EXAMINING THE ENERGY TRANSITION THROUGH THE LENS OF GREAT POWER COMPETITION

ASMERET D. ASGHEDOM

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About the Author

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Preface

Brad Roberts

Despite their many differences, the national security strategies of Presidents Trump and Biden have emphasized the need to both compete and cooperate to advance U.S. national interests in an eroding security environment. To cite the 2022 Biden strategy:

> The post-Cold War era is definitively over and a competition is underway between the major powers to shape what comes next…While that competition is underway, people all over the world are struggling to cope with the effects of shared challenges that cross borders…By their very nature, these challenges require governments to cooperate if they are to solve them.[1]

But success in advancing U.S. interests requires something more than simply competing on some interests while cooperating on others. As the 2022 strategy argues:

> We cannot succeed in our competition with the major powers who offer a different vision of the world if we do not have a plan to work with other nations to deal with shared challenges and we will not be able to do that unless we understand how a more competitive world affects cooperation and how the need for cooperation affects competition. We need a strategy that not only deals with both but recognizes the relationship between them and adjusts accordingly.[2]

This need is nowhere more compelling than on climate change. As the 2022 strategy argues, "of all of the shared problems we face, climate change is the greatest and potentially existential for all nations….requiring

1 *National Security Strategy* (Washington, DC: White House, October 2022), p1.

2 Ibid., p9.

us to think and act in new ways."[3] One of the most important of those shared challenges is the expeditious navigation of the energy transition—that is, the replacement of fossil fuels with clean sources in order to reduce carbon emissions. How that transition will impact the energy security of many nations remains unclear. But there can be no doubt that Russia and China are key actors, whose choices will have a significant impact on the energy transition, on the energy security of many, and on climate change. It is equally clear that leaders in both countries approach energy with a focus on their rivalry with the United States and on their ambition to re-make regional and global orders to their liking. This strongly suggests that competition will frustrate cooperation on climate change, perhaps significantly so.

Asmeret Asghedom's new Livermore Paper maps out this complex new landscape of major power rivalry, climate change, and energy security. Her analysis links energy politics and geopolitics in compelling new ways. It also highlights the key roles of public-private partnerships and of close cooperation among the United States and its allies. Her policy recommendations provide a broad based, coherent, and promising approach to the significant challenges ahead. The paper reflects the Center's ambitions to illuminate the intersections of climate change, energy policy, and national security and to help raise the level of debate about sensitive emerging issues at those intersections.

3 Ibid.

Executive Summary

While the United States embarks on plans to transform its energy system, policymakers should be aware of what role the energy transition will play in great power competition. The energy transition has the potential to reorder energy suppliers and import dependencies, and countries leading the race to supply the transition will reap the economic and geopolitical benefits traditionally afforded to dominant fossil fuel suppliers.

Although still in its infancy, the global energy transition is triggering more competition among great powers—the United States, China, and Russia. Global efforts to transition to low-carbon fuels to meet climate goals have prompted the realization that China is the Saudi Arabia of low-carbon energy manufacturing and exports. The only area of commercial low-carbon energy that China is not yet leading is nuclear reactor and fuel exports, an area in which Russia, the other U.S. adversary, continues to dominate despite its actions in Ukraine. While there has been increased global collaboration and coordination on setting emissions reduction targets, major energy consumers, including the United States, are facing growing competition over resources, such as critical minerals needed for low-carbon technologies, and a race to manufacture and innovate new forms of low-carbon technologies. The United States is currently at a disadvantage, as it is dependent on imports for critical minerals, renewable technologies, and nuclear fuel.

