the end of the oil embargo, oil prices had increased by 300%.

The Department of Energy (DOE) was formed in response to these energy supply chain disruptions and growing concerns in the U.S. about the need for “energy independence”. In April 1977, President Carter addressed the nation, asserting that, “The oil and natural gas that we rely on for 75 percent of our energy are simply running out.… World oil production can probably keep going up for another 6 or 8 years. But sometime in the 1980s, it can’t go up anymore. Demand will overtake production. We have no choice about that.”

In October 1977, President Carter signed a law establishing the Department of Energy. A DOE website describes the impetus for the Department’s establishment as follows (emphasis added):

> “…***the Arab oil embargo motivated a wave of energy-related national policy initiatives…***the establishment of DOE gathered under one authority most of the federal government’s energy-related research, policy, and regulatory activities (with the notable exception of regulation of the nuclear power industry, which became the exclusive duty of the newly created Nuclear Regulatory Commission).”[ii]

As noted, since DOE’s establishment, it has had a critical focus on energy supply chains. This analysis will examine this ongoing need for both conventional and clean energy supply chains in the context of the changed energy profile of the U.S.; what changes might be needed at the Department to accommodate and address this dramatically changed energy profile; international forums for addressing some of these supply chain issues; and some specific areas of focus for federal policymakers.

2. The Changed U.S. Energy Profile

As noted, the energy profile of the United States, from both conventional and clean energy perspectives, has changed dramatically since DOE was founded. The warning that the U.S. was “simply running out” of oil and gas was wildly inaccurate. The U.S. is now the largest exporter of liquefied natural gas in the world and, according to the Energy Information Administration (EIA), 2021 marked the second year in a row since 1949 that the United States was a net exporter of oil. These and other new energy realities include significant and associated supply chain issues, albeit from very different perspectives and policy needs than those when the DOE was founded 45 years ago. These changed realities may also require corresponding changes in government structures and missions.

To understand U.S. energy supply chains since the establishment of DOE, it is important to first look at U.S. gas, oil, and coal production over time, with a focus on production post-1977 and from 2001-2020 (Figure 1). Importantly, since 1977, crude oil and natural gas production have increased by 32% and 81% respectively with very significant increases in volumes between 2001 and 2020. Coal production on the other hand declined dramatically in that same period, down by 52%.

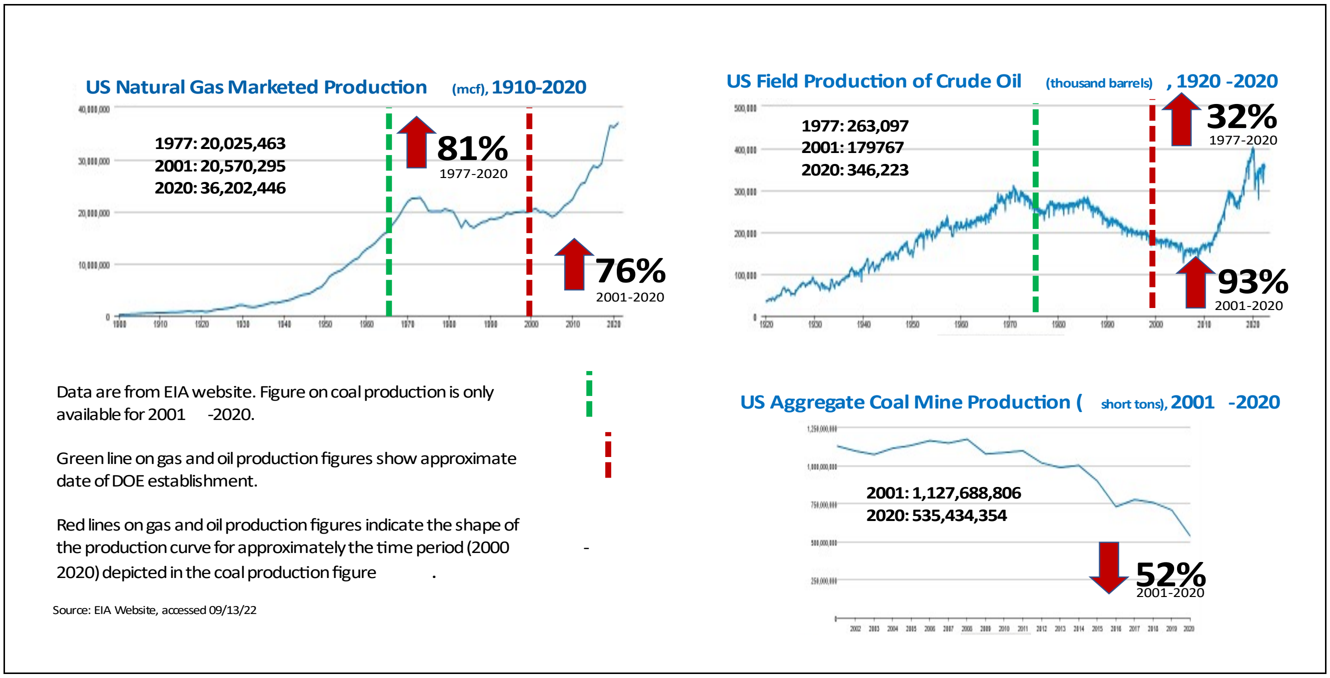


Figure 1: U.S. Production of Natural Gas, Oil, and Coal Over Time.

Wind and solar have had similar, although even more dramatic, changes. In just 20 years, renewable generation increased by 662% (Figure 2) and renewables use by utilities over that period increased by 1176%. In 2021, solar generation provided four percent of total US generation and wind was around nine percent, energy sources enabled by technologies that were virtually nonexistent when DOE was authorized in 1977. Power generation from renewables is also expected to grow significantly over the next 30 years; EIA forecasts that solar will likely provide 20% of US power generation in 2050.

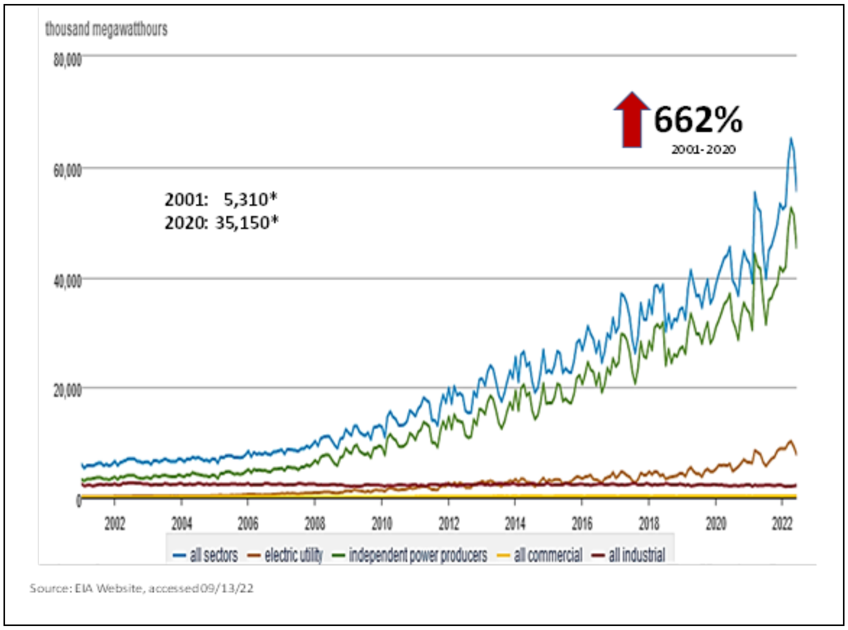


Figure 2: Net Renewables Generation Excluding Hydro, 2001-2022.

There have also been dramatic changes in the use of conventional fuels for power generation, with numerous supply chain implications. Between 2001 and 2021, overall electricity generation/demand in the U.S. increased by ten percent at the same time the population increased by 18%; per capita electricity use declined by seven percent, suggesting, in part, the effectiveness of efficiency and conservation measures.

The use of coal for power generation saw a very significant decrease, going from 51% in 2001, to just 21.8% in 2021. Much of this decline has been picked up by natural gas, which went from 9.9% of generation in 2001 to over 38% in 2021. Nuclear and hydro-electric generation have remained relatively constant as a percentage of total generation and as noted, non-hydro renewables including biomass have seen significant growth over that period, going from just under two percent in 2001 to almost 14% in 2021.

These very significant changes in the U.S. energy and power generation profiles since DOE was created have, in part, switched the policy focus from imports to exports for conventional energy and as discussed later, to imports of the raw metals and minerals and the manufactured products that use them, both of which are needed for the clean energy transition. These changes come with many supply chain implications that, in turn, suggest possible changes in how DOE and the federal government in general manage these issues and the data that are required for doing so.

3. Allies and Trading Partners

To fully assess the implications of the changed U.S. energy profile relative to supply chains, and it allies and trading partners, it's important to first identify who the United States' allies and trading partners are. U.S. trading partners will likely inform a range of issues and policies associated with managing energy supply chain issues. The 15 largest recipients of U.S. exports in 2020 and their percentage of total U.S. exports are seen in Figure 3.

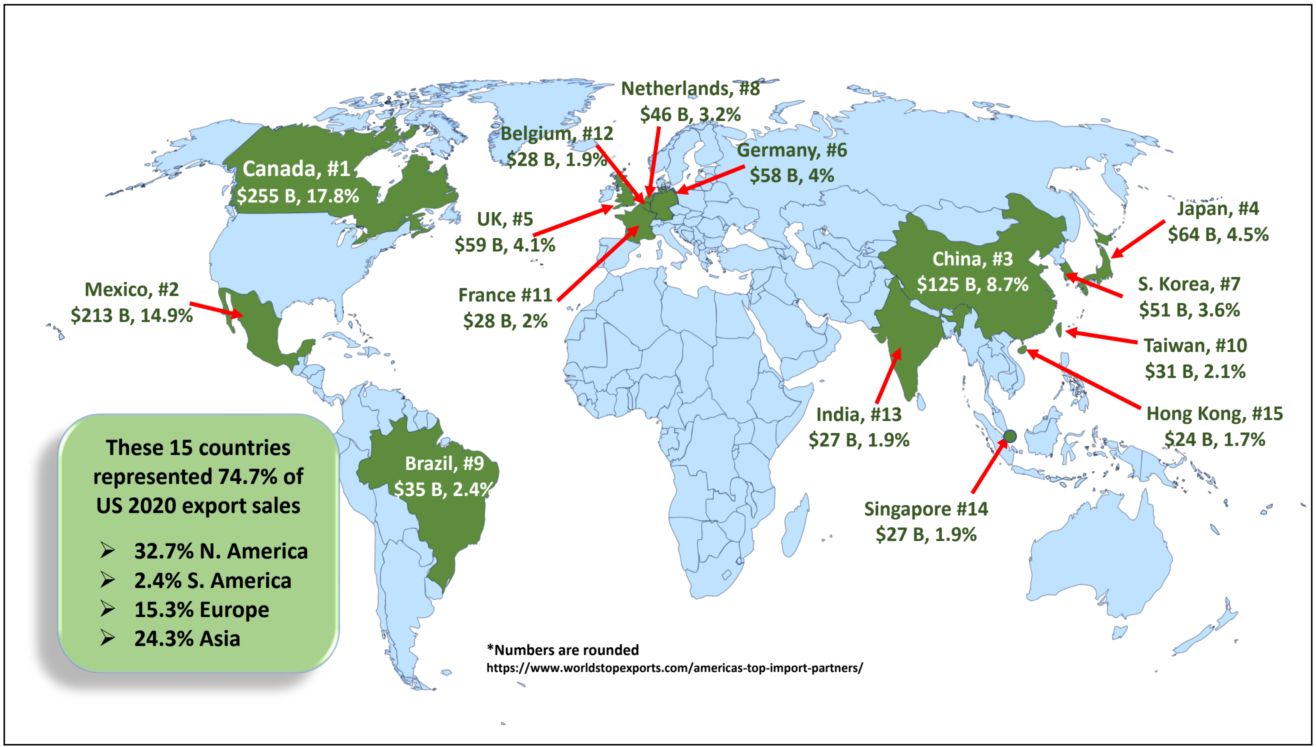


Figure 3: 15 Largest Recipients of U.S. Exports in 2020 (Rank, % Total U.S. Sales to Country, 2020$ Value).*

These 15 countries represent almost 75% of the dollar value of all U.S. exports in 2020. Canada and Mexico are the two largest recipients of U.S. exports, and China is third, receiving $125 billion of U.S. goods in 2020. This trading relationship with China could provide a solid basis for energy supply chain discussions, issues, and protections going forward, especially important for the metals and minerals needed for clean energy technologies.