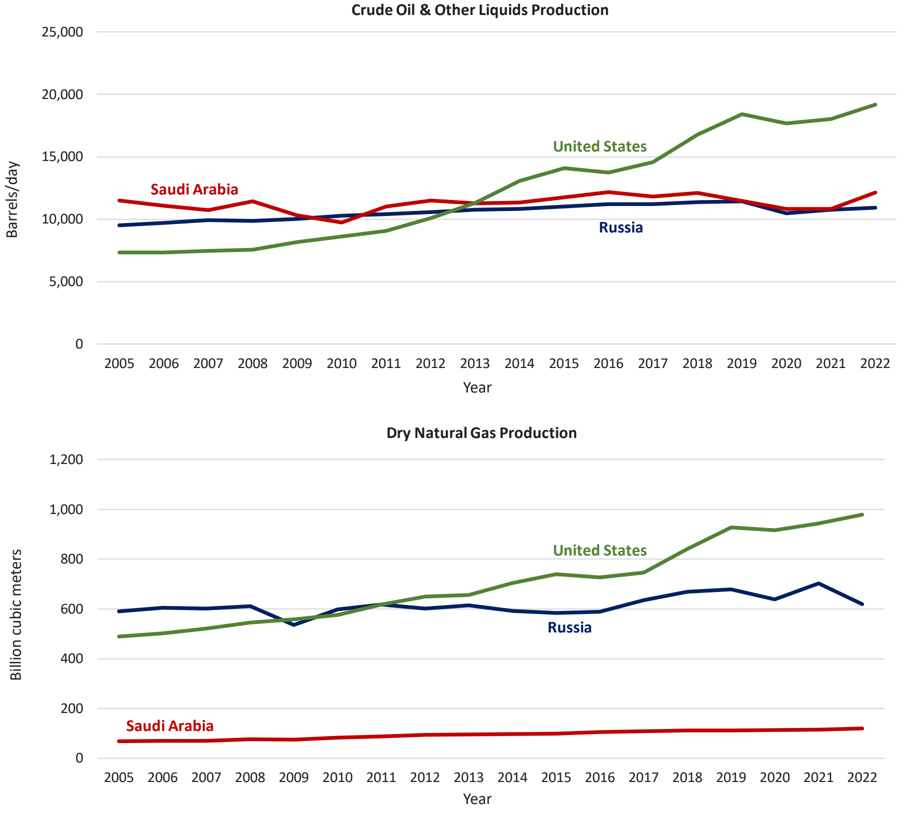
This paper identifies seven competitive flashpoints associated with the energy transition, their risks, and potential implications so policymakers can pursue actions to avoid pitfalls during the transition. These potential pitfalls include increasing U.S. energy reliance on adversaries, weakening U.S. energy security, increasing tensions and divisions between developed and developing countries, bolstering Chinese foreign policy goals, and ceding leadership in the energy domain to both China and Russia, among other drawbacks. The United States' energy planning must be crafted in a way that does not disadvantage the United States politically, economically, and geopolitically vis-à-vis its rivals. Avoiding these pitfalls will require rethinking and reconsideration of the United States' current energy transition strategy.

The paper provides policy recommendations to mitigate risks while still supporting continued growth in low-carbon energy. The central question guiding the recommendations is: How do we embark on the energy transition while not disadvantaging the United States geopolitically and weakening our energy security, especially in the context of great power competition? The policy recommendations seek to challenge policymakers to take a step back and rethink the current strategy of setting mid- and long-term end-consumption goals ahead of mapping out intermediary steps and goals that must be well understood before undertaking a complete overhaul of one's energy system.

Introduction

Ten years ago, the hierarchy among global energy suppliers shifted—thanks to the U.S. shale revolution—as the United States emerged as the largest producer of combined oil and natural gas, rising through the ranks of Saudi Arabia and Russia. For the first time in decades, fears over U.S. energy security and overdependence on resources in the Middle East subsided, and U.S. policymakers hailed a new era of greater energy security for the United States.

Figure 1. Oil and Natural Gas Output from Top Producers



Sources: U.S. Energy Information Administration (www.eia.gov) for oil data and Energy Institute's Statistical Review of World Energy (https://www.energyinst.org/statistical-review) for natural gas data

Fast forward a decade, however, and energy security has reemerged as a topic of great concern among U.S. policymakers. Two events have brought energy security back into the spotlight. First, global efforts to transition to low-carbon energy[4] to meet long-term climate goals—known as the energy transition—prompted the realization that China is the Saudi Arabia of renewable energy manufacturing and exports. The only area of commercial clean energy that China is not leading yet is nuclear reactor and fuel exports, an area in which Russia, the other U.S. adversary, continues to dominate despite its actions in Ukraine. Second, the Russian invasion in Ukraine prompted a serious reexamination of the supply sources of our allies and reinforced the need to diversify energy supplies away from adversaries. Hence, an examination of the energy transition through the lens of great power competition—among the United States, China, and Russia—is warranted.

In response to energy security concerns associated with the energy transition, U.S. lawmakers have introduced or passed legislation targeting a boost in domestic production of critical minerals and low-carbon technologies to both support the energy transition and reduce future U.S. reliance on adversaries. For example, the Bipartisan Infrastructure Law, signed November 2021, included more than $100 billion over five years (FY2022-FY2026) for clean energy, climate, and minerals-related activities. The CHIPS and Science Act, signed August 2022, included millions of dollars per year toward basic energy research, critical minerals, and low-carbon energy technology programs.[5] The 2022 Inflation Reduction Act included $370 billion toward energy and climate activities.[6]

The U.S. bipartisan concern is warranted for two primary reasons. First, U.S. tensions with both China and Russia are high; therefore, reliance on those countries for essential goods, such as critical minerals and renewable technologies from China and nuclear fuel from Russia, is not ideal for U.S.

4 The term "low-carbon energy" is used to describe energy sources, like solar, wind, hydro, and nuclear energy, which have fewer life-cycle carbon emissions. In this paper, "low-carbon energy" is used interchangeably with the term "clean energy."

5 Mariana Ambrose, John Jacobs, and Natalie Tham, "CHIPS and Science Act Summary: Energy, Climate, and Science Provisions" (November 14, 2022). https://bipartisanpolicy.org/blog/chips-science-act-summary/. Accessed July 19, 2023.

6 International Energy Agency, "Energy Technology Perspectives 2023" (January 2023), p40. https://www.iea.org/reports/energy-technology-perspectives-2023. Accessed July 19, 2023.

national security. Second, countries that have traditionally dominated global energy supplies enjoy political and economic leverage and influence. For example, despite Russia's unprovoked invasion of Ukraine, many countries outside of the West remained somewhat politically neutral and have increased imports of Russian energy, taking advantage of price discounts. In the case of Saudi Arabia, domestic human rights violations, and violations of international humanitarian law during its military operations against Houthi forces in Yemen are often overlooked by world leaders.[7] China has traditionally been an energy importer, but the energy transition will tilt the balance of power in China's favor in the energy domain if it continues to dominate clean energy supply chains into the future. China's new role as a dominate supplier of the energy transition bodes well for its broader foreign policy initiatives, such as the Belt and Road Initiative and Global Energy Interconnection.

It's important to examine the energy transition in the context of great power competition to better understand how the world's changing energy landscape could potentially affect U.S. national, economic, and energy security absent prudent planning. This paper will address three key questions:

1. What is the energy transition?
2. What are competitive flashpoints for great powers, and associated risks and potential implications for the United States?
3. How do we embark on the energy transition while not politically and economically disadvantaging the United States and weakening its energy security?

First, this paper will provide a brief overview of the energy transition. Next, it will identify seven competitive flashpoints associated with the energy transition, outlining how each present risks to the United States and its allies. Lastly, the paper will provide policy recommendations to mitigate risks while still supporting increases in low-carbon energy.

7 Somayeh Malekian and Guy Davies, "Saudi Arabia's human rights record may be overlooked over need for cheap oil, groups say," ABC News (March 15, 2022). https://abcnews.go.com/International/saudi-arabias-human-rights-record-overlooked-cheap-oil/story?id=83458741 and Human Rights Watch, "Yemen: Latest Round of Saudi-UAE-Led Attacks Targets Civilians" (April 18, 2022). https://www.hrw.org/news/2022/04/18/yemen-latest-round-saudi-uae-led-attacks-targets-civilians. Accessed July 19, 2023.

What is the Energy Transition?