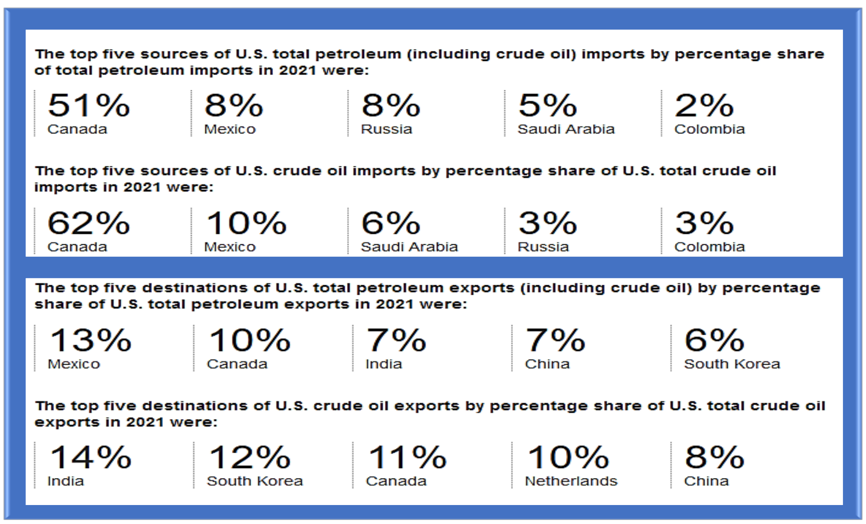
Also, three of the five largest products exported (in dollar value) by the U.S. in 2020 were energy related: first, is refined petroleum valued at over $58 billion, crude petroleum at around $52 billion, followed by petroleum gas, at almost $35 billion[iii]. That same year, the U.S. was also the world's largest exporter of refined petroleum, petroleum gas, and gas turbines.[iv] From a geographic perspective, Texas, California, New York, Louisiana, and Illinois were the states with the highest dollar value exports in June of 2022[v].

On the diplomatic/ security front, in addition to the United States, members of NATO include Albania, Belgium, Bulgaria, Canada, Croatia, Czech Republic, Denmark, Estonia, France, Germany, Greece, Hungary, Iceland, Italy, Latvia, Lithuania, Luxembourg, Montenegro, Netherlands, North Macedonia, Norway, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Turkey, and the United Kingdom.[vi] There are also 18 countries that have Major Non-NATO Ally (MNNA) status.: Argentina, Australia, Bahrain, Brazil, Colombia, Egypt, Israel, Japan, Jordan, Kuwait, Morocco, New Zealand, Pakistan, the Philippines, Qatar, South Korea, Thailand, and Tunisia. Taiwan is also treated as an MNNA, "without formal designation as such".[vii]

Another important diplomatic agreement is the Inter-American Treaty of Reciprocal Assistance, whose members include Argentina, the Bahamas, Brazil, Chile, Colombia, Costa Rica, Dominican Republic, El Salvador, Guatemala, Haiti, Honduras, Panama, Paraguay, Peru, Trinidad and Tobago, Uruguay, and Venezuela. The Quadrilateral Security Dialogue, a strategic security dialogue between the U.S., India, Australia, and Japan is also rising in importance following China's militarization of three islands in the South Pacific earlier this year.

4. Conventional Energy Supply Chains

As noted, on the conventional energy side, the U.S. supply chain profile has also seen major changes in the last decade. The sources/ destinations of U.S. petroleum and crude oil imports and exports in 2021 and the percentage of their totals are highlighted in Figure 4. Notably, 72% of U.S. crude oil imports come from Canada and Mexico, partners in the United States – Mexico – Canada Agreement (USMCA) that replaced the North American Free Trade Agreement in 2020.



The top five sources of U.S. total petroleum (including crude oil) imports by percentage share of total petroleum imports in 2021 were:

51%	8%	8%	5%	2%
Canada	Mexico	Russia	Saudi Arabia	Colombia

The top five sources of U.S. crude oil imports by percentage share of U.S. total crude oil imports in 2021 were:

62%	10%	6%	3%	3%
Canada	Mexico	Saudi Arabia	Russia	Colombia

The top five destinations of U.S. total petroleum exports (including crude oil) by percentage share of U.S. total petroleum exports in 2021 were:

13%	10%	7%	7%	6%
Mexico	Canada	India	China	South Korea

The top five destinations of U.S. crude oil exports by percentage share of U.S. total crude oil exports in 2021 were:

14%	12%	11%	10%	8%
India	South Korea	Canada	Netherlands	China

Source: Energy Information Administration, Oil and petroleum products explained Oil imports and exports, accessed September 12, 2022

Figure 4: Sources/Percentage of U.S. Petroleum Imports/Exports, 2021.

It should be noted that in 2022, the U.S. banned all oil imports from Russia, potentially reducing the volumes of U.S. oil available for export; Russia provided eight percent of U.S. petroleum imports last year, a small but not inconsequential amount. It should also be noted that efforts by some interest groups to ban U.S. oil/ petroleum exports would have significant impacts on key U.S. allies and trading partners – Mexico, Canada, India, South Korea, and the Netherlands. Seven percent of U.S. exports in 2021 went to China. Again, these and other exports are important for focusing shared interests between the U.S. and China, with associated and potentially significant geopolitical implication.

The global LNG trade has been growing rapidly, up from 250 bcm in 2009, to almost double that amount at 485 bcm in 2019, when 38 percent of internationally traded natural gas supply was LNG. IEA expects globally traded LNG volumes to surpass 500 bcm in 2023.[viii]

This has fundamentally changed natural gas market structures, with a significant increase in spot cargoes and the associated implications for market development.

The United States, as a major contributor to this growth, has been an annual net exporter of natural gas since 2017. In 2021, total annual U.S. natural gas exports were 6.65 Tcf (the highest on record) compared to 2.81 Tcf of imports[ix]. Importantly, as noted, this year the U.S. became the largest LNG exporter in the world.[x] U.S. natural gas imports and exports between 1950 and 2021 are seen in Figure 5, with very dramatic increases in exports starting around 2015.

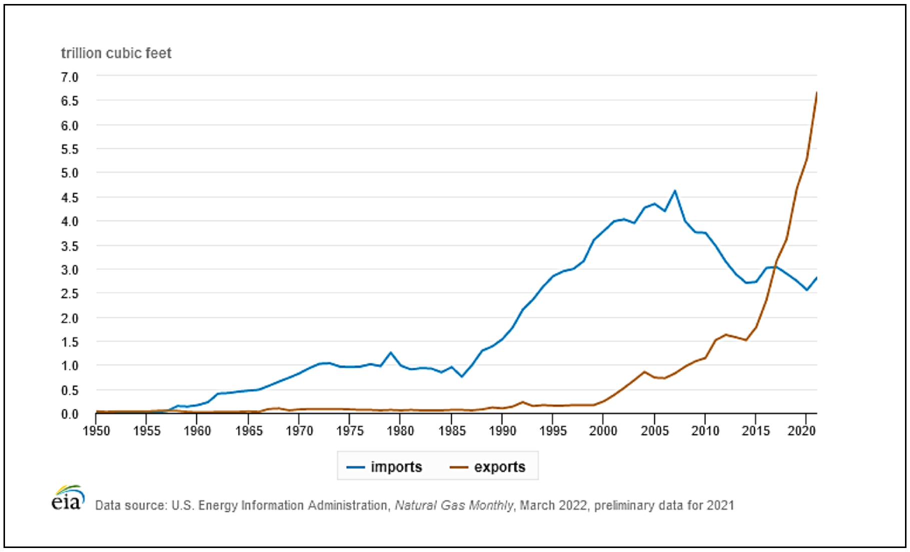


Figure 5: U.S. Natural Gas Exports, 1950-2021.

According to the Energy Information Agency (EIA), U.S. coal production and consumption peaked in 2008 and has declined dramatically since then. U.S. coal exports peaked in 2012, when 125.7 MMst or around 12% of U.S. coal production was exported. By 2021, export volumes had declined to around 85.2 MMst of coal, about 15% of total U.S. coal production, under-scoring overall coal production declines. U.S. coal exports, are however, still important to its trading partners. In 2021. U.S. coal was exported to 83 countries, out of which 58 % went to five countries – India, China, South Korea, Japan, and the Netherlands (Figure 6).[xi]

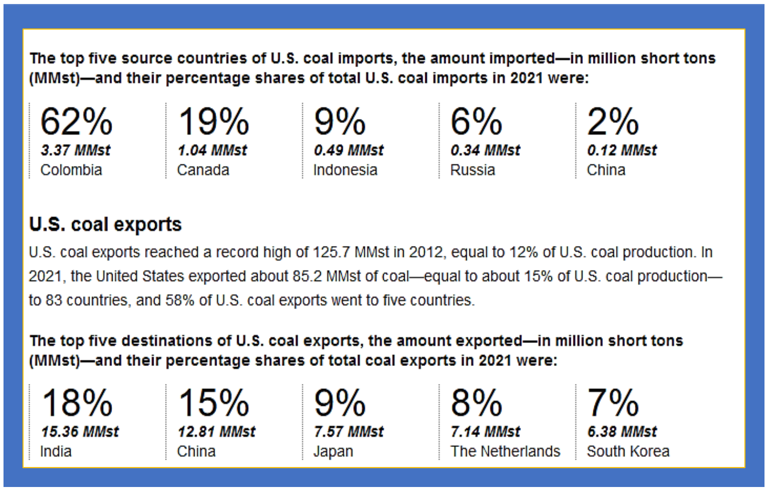


Figure 6: U.S. Coal Exports, Import Suppliers, Export Destinations, 2021.

Between 2020 and 2021, the U.S. followed Australia, Indonesia, and South Africa as the fourth largest supplier of coal to India; the dollar value of U.S. coal exported to India increased by 55.5% in one year. The U.S. was also the fourth largest supplier of coal to Japan, following Australia, Indonesia, and Russia; over that same period, the dollar value of U.S. coal exported to Japan increased by 18%. The U.S. was the sixth largest supplier of coal to South Korea although the dollar value of these exports decreased by 26% over the year.[xii] These importers of U.S. coal are highlighted to underscore the importance of U.S. coal exports to key allies.

4.1. Energy Security Concerns

While natural gas is a significant source of GHG emissions, it is also a mainstay of the global energy economy, meeting approximately one-third of total energy demand growth over the last decade. U.S. LNG exports are critical to the current situation in Europe; these U.S. exports to Europe increased by 686% between 2018 and 2021 (Figure 7). At the same time, imports to Asia increased by 199% and the region remains the largest importer of U.S. LNG. Importantly, in that same period, exports to U.S. neighbors in the Caribbean and Central and South America also increased by 965% and 350% respectively.

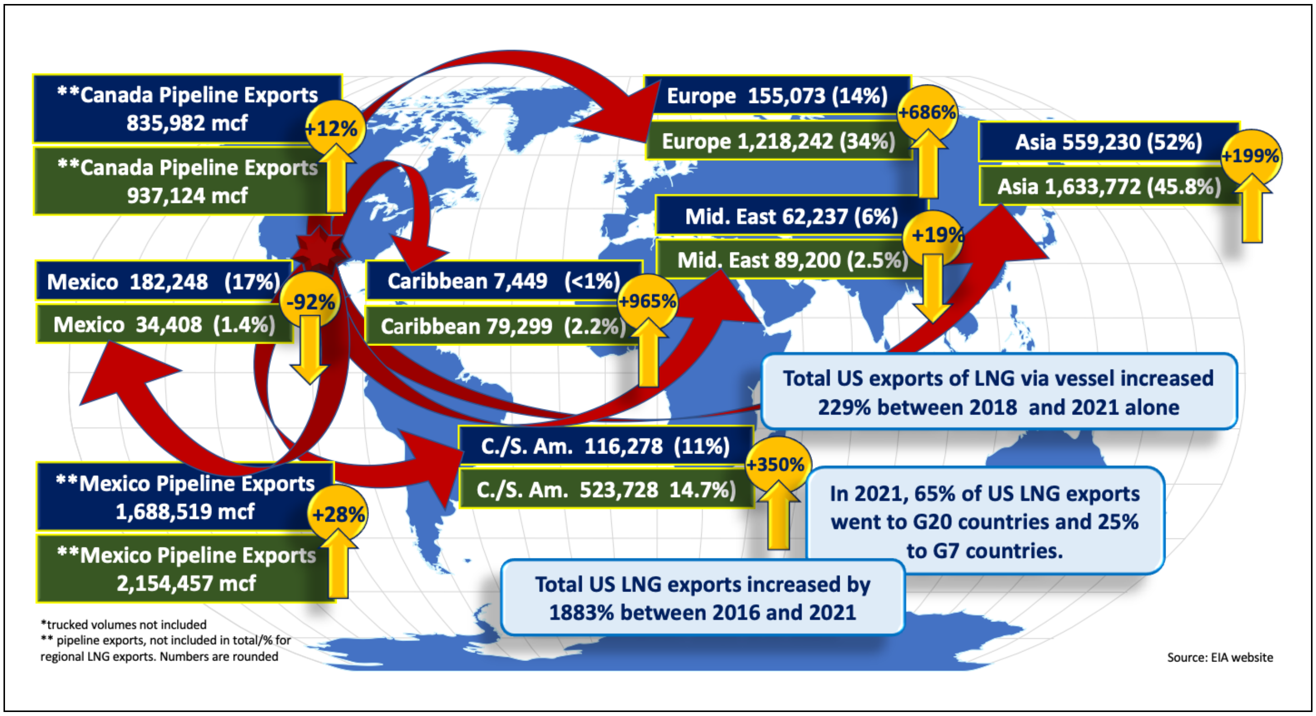


Figure 7: U.S. LNG by Vessel/Pipeline Export Destinations by Region, Total Volume (mcf) & %, 2018 and 2021.*

Europe clearly has critical needs in the near term. Many countries in Europe have been highly dependent on Russian natural gas (Figure 8). This September, Russia announced plans to shut off all gas through Nord Stream 1 indefinitely. That same month, there were explosions at both Nord Stream 1 and 2; sabotage was expected. This further exacerbates Europe's needs for natural gas in the near to mid-term. Earlier this year, EU leaders announced plans to reduce Europe's use of Russian gas by 2/3rds by the end of this year; this underscores how important U.S. LNG exports are to its allies in Europe. At the same time, the U.S. and the gas industry have both policy and contractual obligations with other allies and trading partners. This strongly suggests the need for additional and sustained LNG exports.

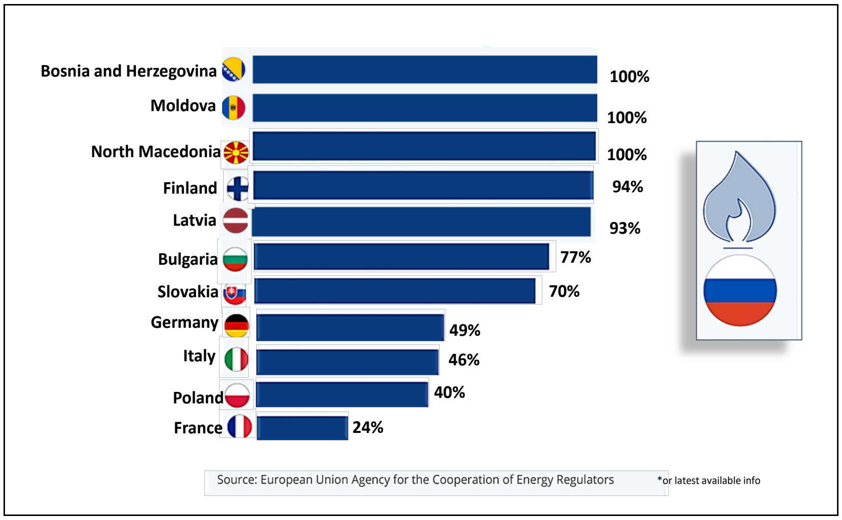


Figure 8: Share of Gas Supply from Russia in Select European Countries, 2020.

It is critical in the context of efforts to get more U.S. LNG to Europe, to understand the degree to which other allies and trading partners rely on U.S. LNG (Figure 9). As seen in the figure, of the 15 largest recipients of U.S. LNG by volume includes eight NATO allies (France, Greece, Italy, Netherlands, Portugal, Spain, Turkey, and the UK); four with MNNA status. (Brazil, Japan, Taiwan, South Korea); and two that are parties to the Inter-American Treaty of Reciprocal Assistance (Chile, Brazil).

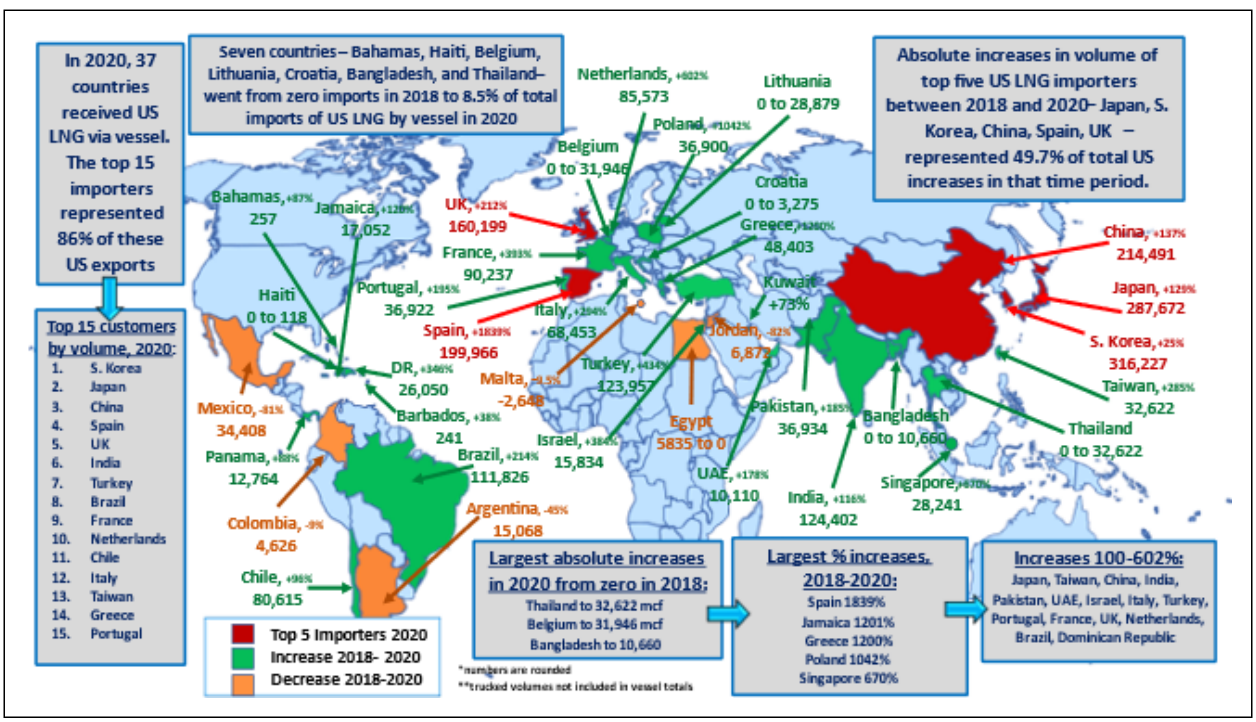


Figure 9: U.S. LNG Exports, Increase, Total 2020 (mcf), % Increase/Decrease, 2018-2020**.*

In addition, many factors point to a continued and robust trajectory for global natural gas demand and production. In IEA's Sustainable Development Scenario, natural gas continues to play a substantial role in global energy supply and demand through 2040. This scenario "maps out a way to meet sustainable energy goals in full, requiring rapid and widespread changes across all parts of the energy system. This scenario charts a path fully aligned with the Paris Agreement by holding the rise in global temperatures to 'well below 2°C … and pursuing efforts to limit [it] to 1.5°C', and meets objectives related to universal energy access and cleaner air."

Under this scenario, gas demand in 2030 is seven percent higher than 2018 levels and over 25% of total primary energy demand. In 2040, gas demand declines by three percent from 2018 levels but is still 24% of total primary energy demand; this compares to a 32% decline in oil consumption and a 61.5% decline in coal consumption over the same period. This reflects, in part, the fact that natural gas is the least carbon intensive of fossil fuels.

4.2. The Federal Government's Management of Conventional Energy Supply Chain Risks

In February 2021, President Biden issued an *Executive Order 14017, America's Supply Chains* that stated (emphasis added), among other things that –

> *"…*The United States needs resilient, diverse, and secure supply chains to ensure our economic prosperity and national security…climate shocks and extreme weather events…geopolitical and economic competition, and other conditions can reduce critical manufacturing capacity and the availability and integrity of critical goods, products, and services…More resilient supply chains are secure and diverse — facilitating greater domestic production, a range of supply, built-in redundancies, adequate stockpiles, safe and secure digital networks, and a world-class American manufacturing base and workforce. Moreover, close cooperation on resilient supply chains with allies and partners…will foster collective economic and national security and strengthen the capacity to respond to international disasters and emergencies…*Climate change has had a significant impact on supply chains, including energy supply chains. These impacts are not exclusive to conventional energy supply chains but the near-term impacts on energy security, regional and national economies, and energy affordability will likely be much greater."*

4.3. Energy Security Concerns

In response to this executive order, DOE has issued "America's Strategy to Secure the Supply Chain for a Robust Clean Energy Transition". From a conventional energy perspective, the strategy includes options for carbon capture. It should be noted, however, that this DOE strategy was released on the same day that Russia launched its invasion of Ukraine on February 24, 2022, when the value of U.S. LNG exports to the energy security of our European allies became abundantly clear.

To address this new energy security concern, within a month the DOE authorized increased exports from two U.S. companies.xiii According to the DOE press release on this action, "The U.S. Department of Energy (DOE) today issued two long-term orders authorizing liquefied natural gas (LNG) exports from two current operating LNG export projects, Cheniere Energy Inc.'s Sabine Pass in Louisiana and Corpus Christi in Texas. The two orders allow Sabine Pass and Corpus Christi additional flexibility to export the equivalent of 0.72 billion cubic feet per day of natural gas as LNG to any country with which the U.S. does not have a free trade agreement, including all of Europe."

Since July, the U.S. has, as noted, exported more LNG than any country in the world, averaging 11.1 bcfd in the first half of this year.xiv Three LNG export projects currently under construction will, by 2025, add another 5.5 bcfd of capacity.

These export increases need to be considered not only in the context of the near-term needs of our allies in Europe but, as discussed earlier, also considering the needs of our allies in Asia, where South Korea and Japan are the two largest importers of U.S. LNG. FERC and MARAD, the federal regulatory agencies of jurisdiction, approved export facilities by volume as of February 2022 are seen in Figure 10, showing volumes of U.S. LNG exports approved the same month Russia invaded Ukraine.

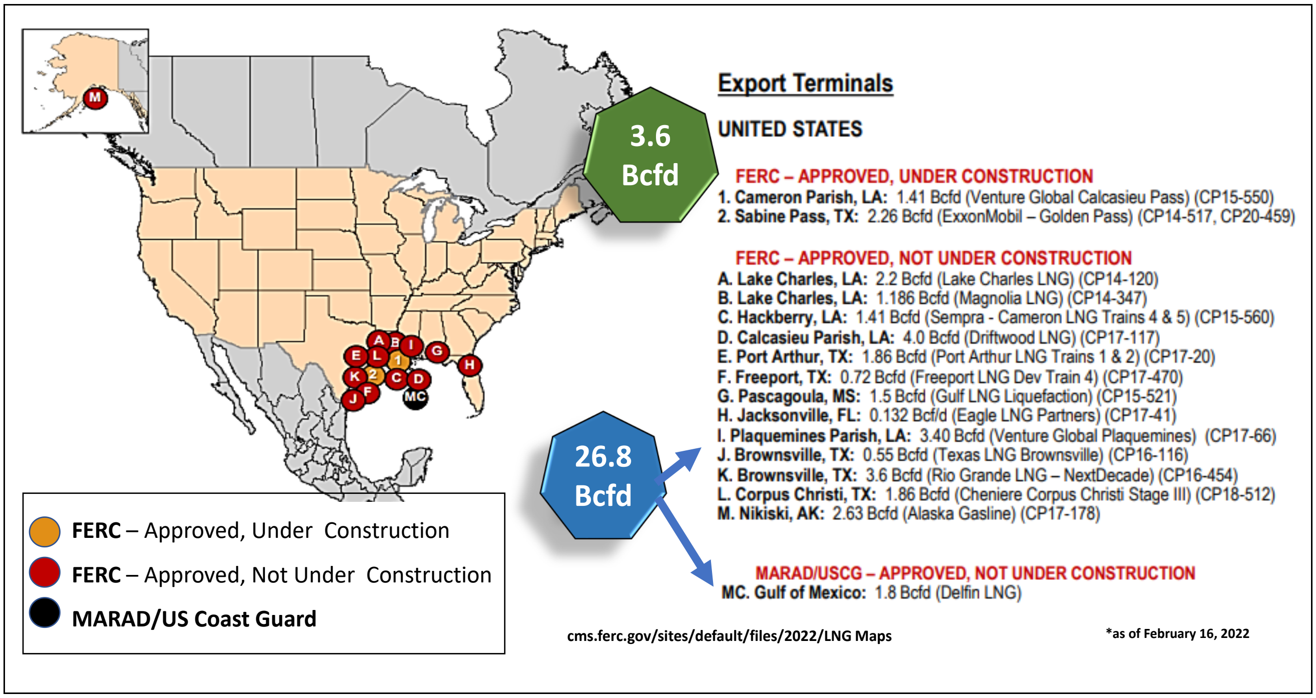
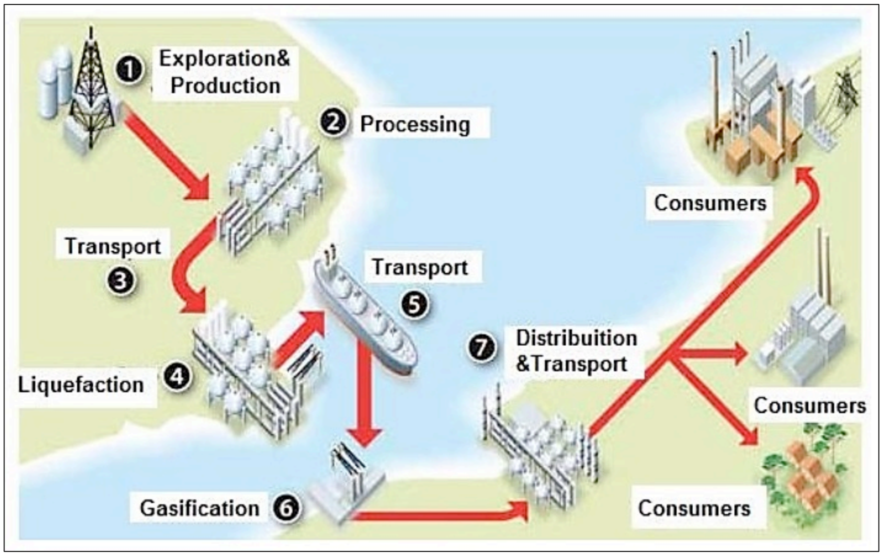


Figure 10: Approved North American LNG Export Terminals as of February 2022.

The LNG volumes approved for facilities not yet under construction are substantial. Expediting construction of the most feasible of these approved facilities could help address the near- to mid-term energy security needs for U.S. LNG exports, as the U.S. and its allies work to implement a range of clean energy strategies to reach mid-century net zero targets.