The energy transition is defined as greatly reducing the share of fossil fuels in a country's energy mix and, in exchange, increasing the share of low-carbon fuels, with the goal of reducing greenhouse gas (GHG) emissions. The extent of the desired shift from fossil fuels to low-carbon fuels differs across countries. Several countries do not plan to eliminate the use of fossil fuels, but instead plan to offset emitting activities by incorporating carbon removal technologies, such as carbon capture and storage (CCS) and direct carbon capture, and/or investing in carbon sinks, such as forests and tree planting.

The energy transition is currently in its infancy stage. Fossil fuels (oil, natural gas, and coal) still meet 80% of the world's total energy consumption.[8] Nonetheless, many countries worldwide are implementing measures with long-term goals to shift their energy portfolios to predominately low-carbon fuels. Some of the world's largest energy consumers and emitters—including China, the United States, India, Japan, South Korea, and European Union (EU) members—have set targets to increase the share of low-carbon fuels in their energy consumption mixes and incorporate carbon removal technologies. Western governments, such as the United States and the EU, are taking a more aggressive approach to the energy transition. For example, the United States is targeting 100% zero-emission vehicle acquisitions and 100% carbon pollution-free electricity both by 2035.[9] For reference, fossil fuels made up 60% of U.S. utility-

8 Ashutosh Singh, Roman Kramarchuk, and Karl Nietvelt, "Energy Transition: Gaps in the Pathways," S&P Global (January 13, 2023). https://www.spglobal.com/en/research-insights/featured/special-editorial/look-forward/energy-transition-gaps-in-the-pathways. Accessed July 19, 2023.

9 The White House, "FACT SHEET: President Biden Signs Executive Order Catalyzing America's Clean Energy Economy Through Federal Sustainability" (December 8, 2021). https://www.whitehouse.gov/briefing-room/statements-releases/2021/12/08/fact-sheet-president-biden-signs-executive-order-catalyzing-americas-clean-energy-economy-through-federal-sustainability/. Accessed July 19, 2023.

scale electricity generation and nearly 80% of total U.S. primary energy consumption in 2022.[10]

The guiding principle of the energy transition is enshrined in the 2015 Paris Agreement signed at the twenty-first session of the Conference of the Parties (COP21). Signatories agreed to undertake efforts to limit global temperature rise to below 2°C, preferably to 1.5°C, from pre-industrial levels (late 1800s).[11] According to the United Nations (UN), global GHG emissions must be nearly halved by 2030 and net-zero emissions reached by 2050 to limit global temperature rise to 1.5°C; currently, the global average surface temperature is 1.1°C higher than pre-industrial levels. Since the Paris Agreement was signed, more than 70 countries (which make up more than 75% of global emissions) have committed to achieving net-zero GHG emissions or carbon neutrality by mid-century (Figure 2).[12] Achieving carbon neutrality has become synonymous with the energy transition, as carbon-intensive energy consumption is believed to be responsible for more than 70% of human-caused GHG emissions. [13]

10 U.S. Energy Information Administration, "What is U.S. electricity generation by energy source?" (Data as of February 2023). https://www.eia.gov/tools/faqs/faq.php?id=427&t=3; U.S. Energy Information Administration, Total Energy: Table 1.3 Primary Energy Consumption by Source (Data as of February 2023). https://www.eia.gov/totalenergy/data/browser/. Accessed June 2023.

11 United Nations, "What is the Paris Agreement?" https://unfccc.int/process-and-meetings/the-paris-agreement/the-paris-agreement. Accessed May 30, 2023.

12 United Nations, "Net Zero." https://www.un.org/en/climatechange/net-zero-coalition. Accessed June 2023.

13 Mengpin Ge, Johannes Friedrich, and Leandro Vigna, "4 Charts Explain Greenhouse Gas Emissions by Countries and Sectors," World Resource Institute (February 6, 2020). https://www.wri.org/insights/4-charts-explain-greenhouse-gas-emissions-countries-and-sectors. Accessed July 19, 2023.