In this context, it is also important to understand that the geostrategic value of U.S. LNG exports for its allies and trading partners also requires domestic natural gas supply chains. A schematic of the LNG supply chain, from production to processing, to liquefaction, to transport and beyond is seen in Figure 11. The need for U.S. natural gas domestic production, transport and processing needs to be placed and fully analyzed in the context of the current energy security needs of the U.S. allies and trading partners who, in the face of Russia's invasion of Ukraine and its closure of Nord Stream1 are in urgent need of U.S. gas exports.



https://www.researchgate.net/figure/Supply-Chain-for-LNG_fig1_334207606

Figure 11: Example of LNG Supply Chain.

These needs are underscored in the President's statement issued with his Executive Order 14017 on energy supply chains, where the near-term impacts of Russia's actions on energy security and regional economies are highlighted. A range of policy options should be examined and analyzed by the DOE to help meet these energy security needs, including the need for additional natural gas production as a critical component of the LNG export supply chains. As former Secretary of Energy Ernest Moniz recently recommended, the U.S. needs to:

- advance collective energy security and climate change mitigation in the near- and midterm
- expand the oil and gas sector dialogue to include the financial sector (which has been driving balance sheet gains rather than production) and international allies (with a particular focus on demand-side commitments that support private investment)
- support expediting additional LNG export capacity in exchange for measurable progress on net-zero LNG and methane emissions reductions across supply chains.

Several federal agencies are involved in regulating the natural gas (and oil) industries. The critical needs that are served by the various functions in the supply chain and the supply chain risks for which the various agencies are responsible are seen in Table 1.[xv] It is important to note that there no federal agencies highlighted as being responsible for conventional energy supply chain risks.

Lead federal regulatory agencies

	Process Safety	Physical Security	Cybersecurity	Supply Chain
Exploration and Production (offshore)	BSEE	USCG	USCG	
Exploration and Production (onshore)				
Fuel Refining and Processing	OSHA	CISA	CISA	
Storage and Reserves	OSHA	CISA	CISA	
Pipeline Transport	PHMSA	TSA	TSA	

Source: CRS analysis of federal agency sources and relevant sections of C.F.R.

Notes: Blank cells indicate no federal regulatory oversight of risk-management plans or practices. CISA oversight applies only to designated high risk facilities subject to CFATS requirements for facility security plans. TSA has not issued physical security regulations for pipelines. Abbreviations: BSEE = Bureau of Safety and Environmental Enforcement, Interior; CISA = Cybersecurity and Infrastructure Security Agency, Homeland Security; OSHA = Occupational Safety and Health Administration, Labor; PHMSA = Pipeline and Hazardous Materials Safety Administration, Transportation; TSA = Transportation Security Administration, Homeland Security; and USCG = U.S. Coast Guard, Homeland Security.

Table 1: Oil and Gas Subsector Regulation by Risk Type and Critical Function.

It is important to note in this context that the Department of Energy has created a new Manufacturing and Energy Supply Chains Office. Its focus is "…strengthening and securing manufacturing and energy supply chains needed to modernize the nation's energy infrastructure and support a clean and equitable energy transition". It also has a data mission that is and could be critical for informing many important supply chain issues and policies.

While this new office has been designed to, among other things, address a critical need – energy supply chains – its 2021 report, Building Resilient Supply Chains, Revitalizing American Manufacturing and Fostering Broad-based Growth, focuses in the energy space on semi-conductor manufacturing, large capacity batteries, critical metals and materials, and addressing the growing supply chain issues associated with the U.S. reliance on imports for the clean energy transition (these are discussed later in this paper). It does not, however, appear to have a mission focus on conventional energy supply chains and how the associated U.S. exports are critical for meeting the energy security needs of its allies and trading partners.

Since the Russian invasion of Ukraine, there is a clear and timely need for DOE to place an additional and sustained focus on U.S. conventional energy exports and their associated supply chains, both domestic and international; on the geostrategic value to the U.S. and its allies that is enabled by these supply chains; and on the data that are needed to inform the range of issues and policies that are needed to support them. Expanding the mission of this new office to include a specific focus on these issues could help address these critical issues.

4.4. Climate Change Issues

At the same time there are growing and demonstrated energy security concerns, the world is also facing a climate crisis, the impacts of which are becoming increasingly visible across the globe. The drying up of the Colorado River and severe shrinkage of Lake Mead has been making headlines in the US. But the US is not alone.

The Danube, the Rhine, the Volga; some European rivers are so low that European river cruises had to bus travelers to get across their low spots. CCTV in China reports that 66 rivers in one municipal region have dried up and there has been three months of excessive heat across the country. Pakistan is suffering from the opposite problem – torrential rains that have left thousands dead and millions homeless.

According to Phys.Org, “Extreme weather events linked to climate change caused about $65 billion in total losses in the first half of 2022, roughly half of which hit uninsured assets, according to data compiled by Munich Re.”[xvi] NASA recently reported that a recent ice melt in Greenland was, “… the largest for any September since the start of record-keeping in 1979. Melt events of this magnitude are unlikely in September because seasonal temperatures usually drop as the hours of sunlight decrease.”[xvii]

Melting glaciers are a critical concern for power generation in regions of the U.S. and the world that heavily rely on glacier-fed hydropower. These regions include the Northwestern U.S., parts of Canada, many countries in South America and Asia, and parts of northern Europe, all of which could be impacted by melting glaciers and the potential impacts on electricity supplies in those regions of the world. From a U.S. perspective, this could create additional demand for domestic natural gas generation, with potential to affect supplies available for export.

Another climate change manifestation that is of great concern for global supply chains is its impact on the oceans. According to the 4th National Climate Assessment, “The world’s oceans have absorbed 93% of the excess heat from human-induced warming since the mid-20th century and are currently absorbing more than a quarter of the carbon dioxide emitted to the atmosphere annually from human activities, making the oceans warmer and more acidic. Increasing sea surface temperatures, rising sea levels, and changing patterns of precipitation, winds, nutrients, and ocean circulation are contributing to overall declining oxygen concentrations in many locations.”

Additional issues with global supply chains and shipping are analyzed in a joint study by the Environmental Defense Fund and RTI International released earlier this year. The study concludes that by 2100, the costs of climate change to the shipping industry could be as high as $25 billion a year.[xviii] Important to U.S. LNG exports and supply chains, the report concludes that “For ships at sea, stronger storms will require adaptation through re-routing, which increases in delays and operating costs.”

Global shipping, including LNG transport and movement of metals, minerals, and the associated technology for clean energy uses, also raises emissions concerns. Global shipping in total is under three percent of annual greenhouse gas emissions; while overall, this is a relatively small amount, it is significant in the face of the U.S.'s and other nations' net zero targets and an important consideration for both domestic and international policies.

These and other events and additional and alarming climate data come with growing weather threats to energy supply chains, including global shipping of metals, minerals, and a range of energy technologies. In July of this year, the Joint Statement on Cooperation on Global Supply Chains from Australia, Brazil, Canada, Costa Rica, the Democratic Republic of the Congo, the European Union, France, Germany, India, Indonesia, Italy, Japan, Mexico, the Netherlands, the Republic of Korea, Singapore, Spain, the United Kingdom, and the United States, noted, among other things (emphasis added):

> "The shocks to global supply chains from pandemics, wars and conflicts, extreme climate impacts, and natural disasters have put in stark relief the urgent need to further strengthen supply chains, to work to reduce and end near-term disruptions, and to build long-term resilience. This is a global challenge we intend to approach resolutely and cooperatively…in an effort to **alleviate near-term transportation, logistics, and supply chain disruptions and bottlenecks as well as the long-term resilience challenges that make our supply chains vulnerable…**"

Another important issue associated with U.S. LNG: from a climate perspective, in 2018, U.S. natural gas was the source of 21% of energy-related carbon emissions (coal was 44% and oil, 35%). The carbon intensity of upstream natural gas production, processing, and transport are responsible for half of total emissions in the LNG supply chain, liquefaction is 33%, shipping is 16% and regasification is one percent (Figure 12), important information for importers of U.S. LNG, including the EU, which plans to implement carbon border adjustments on select imports in 2026.

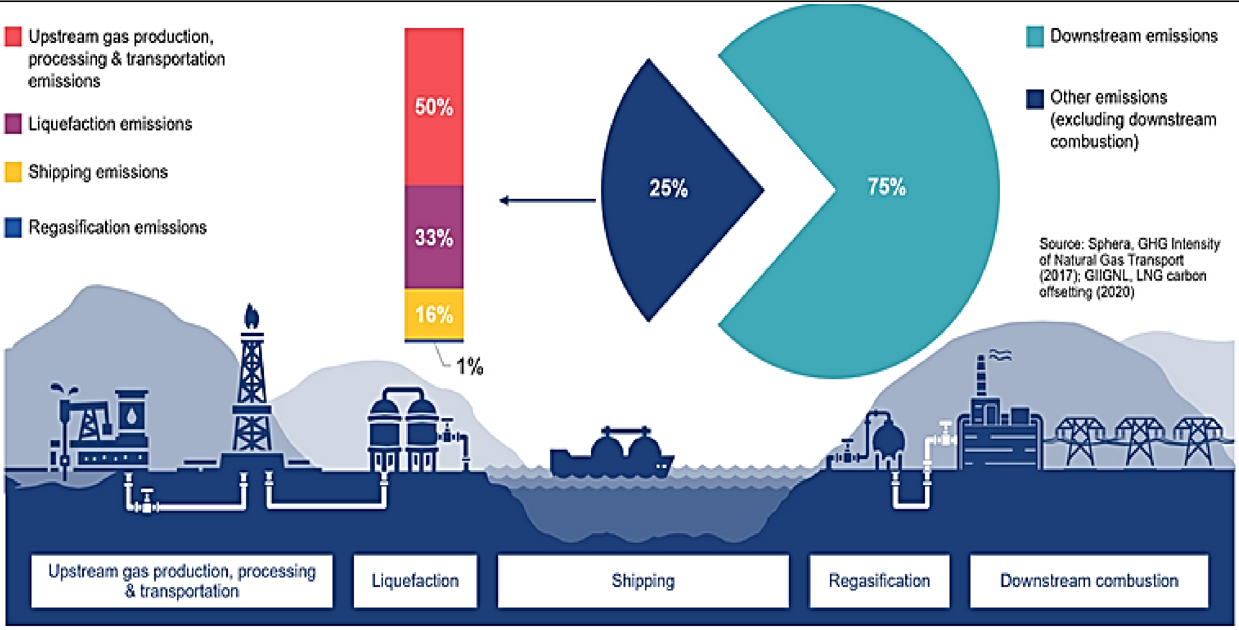


Figure 12: Carbon Intensity of the LNG Supply Chain.

A Another climate change impact from these supply chains is methane emissions. According to EPA, methane emissions from oil and gas systems in 2020 were 38% of total methane emissions. Importantly, small stripper wells, while limited contributors to oil and gas supply, are a large part of methane emissions from oil and gas production. It should also be noted that, while methane emissions from oil and gas systems are significant, 53% of methane emissions are from agriculture and landfills. EPA also indicates that since 1990, methane emissions from gas systems declined by 5% between 2016 and 2020[xix], at the same time U.S. natural gas production increased by almost 24%.[xx] This compares to a 1.3% increase in methane emissions from landfills between 2016 and 2020, and a 2.5% increase from agricultural emissions over the same time period.[xxi] These data suggest the need to accelerate the reduction of methane emissions from natural gas and oil systems, as well as the need for additional innovation and policies to address agricultural and landfill methane emissions. From a DOE perspective, this could include, for example, additional innovation in biodigesters.

It should also be noted that many analyses point to the dramatic undercounting of methane emissions. According to a recent paper published by the American Chemical Society focused on methane emissions in the Permian Basin of New Mexico, “We estimate emissions to be 9.4% (+3.5%/–3.3%) of the gross gas production for the region, much higher than found in previous studies with overlapping, although not identical, domains.”[xxii]

While there is an ongoing need for regulation of methane emissions from oil and gas systems, regulatory actions and authorities have had a tortured history over the last several years. In April 2022, after an analysis of the range of issues associated with attempts to regulate methane emissions from the oil and gas sectors, the Government Accountability Office (GAO) concluded that –

> "While EPA and BLM have taken steps in an array of rules to reduce methane emissions, administrative and legal challenges have hindered their implementation…Without greater flexibility in its process for approving alternative technologies, EPA may hinder the adoption of innovative approaches by operators for detecting and reducing methane emissions. Large oil- and gas-producing states are taking steps to regulate methane that go beyond what BLM demands, such as requiring operators to submit gas capture plans prior to drilling and to establish and meet goals for gas capture. Without BLM taking steps to institute similar requirements for operators on federal lands, operators will continue to vent or flare methane that contributes to pollution and greenhouse gas emissions, and the federal government will continue to lose revenues from the production of oil and gas. We are making the following two recommendations: *The EPA Administrator should provide greater flexibility to operators for using alternative technologies to detect methane emissions. (Recommendation 1) The Director of BLM should consider whether to require gas capture plans that are similar to what states require, including gas capture percentage targets, from operators on federal lands. (Recommendation 2).*" [emphasis added]

These and other data and events underscore how important it is to reduce the carbon and methane intensity of the natural gas/LNG supply chain and oil/coal export supply chains, at the same time these energy supplies are enhancing the energy security of U.S. allies and trading partners.

4.5. Conventional Energy Supply Chain Data Needs

Another important conclusion of the EDF/RTI report on the impacts of climate change on global shipping and important to DOE analysis, actions, and inter-agency areas of focus: "…data on this topic is sparse and these estimates of added costs only reflect port damages and disruptions, meaning future costs overall could be far higher than estimated here."[xxiii]

The broader need for additional data to adequately respond to and manage the impacts of climate change on both conventional and clean energy global supply chains, their associated domestic supply chains, emissions, and energy security, is not limited to data on shipping. In this regard, DOE's supply chains strategy referenced earlier includes several recommendations on the data needed for clean energy supply chains that could be expanded to include conventional energy supply chains. These included recommendations to:

- Promote adoption and implementation of traceability standards to improve global supply chain mapping capabilities, instill integrity of produce custody, promote social responsibility, and support carbon foot printing of energy supply chains. (Department of State, DOE, Department of Commerce, Department of Labor, the Environmental Protection Agency, Department of Homeland Security, NASA, Department of Defense)
- Create and maintain a manufacturing and energy supply chain office as well as database and analytical modeling capabilities, where –
    - "DOE will work across the agency, including with the Energy Information Administration, building on the BIL to expand EIA analysis activities that will include the upstream clean energy critical materials. EIA will integrate upstream critical material data and analysis into its analytical activities and report, such as the Short-term Energy Outlook and the Annual Energy Outlook, where appropriate and feasible" and
    - "DOE will create standard definitions and frameworks to characterize and synthesize status and dynamics across clean energy technology supply chains and to encourage use of these definitions and frameworks, where appropriate, by Federal agencies and state and local governments."

It should also be noted that the EIA has recently added a new interface on its website called "Energy Disruptions". This provides information on tropical storms, flooding, cyclones, droughts, and wildfires. The website also provides a mapping of energy resources in the United States. Presumably, more data are being added consistent with the recommendations in the DOE clean energy supply chain strategy.

Additional data are also needed on Scope 1, 2 and 3 emissions associated with conventional energy supply chains (described in greater detail in Figure 24 below). As noted, conventional energy supply chains and end uses are the major contributors to climate change. Every effort should be made to reduce and eliminate emissions associated with these chains from production to end use. In this regard, it should be noted that DOE's 2022 supply chain strategy includes a focus on carbon capture and sequestration, essential for near- to mid-term emissions reductions and a suite of technologies that the U.S. should be exporting to its allies and trading partners where needed to assist in achieving net zero targets.

During the transition period, it is important to develop these and other data and methodologies for conventional energy as well, given their near- to mid-term importance to global energy security and to our allies and trading partners. Additional data on a range of issues for conventional energy supply chains should be developed or expanded including, for example, the number and location of LNG tankers available for U.S. exports, and the domestic supply chains.

4.6. Summary: Conventional Energy Supply Chains

Areas, where DOE and the federal government should focus on conventional energy supply chains from both a policy and structural perspective, include:

- the very significant changes in the U.S. energy and power generation profile since DOE was created that have, in part, switched the policy focus from imports to exports for conventional energy and as discussed later in the paper, to imports for the metals and minerals needed for clean energy technologies
- the substantial LNG volumes approved for facilities that are not yet under construction. Expediting construction of the most feasible of these approved facilities could help address the near- to mid-term energy security needs for U.S. LNG, as the U.S. and its allies work to implement a range of clean energy strategies to reach mid-century net-zero targets. These should be expedited in exchange for measurable progress on net-zero LNG and methane emissions reductions across natural gas supply chains
- the need to expand the oil and gas sector dialogue to include the financial sector (which has been driving balance sheet gains rather than production) and international allies (with a particular focus on demand-side commitments that support private investment);
- support for the domestic supply chains needed to enable U.S. LNG exports to U.S. allies and trading partners
- the possible expansion of the mission of DOE’s new Manufacturing and Energy Supply Chains Office to include a focus on policies that could support both LNG export supply chains and the domestic supply chains that help enable that capacity
- the need to analyze the growing weather threats fully and continually to inform needs for energy supply chains

- the need to develop additional data on a range of issues for conventional energy supply chains to meet both domestic and export demands including, for example, the number and location of LNG tankers available for U.S. exports; and
- the need for the federal government, with input from DOE, to revise and re-institute regulation of methane emissions from oil and gas systems as well as take additional actions to reduce methane emissions from non-energy sectors. With its expertise on biogas and biodigesters, DOE could provide valuable input on regulation of methane emissions from other sectors.

5. Clean Energy Technology Supply Chains

The technologies needed to help the U.S. meet its net zero targets by 2050 use a number of critical metals and minerals. Forecasts suggest that there will be up to a 600% increase in global demand for critical materials over the next 30 years. According to DOE, "for certain materials, such as lithium and graphite used in electric-vehicle batteries, demand is expected to increase by as much as 4,000%."[xxiv]

The Energy Act of 2020 defined critical minerals as those that:

- are essential to the economic or national security of the United States;
- the supply chain of which is vulnerable to disruption (including restrictions associated with foreign political risk, abrupt demand growth, military conflict, violent unrest, anti-competitive or protectionist behaviors, and other risks throughout the supply chain); and
- serve an essential function in the manufacturing of a product (including energy technology-, defense-, currency-, agriculture, consumer electronics-, and healthcare-related applications), the absence of which would have significant consequences for the economic or national security of the United States.'

The current mining, processing, and manufacturing of these metals and minerals and the clean energy technologies and products that use them, tends to be highly geographically concentrated. Also, demand for key metals and minerals could further increase as more countries are challenged to meet new and increasingly stringent net zero goals. According to the UN, "…a growing coalition of countries, cities, businesses, and other institutions are pledging to get to net-zero emissions. More than 70 countries, including the biggest polluters – China, the United States, and the European Union – have set a net-zero target, covering about 76% of global emissions. Over 1,200 companies have put in place science-based targets in line with net zero, and more than 1000 cities, over 1000 educational institutions, and over 400 financial institutions have joined the Race to Zero, pledging to take rigorous, immediate action to halve global emissions by 2030."[xxv]

Without adequate supplies of these metals and minerals – or for substitutes that might be developed - it will be difficult if not impossible for the U.S. to meet its energy security requirements or to deploy clean energy technologies at a sufficient pace and scale to deeply decarbonize the economy. Scarcity could also increase the costs of clean energy.

In February 2022, the U.S. Geological Survey released its latest minerals commodity summary that looks at trends for 88 non-fuel metals and minerals. Of that list, between 2016-2019, the U.S. was 100% import dependent on 13 of them, and 50-96% import dependent on another 14 of them (Figure 13). Of those 38 metals and minerals, 27 of them are designated by the USGS as critical.

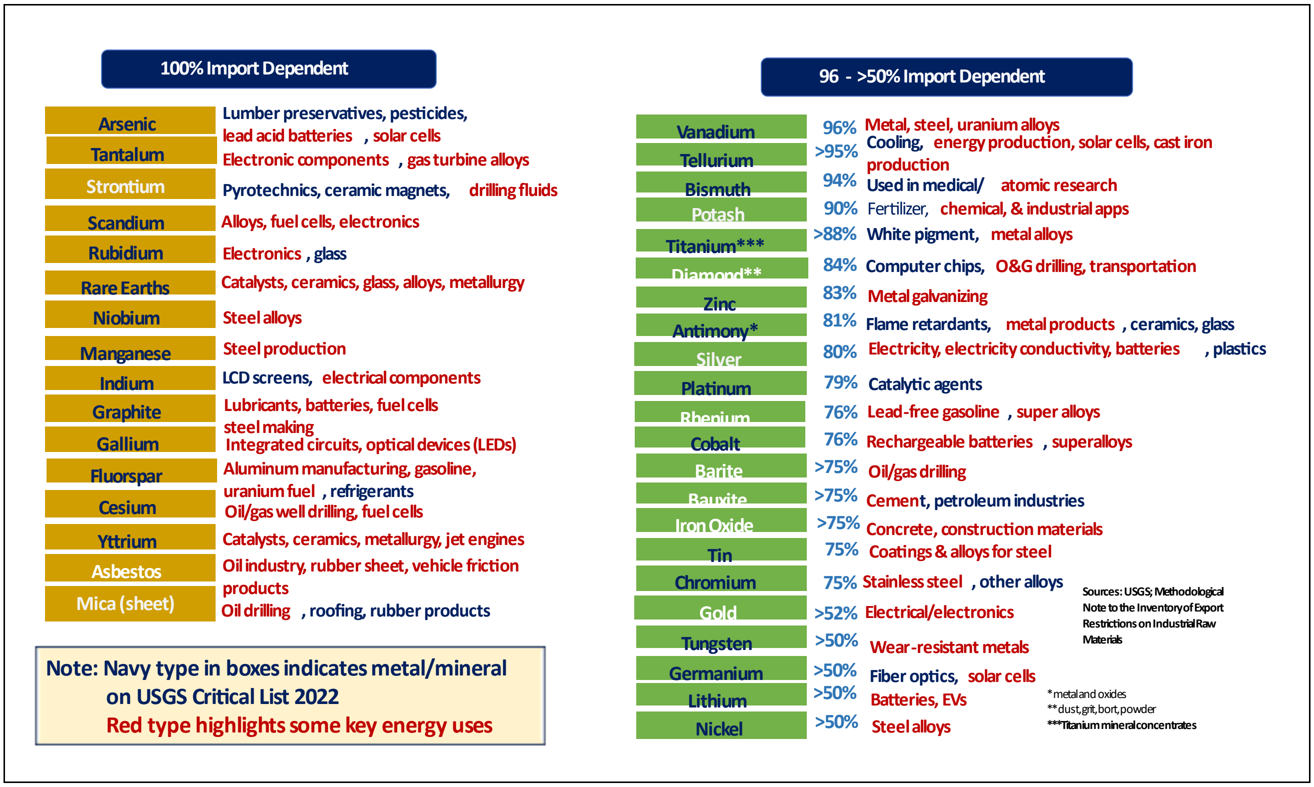


Figure 13: U.S. Import Dependence on Key Metals and Minerals, 2022.

Some key uses of those metals and minerals by both conventional and clean energy technologies are also highlighted in the figure. These include, for example, graphite used in batteries, steel making, and fuel cells and on which the U.S. is 100% independent. Another example of metals and minerals on which the U.S. is 100% import dependent: scandium, indium, and rubidium used for electrical components, key to increased electrification needs for clean energy technologies. As noted however, these imports are not exclusive to clean energy technologies. Cesium and fluorspar, for example, on which the U.S. is also 100% import dependent, are used for oil/gas well drilling and gasoline.

The major suppliers of U.S. imports of metals and minerals on which the U.S. is 80-100% important dependent, and the percentage of U.S. imports supplied from that country between 2016-2019 are shown in Figure 14. Notably, China supplied the U.S. with nine metals/minerals on which the U.S. was 100% import dependent between 2016-2019. Of the list of nine imported metals and minerals from China on which the U.S. was 100% import dependent during that time period, seven were classified as “critical” by the United States Geological Survey.

Figure 14: Metals, Minerals on Which the U.S. is 80 to 100% Import Dependent, Country Suppliers of U.S. Market / %U.S. Imports by Export Country, 2016-2019.

Other significant concentrations of metals/minerals on which the U.S. is 100% import dependent and the USGS classifies as critical, include niobium (66% from Brazil); fluorspar (70% from Mexico); and manganese ore (69% from Gabon). Also, on the critical list but on which the U.S. is only 76-96% import dependent include: antimony (63% from China); bismuth (69% from China); and tellurium (57% from Canada). An example of energy applications of a key metal on which the U.S. is 100% import dependent: niobium is used in steel alloys that are, in turn, used in battery storage, gas and wind turbines, and solar arrays; fluorspar is used in manufacturing products such as insulation, refrigerants, and uranium fuels; and manganese ore is used in batteries, steel, aluminum, and nuclear fuel.

5.1. The Federal Government's Management of Clean Energy Supply Chain Risks

As noted, – and an indication of the importance placed on the issue of clean energy supply chains – just a month after taking office, President Biden issued an executive order on the topic of clean energy supply chain risks. This order highlighted the importance of secure, resilient, geopolitics and economic competition, among other things. The order also emphasized domestic production, stockpiles, jobs, the security of digital networks, and collaboration with allies and trading partners. There are many potential forums for such collaborations on the range of issues associated with the metals and minerals supply chains needed for a range of both clean energy and conventional energy technologies (Figure 15).

Figure 15: Country Members of G7, G20, OECD, Quadrilateral Security Dialogue, TPP Parties + Top 15 U.S. Export Recipients.

5.2. Energy Security Concerns

To address several the issues highlighted in the Administration's statement released with the signing of Executive Order 14017, it is also important to look at the current geopolitical situation. In the future, it cannot be assumed that Russia will a reliable supplier of any metal and mineral exports to the U.S.; the U.S. has already banned imports of Russian oil and gas.

The Senate's recent passage of a bill to provide $4.5 billion to Taiwan said Taiwan "shall be treated as though it were designated a major "non-NATO" ally for the purposes of transfer or the transfer of defense", and other actions have also raised tensions with China. It's important, as noted, that existing commerce between the U.S. and China offers pathways for minimizing tensions and the two nations have a mutual interest in global stability post Russian invasion of Ukraine. Also, as noted, China is the third largest recipient of U.S. exports in general and is a major importer of U.S. petroleum, petroleum products, and coal.

At the same time, DOE Secretary Granholm, in response to the Administration's decision to invoke the Defense Production Act (discussed in greater detail below), highlighted an objective of "clean energy independence" supported by a major focus on domestic production of key metals and minerals, as well as enhancing the associated processing, refining and production. The President's Executive Order discussed earlier also noted the need for "diverse supply chains".

Countries that exported the same metals and minerals to the U.S. that could potentially replace those supplied by Russia and China during that same time period are seen in Figure 16; this provides a map of potential options that may exist for alternative suppliers of these key resources. An analysis would, of course, need to be conducted to see if it is possible for these countries to increase supplies and exports to the U.S.

Importantly, however, all but two of these potential alternative suppliers have net zero targets for addressing climate change; Canada, Australia, the UK, Belgium, Germany, Austria, Japan, South Korea, and Vietnam, for example, have 2050 net zero targets. The internal policies of those countries with net zero targets that could potentially replace Russian and Chinese metal and mineral exports to the US, will likely place additional domestic demands on the supplies of these metals and minerals needed for clean energy technologies and reduce the potential availability of supplies for export to the U.S.

Those countries that were one of the U.S.'s top 15 trading partners in 2020, and potential forums where the security of these supply chains could be addressed, are seen in Figure 16. Australia, for example, provided the U.S. with about 10% of its tantalum imports for that time period and is also a member of the G20, OECD, was a party to both the 2016 and 2018 Trans-Pacific Partnership agreements, and is a participant in the Quadrilateral Security Dialogue. All these organizations/agreements provide venues to discuss and enhance the security of these supply chains and to discuss the potential for increasing exports to the United States.

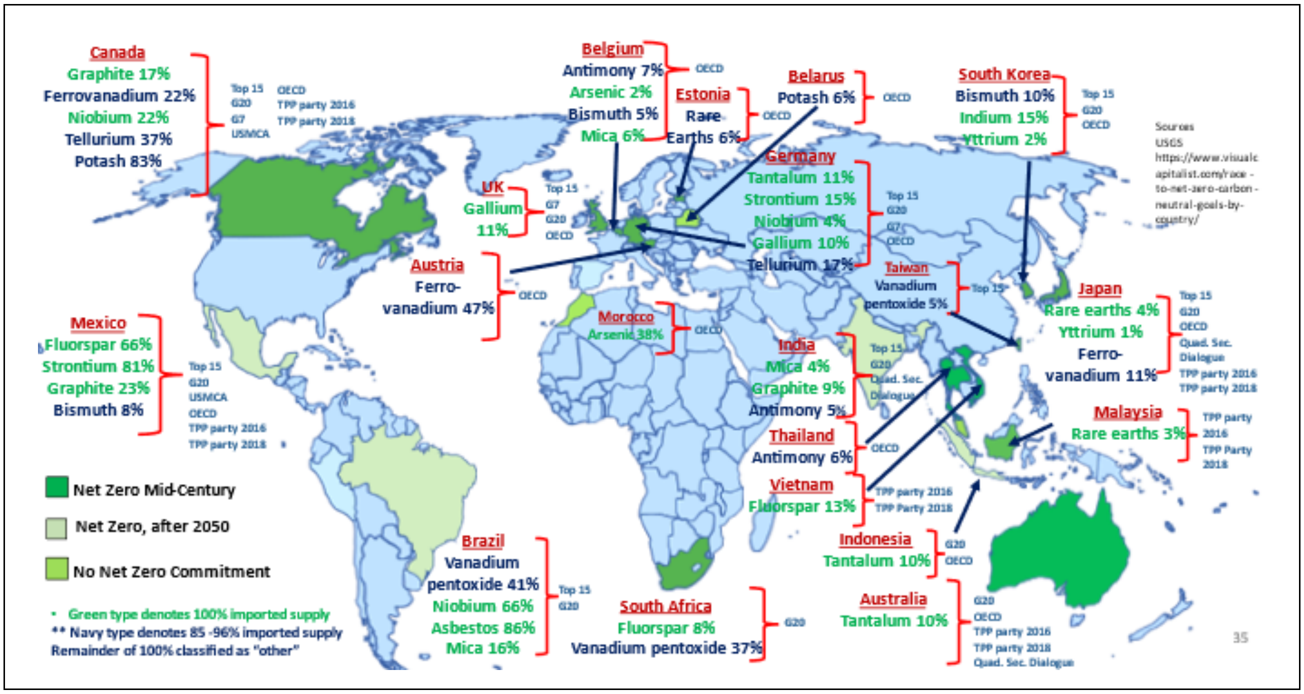


Figure 16: Potential Suppliers of Key Metals and Minerals Currently Supplied, in Part by Russia and China, and on Which the U.S. is 80-100% Dependent + Potential Forums for Collaboration on Supply Chains.

There are also countries that have metals and minerals needed to meet clean energy technology needs that are not currently being exported to U.S.; these countries could theoretically replace some of the metals and minerals the U.S. is currently importing from China and Russia (Figure 17).

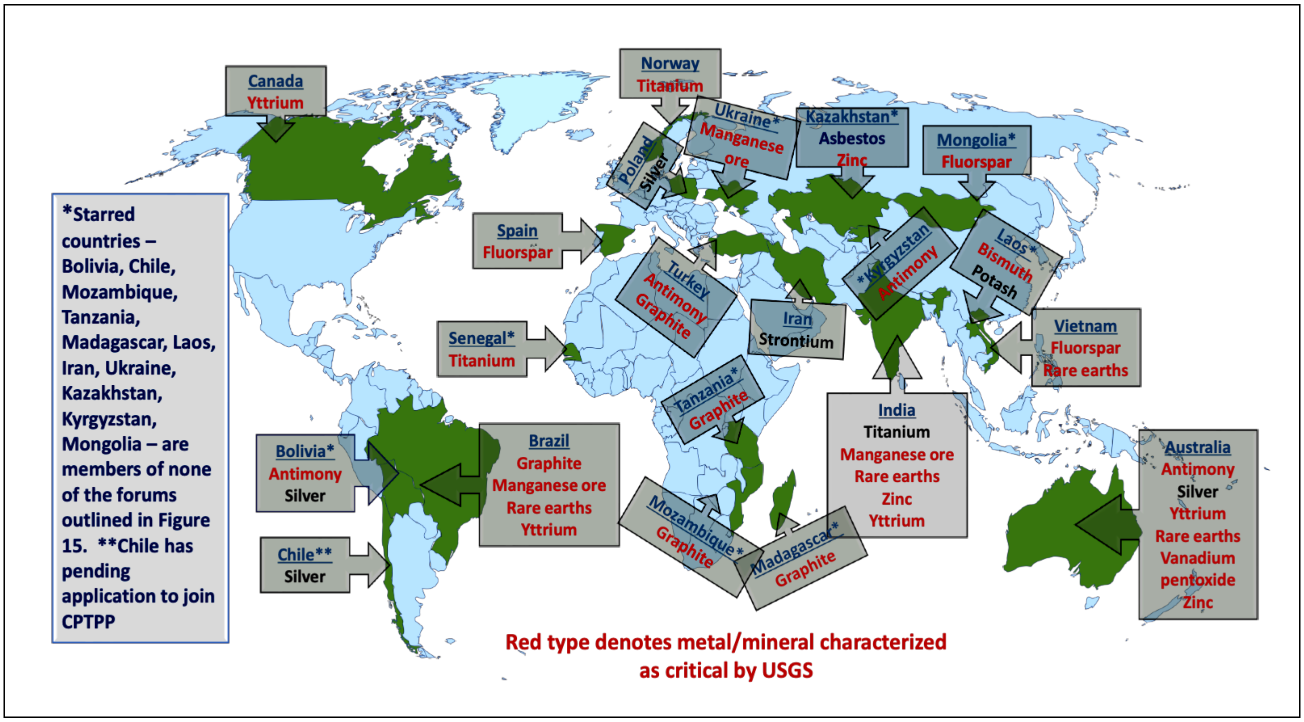


Figure 17: Countries w/ Large Reserves of Metals/Minerals on Which the U.S. is 80-100% Import Dependent, Currently Imported from Russia/China, Not Current U.S. Suppliers of Specific Metal/Mineral.

Bilateral discussions with these countries about the possibility of increased exports to the U.S., or in forums identified in Figure 15 for countries that are members, e.g., Australia, could help address some of the geopolitical considerations the U.S. must make in view of the current state of world affairs.

In addition, supply chain concerns are not only about the geographic concentration of mining these metals and minerals; there are also significant concerns about the geographic concentration of the uses of these resources in the processing, refining, manufacturing, and production of key technologies. The EU, U.S., and China percentage shares of global mining, processing, manufacturing, and component production for EV batteries in 2019 are seen in Figure 18 below. It is not surprising that these supply chains are dominated by China. Examples: China processed/refined 100% of the world's graphite. The U.S. and the EU both had zero percent of cathode and anode production that year, compared to China's 61% of global cathode production and 83% of its anode production.

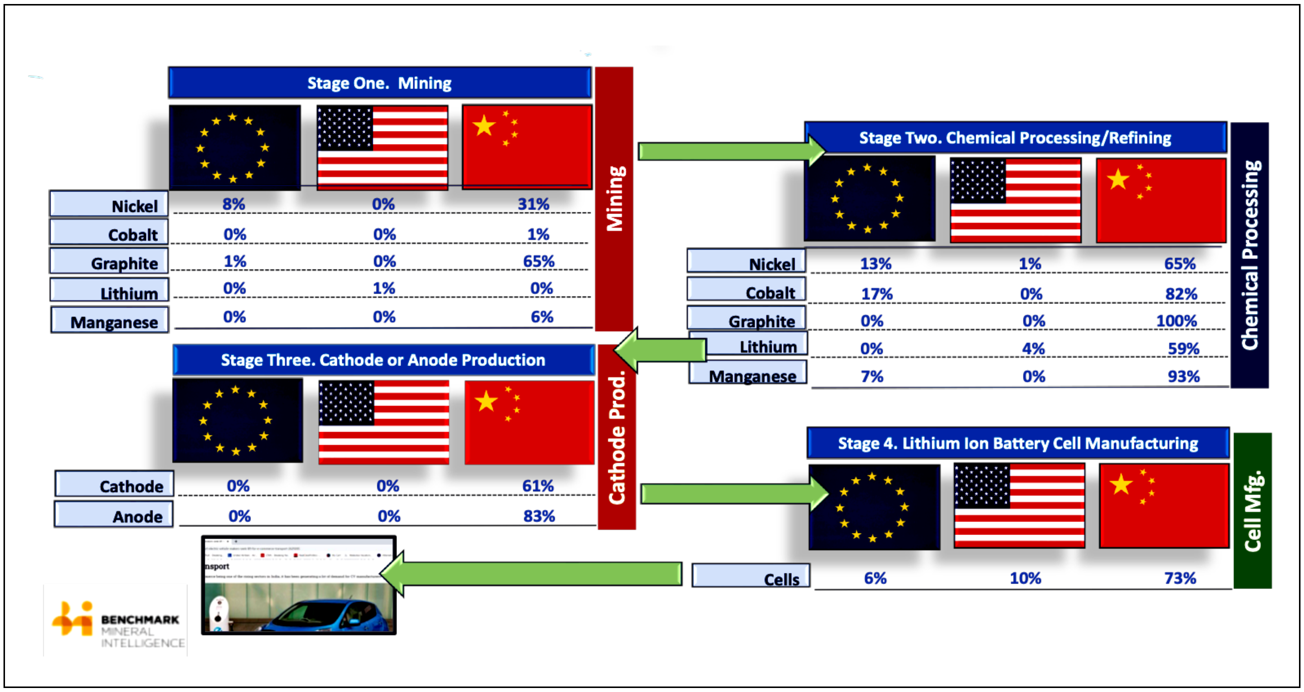


Figure 18: EV Batteries: Global Production, Mining, Processing, Manufacturing, Production Shares, EU/U.S./China, 2019.

Concerns about these supply chains are reflected in President Biden's June 2022 presidential determination, which gave DOE the authority to utilize the Defense Production Act to enable accelerated development of domestic supplies for a number of energy technologies specifically solar, transformers and grid components; heat pumps; insulation; electrolyzers; fuel cells; and platinum group metals.

In response to this action by the President, DOE Secretary Granholm noted that, "President Biden has invoked the Defense Production Act so that the U.S. can take ownership of its clean energy independence…For too long the nation's clean energy supply chain has been over-reliant on foreign sources and adversarial nations. With the new DPA authority, DOE can help strengthen domestic solar, heat pump and grid manufacturing industries while fortifying America's economic security and creating good-paying jobs and lowering utility costs along the way… In conflict, fossil fuel supply lines are especially vulnerable. *The actions President Biden announced today will help strengthen our supply chains and ensure that the United States is a leader in producing the energy technologies that are essential to our future success.*" [emphasis added]

As noted, earlier this year and consistent with both the direction and technology areas in the DPA direction from the President, DOE released America's Strategy to Secure the Supply Chain for a Robust Clean Energy Transition. This plan includes many strategies that address issues that support the DPA's objectives. Examples that would address **global supply chain issues** include:

- Coordinate and expand existing programs, market analysis, and technology commercialization activities for clean energy materials, including secondary/recycled and unconventional sources, that are vital for clean energy manufacturing, across multiple national labs, academia and in partnership with industry
- Promote improvement and enforcement of global environmental, human rights, and labor standards for mineral extraction, mineral processing and product manufacturing and advance development and utilization of traceability solutions to enable greater supply chain visibility and standards enforcement
- Increase Federal government financial support to eligible U.S. companies investing in or exporting to foreign countries to secure supply chain inputs that fill challenging domestic gaps and support the growth of other domestic segments of the supply chain
- Establish and fund an initiative for expanding clean technology manufacturing capacity globally to achieve the dramatic scale-up in manufacturing of key climate and clean energy equipment associated with meeting net-zero commitments
- Support studies that assess and quantify the economic, environmental, social, and human rights impacts of different aspects of the energy supply chain for all clean technologies.

The plan also has a significant focus on ***building domestic supplies and capabilities***. Strategies for these areas include:

- Review and update Federal mining laws and regulations to provide for more efficient permitting while strengthening Tribal consultation and community participation processes and improving environmental performance
- Coordinate and expand existing programs, market analysis, and technology commercialization activities for clean energy materials, including secondary/recycled and unconventional sources, that are vital for clean energy manufacturing, across multiple national labs, academia and in partnership with industry
- Coordinate with manufacturers and state, local, and tribal governments to support the establishment of regional clean energy industrial clusters, including providing technical assistance
- Chart a path forward on how communities, industry, and government envision and should pursue next generation large industrial facilities (e.g., steel mills, processing, and fabrication sites, etc.) necessary for an expanded domestic manufacturing base; and

- Support innovation for environmentally sustainable and next generation critical mineral and material extraction, processing, and refining activities.

Acknowledging both the need for domestic mining and the history of environmental problems associated with mining, the Biden Administration also, in February 2022, released its, "*Fundamental Principles for Domestic Mining Reform*." These principles recommend that the U.S.:

- Establish strong responsible mining standards
- Secure a sustainable domestic supply of critical minerals
- Prioritize recycling, reuse, and efficient use of critical minerals
- Adopt fair royalties so taxpayers' benefit
- Establish a fully funded hard rock mine reclamation program
- Conduct comprehensive planning
- Provide permitting certainty
- Protect special places
- Submit community input and conduct tribal consultation
- Utilize the best available science and data; and
- Build civil service expertise in mining.

Another obvious grouping of needs reflected in the list of strategies is the ***need for data and analysis of metals/minerals supply chains*** including:

- Promoting adoption and implementation of traceability standards to improve global supply chain mapping capabilities, instill integrity of product custody, promote social responsibility, and support carbon foot printing of energy supply chains (previously noted)
- Creating and maintaining a manufacturing and energy supply chain office as well as database and analytical modeling capabilities; and
- Engaging government and private sector to create national standards, guidelines, and requirements for the security of energy-related software, firmware, virtual platforms and services, and data.

At the same time the comprehensive strategy was released, DOE released 12 technology specific strategies and one strategy specific to commercialization. The technology specific strategy documents included: Carbon Capture Materials; Electric Grid including Transformers and High Voltage Direct Current (HVDC); Energy Storage; Fuel Cells and Electrolyzers; Hydropower including Pumped Storage Hydropower (PSH); Neodymium Magnets; Nuclear Energy; Platinum Group Metals and Other Catalysts; Semiconductors; Solar Photovoltaics (PV); Wind; and Cybersecurity and Digital Components.

DOE has also solicited and recently received comments on "…the development and implementation of a $675 million Critical Materials Research, Development, Demonstration, and Commercialization Program. Funded by the Bipartisan Infrastructure Law, the program will address vulnerabilities in the domestic critical materials supply chain, which are both an economic disadvantage and an impediment to the clean energy transition…The program will advance domestic sourcing and production, strengthening America's position as a global manufacturing leader."

5.3. Climate Change Issues

These issues, strategies, and the establishment of a new office are highlighted to underscore the very significant focus the federal government has placed on supply chains for critical metals and minerals and their refining, processing and uses in manufacturing. Also, the climate and supply chain funding in the Infrastructure Investment Jobs Act of 2021 and the Inflation Reduction Act have created unprecedented options for addressing these needs, issues, and concerns. The speed at which these strategies need to be implemented is critical if the U.S. is going to reach its net zero targets by mid-century.

At the same time, greenhouse gas emissions associated with primary mineral and metal production was equivalent to approximately 10% of the total global energy-related greenhouse gas emissions in 2018.[xxvi] It should also be noted that many of the climate change issues affecting conventional supply chains discussed earlier also impact clean energy supply chains. The results of a recent survey of 63 participants and decisionmakers in the mining industry about key industry risks are shown in Figure 19. In 2022, "climate change and shareholder activism" was third on the list of key issues in the industry with 16% of respondents listing is as the key risk. Supply chain disruptions was right behind climate change at 15%.[xxvii]

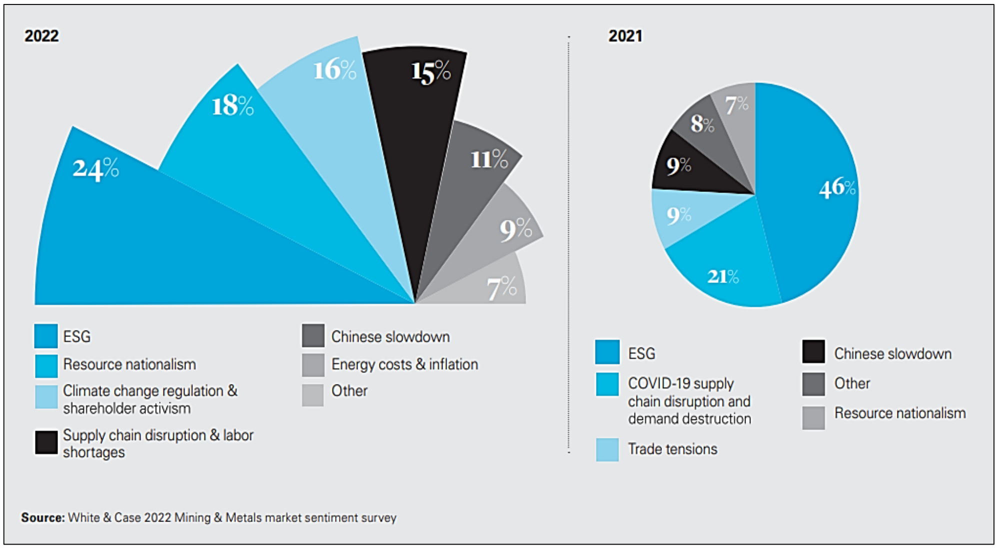


Figure 19: What is the Key Risk for Mining and Metals?

This same survey also asked respondents how the industry would be affected by the increased focus on ESG could most effectively respond to climate change policies and investor pressure (Figure 20). Not surprisingly, 74% of respondent's highlighted the need to reduce their carbon footprints and place greater emphasis on green metals, including recycling. Only six percent of respondents expected there to be geographic diversification of supplies.

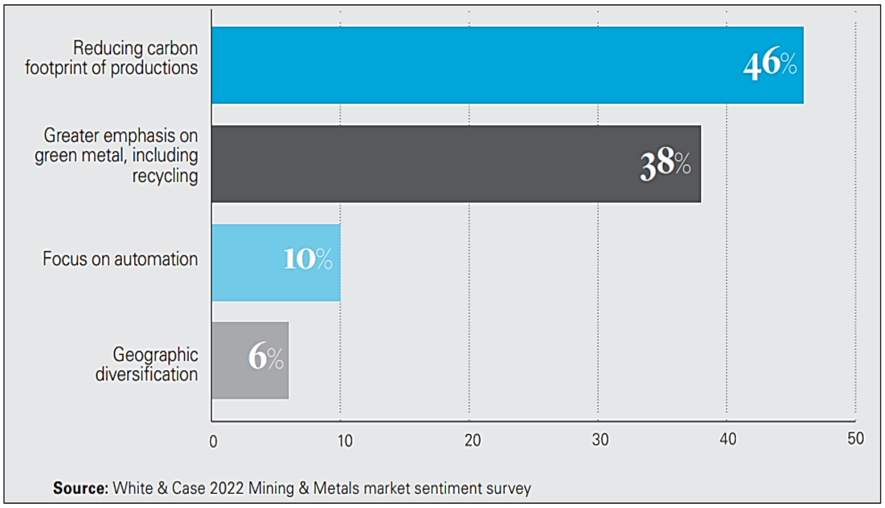


Figure 20: What is the Most Significant Structural Change You Expect to See in the Mining and Metals Industry as a Result of the Increased Focus on ESG?

One more important insight from this survey -- what areas in mining and metals will receive the most scrutiny from regulators and investors in light of increased focus on ESG and sustainability -- could help guide the DOE and federal government as it works to address supply chains for clean energy technologies. Greenhouse gas emissions were a major concern of survey participants, including both onsite emissions and emissions from customers, with tailings and water management also receiving a significant focus from those surveyed (Figure 21).

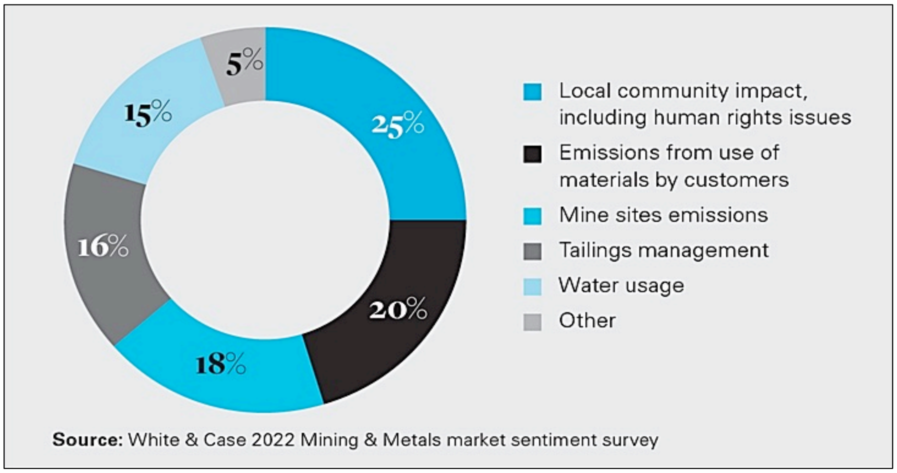


Figure 21: What Area of Mining and Metals will Face the Most Scrutiny from Investors and Regulators Related to ESG and Sustainability Issues?

5.4. Clean Energy Supply Chain Data Needs

There are significant needs for data to inform the imports and domestic mining of critical metals and minerals. The USGS provides very valuable information about global resources and reserves of a range of critical metals and minerals, but more data are needed to inform supply and demand curves for these metals and minerals. The DOE clean energy supply chain strategy also, as noted, included a data focus. Additional data could help inform both import needs and domestic supplies. These include:

- the impacts of carbon border adjustments on the availability/cost of imports
- the lifespans of clean energy technologies, data that will help inform the draw on key metals and minerals; the availability of domestic supplies including what might be available at inactive mines across the country, mines with some production, and mines for metals/minerals on the USGS critical list in 2022 are seen in Figure 22)

- the costs and potential for recycling critical metals and minerals, including an analysis of the potential for recycling centers to create jobs and commercial activity in areas that have been affected by the clean energy transition, e.g., small rural towns where auto repair is a major center of commerce'
- critical indicators needed for environmentally responsible domestic mining. Some key indicators that could form the basis of Energy Star or LEED-like standards for mining are shown in Figure 23.xxviii

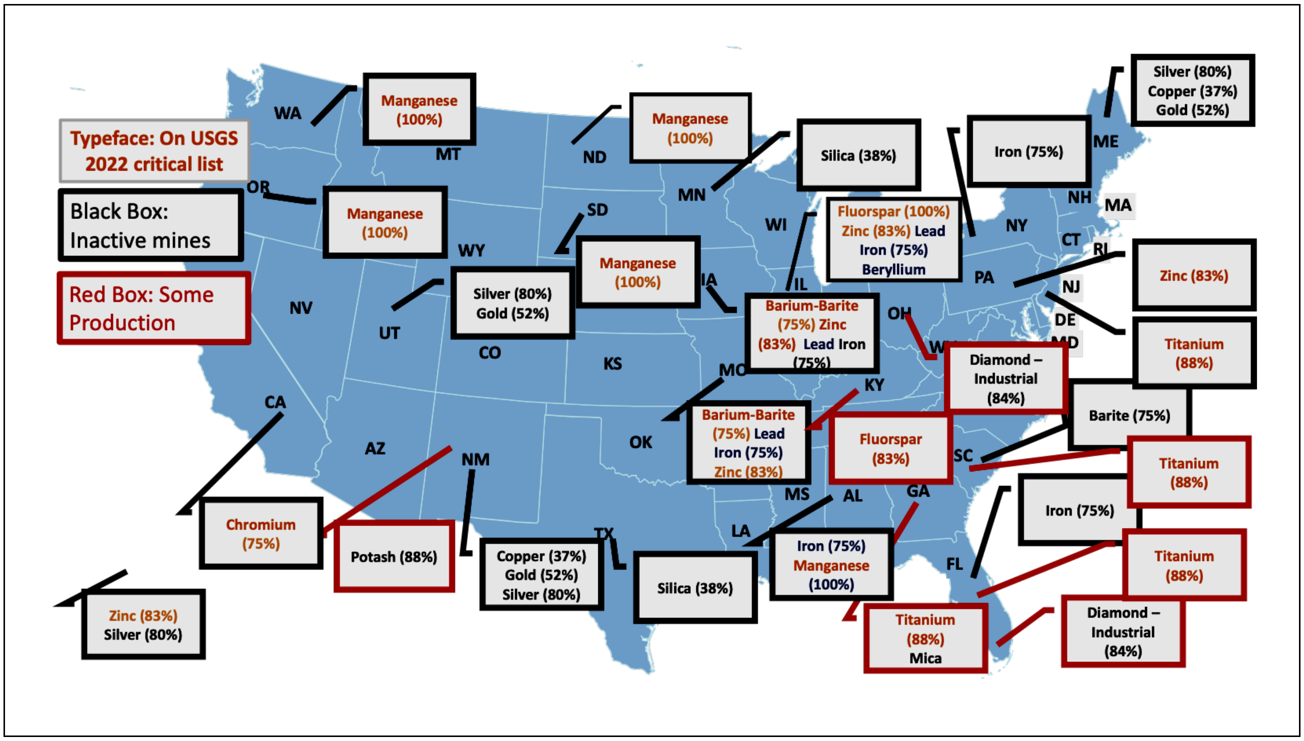


Figure 22: Locations of Inactive U.S. Mines, Mines with Some Production of Select Metals and Minerals/% Import Dependence.

- The company has systems in place to ensure its operations conduct and disclose regular assessments of its environmental impacts through an integrated approach that considers the linkages between socioeconomic and environmental impacts
- The company commits to not use riverine, lake or marine disposal of tailings
- The company has systems in place to ensure its operations design and implement water stewardship strategies and plans, based on a catchment-level approach, to address water security in the affected area for current and future water users and the environment
- The company tracks, reviews and acts to improve its performance on reducing its water consumption and its adverse impacts on water quality
- The company tracks, reviews and acts to improve its performance on biodiversity and ecosystem services management
- The company has systems in place to identify and report on the potential implications of climate change on its current and future operations' impacts on communities, workers and the environment, and to design and implement appropriate adaptation and transition strategies.
- The company tracks, reviews and acts to improve its performance on managing the greenhouse gas (GHG) emissions generated by its activities and its energy use.
- The company tracks, reviews and acts to improve its performance on managing energy consumption throughout its operations

Figure 23: Responsible Mining Index: Some Key Environmental Responsibility Indicators.

5.5. Summary: Clean Energy Supply Chains

The increasing unpredictability of weather, drought, the need for infrastructure resilience including the impacts of climate change on global shipping, the climate and other environmental impacts of mining and processing of metals and minerals for clean energy technologies, and the availability of additional supplies from current exporters to the U.S., are all issues that affect clean energy supply chains and need structural and policy support at DOE and across the government. Additional issues and associated structural needs that could be explored/considered in the days ahead might include:

- Develop an Energy Star-like program for domestic mining and data to support the development of a global LEED-like standard for environmentally responsible and humane mining. Such a standard – a Leadership in Equitable and Environmentally Responsible Mining (LEERM) -- would need to be updated on a regular basis as mining is an ongoing activity; the certification could, however, serve as a critical differentiator for mining companies and activities. As part of this effort, the DOE should conduct significant community outreach and listening programs to discuss concerns, needs, and issues surrounding domestic mining for the metals and minerals needed to support clean energy technologies
- increase the international focus on protecting supply chains for the metals and minerals needed for clean energy technologies and, if possible, importing

additional supplies from countries that have those resources we are currently importing from Russia and China. These forums could include active discussions in a range of international forums including the OECD, G-20, G-20, TPP, the Quadrilateral Security Dialogue, and with our formal allies and trading partners.

- increase bilateral discussions with countries that are not members of these forums and who we are not currently importing metals and minerals from but have supplies that may be available for export
- develop a specific and ongoing area of analytical focus to accurately assess the lifespans of clean energy technologies, a clear need for understanding the potential draw on the metals/minerals, their refining, processing, and uses in manufacturing. This would be a major indicator for assessing the energy/national security implications of these supply chains
- analyze the competition with other economic sub-sectors for the metals and minerals needed for the clean energy transition. Copper provides an example as the need for copper in clean energy technologies, e.g., grid components, wind turbines, electric vehicles, is significant. The percentages of copper use by industry subsectors in the U.S. in 2021 break down as follows: building construction, 46%; electric and electronic products, 21%; transportation equipment, 16%; consumer and general products, 10%; and industrial machinery and equipment, seven percent[xxix]
- develop standardized, transparent, and comprehensive methodologies for calculating embodied emissions, essential for achieving true net zero targets. This will also become important as the EU implements its carbon border adjustment policies in 2026. A visualization of Scope 1, 2 and 3 emissions that need to be included in calculating the embodied emissions of clean energy technologies, including their mining, processing, and uses in production and manufacturing are seen in Figure 24.

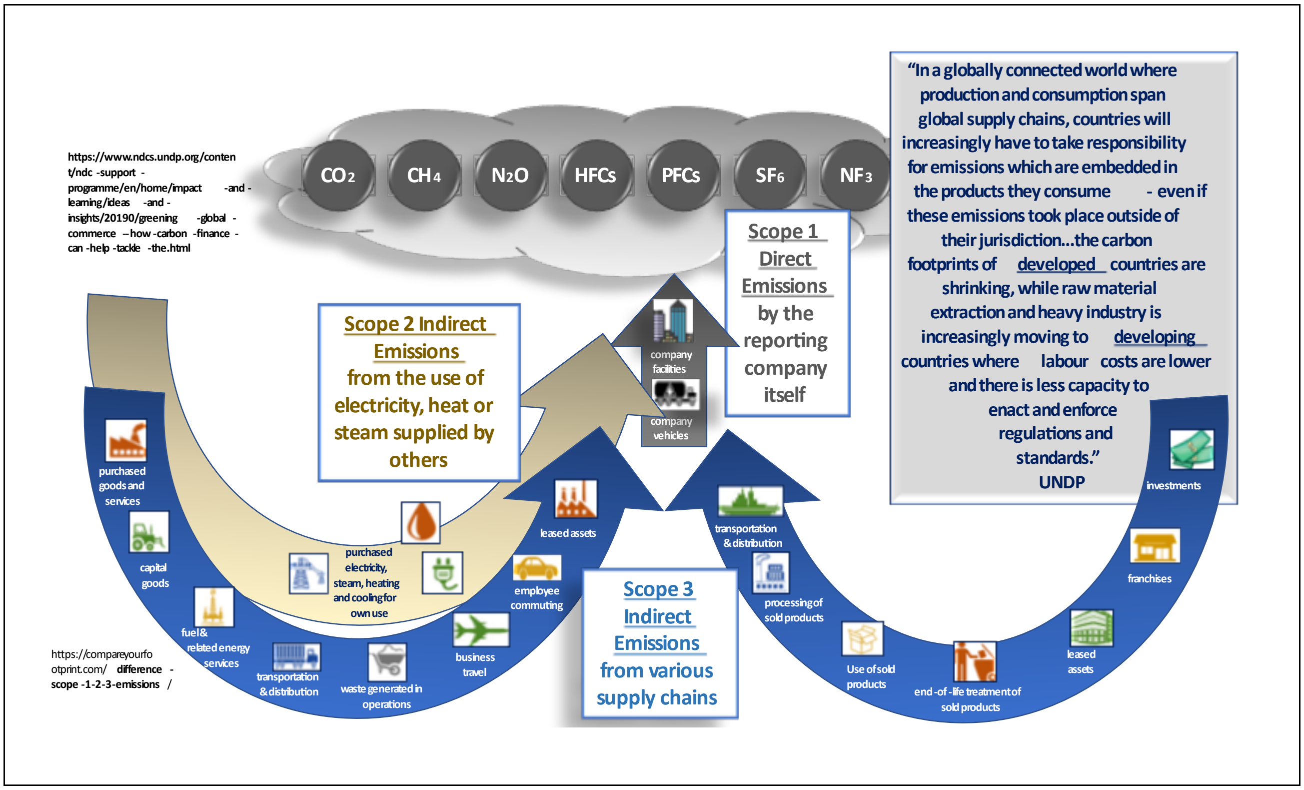


Figure 24: Scope 1, 2 and 3 Emissions: Growing Impacts on Trade.

- analyze the water needs for mining and blue and green hydrogen. DOE would benefit from having an office with a specific focus on energy and water. This is not only important from a metals and minerals perspective (as noted in Figure 21, water use for mining is a major concern), but also because climate change is affecting water supplies in many parts of the country and world. As noted earlier, beyond drought, regions that rely on glacier-fed hydropower for their electricity may need adaptation options or new water infrastructure. Analysis, data, and development of policy options need a home in DOE; and
- conducting significant community outreach and listening programs to discuss concerns, needs, and issues surrounding domestic mining for the metals and minerals needed to support clean energy technologies.

6. Cross-walking Conventional and Clean Energy Supply Chain Strategies

Today's global crises – climate change, the war in Ukraine and the pandemic's supply chain issues - underscore tomorrow's needs. Managing the intersection of these critical issues -- including the need for large investments in both conventional and clean energy --has implications for the structures and policies of the federal government in general and the Department of Energy specifically.

The urgent need for both conventional energy supplies and the role of the U.S. in meeting this need, drives home a very inconvenient truth: oil and gas, while major contributors to climate change, are critical to the energy security of the U.S. and its allies for the foreseeable future. Managing the transition to a clean energy future must accommodate this need while mitigating the emissions associated with near-term critical energy security needs.

Critical and fundamental to managing this very complicated task are appropriate organizational structures at DOE and across the government. Interagency structures are needed as well. It should be noted however that in times of crisis, there is often a need for rapid response. This suggests not only the need for strong, corresponding White House structures (current structures many need expansions or additions), but also for simplifying inter-agency decision-making; this could involve a re-thinking of agency jurisdictions that may, in turn, require Congressional support and action.

Another fundamental issue: the need for new kinds of data to adequately inform the energy security needs for both conventional and clean energy supply chains. It has been noted that DOE's comprehensive clean energy supply chain strategy includes a focus on data, methodologies, and supply chain tracking. Accurate data are also needed to: inform methodologies for embodied emissions that are critical in a net zero world; exports of conventional energy and the specific data on the domestic supply chains that support those exports; the range of metals and minerals needed for both conventional and clean energy technologies, accurate assessments of the lifespans of clean energy technologies to inform and assess the demand for critical metals and minerals; the specific needs of regional infrastructures; the potential for domestic mining of those metals and minerals; and many other supply chain issues. In this regard, it should be noted that this is not only important for the Energy Information Administration but for the International Energy Agency (IEA) in Paris. IEA, like DOE, was formed in response to the supply chain disruptions created by the Arab

Oil Embargo. New IEA data may be needed to inform both conventional and clean energy supply chain security.

In conclusion, the overlapping system issues raised by the convergence of today's trio of crises – the Russian invasion, climate change, and the pandemic -- drives home a key point: the need for thoughtful, practical, technically- grounded, data-driven, and sequenced actions to address the clean energy transition as rapidly as possible while preserving the energy security of the U.S. and its allies. The U.S. is in a commanding position in all three areas, is moving forward with discrete actions, and is well-positioned to develop an integrated plan to address these critical imperatives.

Appendix

i Lacey, Robert (1981). The Kingdom. Harcourt Brace Jovanovich. ISBN 0151472602.

ii https://www.energy.gov/science/history

iii https://oec.world/en/profile/country/usa/

iv https://oec.world/en/profile/country/usa/

v https://oec.world/en/profile/country/usa/

vi https://www.nato.int/cps/en/natolive/nato_countries.htm

vii https://www.state.gov/major-non-nato-ally-status./

viii https://www.aa.com.tr/en/energy/downstream/global-lng-trade-to-surpass-500-bcm-by-2023-iea/20655

ix https://www.eia.gov/energyexplained/natural-gas/imports-and-exports.php

x https://www.eia.gov/todayinenergy/detail.php?id=53159#:~:text=The%20United%20States%20became%20the%20world's%20largest%20liquefied%20natural%20gas,day%20(Bcf%2Fd).

xi https://www.eia.gov/energyexplained/coal/imports-and-exports.php

xii https://www.worldstopexports.com/coal-imports-by-country/

xiii https://www.reedsmith.com/en/perspectives/energy-transition/2022/06/us-ramps-up-lng-exports-in-response-to-invasion-of-ukraine

xiv EIA website, accessed September 19, 2022

xv CRS, Critical Infrastructure Risk Management: Securing the Oil and Gas Supply Chain, December, 2021

xvi https://phys.org/news/2022-07-extreme-weather-billion-losses.html

xvii https://earthobservatory.nasa.gov/images/150324/late-season-melting-in-greenland?linkId=180778936

xviii https://www.edf.org/media/shipping-industry-and-ports-susceptible-billions-dollars-damage-disruption-climate-change

xix EPA Inventory of US Greenhouse Gas Emissions and Sinks: 1990-2020

xx https://www.eia.gov/dnav/ng/hist/n9010us2m.htm

xxi EPA Inventory of US Greenhouse Gas Emissions and Sinks: 1990-2020

xxii https://pubs.acs.org/doi/10.1021/acs.est.1c06458

xxiii https://www.edf.org/media/shipping-industry-and-ports-susceptible-billions-dollars-damage-disruption-climate-change

xxiv https://www.energy.gov/articles/doe-releases-first-ever-comprehensive-strategy-secure-americas-clean-energy-supply-chain

xxv https://www.un.org/en/climatechange/net-zero-coalition

xxvi Azadi, M., Northey, S.A., Ali, S.H. et al. Transparency on greenhouse gas emissions from mining to enable climate change mitigation. Nat. Geosci. 13, 100–104 (2020)

xxvii Mining & metals 2022: ESG and energy transition – the sector's biggest opportunity

xxviii https://www.responsibleminingfoundation.org/media/responsible-mining-index-framework-2020-published/

xxix https://www.statista.com/statistics/254870/use-of-copper-and-copper-alloys-in-the-us-by-purpose/