Figure 2. Countries' Net-Zero, Climate Neutrality, or Carbon Neutrality Targets[14]

Achieved (self-declared)	2030	2040	2050		2060	2070
Benin Bhutan Comoros Gabon Guyana Suriname	Finland (2035) Maldives Barbados Dominica	Austria Germany (2045) Iceland Sweden (2045) Antigua and Barbuda Nepal (2045)	Australia Canada Chile Colombia Denmark Greece European Union Fiji France Hungary Ireland Japan Luxembourg New Zealand Nigeria Portugal South Korea Spain Switzerland United Kingdom Andorra Argentina Belgium Belize Brazil Cambodia Cape Verde Costa Rica Croatia Cyprus Ecuador Italy	Laos Latvia Liberia Lithuania Lebanon Malta Marshall Islands Monaco Oman Panama Papua New Guinea Peru Romania Singapore Slovakia Slovenia The Gambia Tunisia Turkey (2053) Tuvalu United Arab Emirates United States Uruguay Vanuatu Vietnam Estonia Haiti Malaysia Micronesia South Africa Sri Lanka	China Kazakhstan Russia Saudi Arabia Thailand (2065) Ukraine Bahrain Kuwait	India Ghana

In Law
In Policy Document
Declared/Pledged

Source: https://zerotracker.net/

While there has been increased global collaboration and coordination on clean energy and emissions targets, the global transition has also triggered competition. Major energy consumers, including the United States, are facing growing competition over resources, such as minerals needed for low-carbon technologies, and a race to manufacture and innovate new forms of low-carbon technologies to capture future market share. The United States is currently at a disadvantage, as it is dependent on imports for critical minerals, renewable technologies, and nuclear fuel.

14 For definitions of net-zero, climate neutrality, and carbon neutrality, see https://netzeroclimate.org/what-is-net-zero/.

What are the Energy Transition's Competitive Flashpoints?

The energy transition will increasingly become a focal point of great power competition. The transition to low-carbon fuels has the potential to reorder energy suppliers and import dependencies, and countries leading the race to supply the transition will reap the economic and geopolitical benefits traditionally afforded to dominant fossil fuel suppliers. There are several competitive flashpoints with the potential to generate risks and implications for the United States and allied countries. Competitive flashpoints are areas that can amplify strategic competition economically, technologically, and politically, and can increase tensions among great powers. If struggling to compete, competitive flashpoints can introduce political, economic, and security risks for the United States, which can potentially adversely affect its energy security, economic competitiveness, political relationships, and global trade and investment opportunities.

There are at least seven competitive flashpoints associated with the energy transition. Absent prudent planning by United States and allied countries, each area has the potential to advance the power of U.S. adversaries. The remainder of this section will provide an overview of each competitive flashpoint and describe risks and potential implications. These areas include:

- Competition to acquire critical minerals
- Chinese dominance of low-carbon technology manufacturing
- Race to lead nuclear-related exports
- Trade and finance tensions between developed and developing nations
- Growing risk of cyber threats due to increased electrification and digitalization
- Energy-related disinformation campaigns from China and Russia
- Energy insecurity sparked by inadequate investment

Competition to Acquire Critical Minerals

In general, low-carbon energy technologies—like solar panels, wind turbines, and electric vehicles (EV)—require more mineral inputs than fossil fuel energy.[15] In the past, renewable energy generation from solar and wind was perceived as a source of domestic supply that could boost energy security and reduce a country's dependence on major oil and gas producers. While this is somewhat true, a more complex picture has emerged in recent years as experts have pointed out that minerals, largely sourced from unstable or unideal suppliers, were essential inputs to low-carbon energy technologies. Thus, the shift to renewable energy does not automatically equate to increased energy independence but rather a reshuffling of energy dependencies.

In the United States' list of critical minerals published in 2022, the U.S. Department of the Interior designated 50 minerals as critical, based on supply risk, potential supply chain failure, and U.S. reliance on foreign suppliers, among other factors.[16] The list includes several minerals that are inputs to low-carbon energy technologies, like lithium, cobalt, nickel, and graphite.

Two main issues are intensifying competition for critical minerals. First, industry forecasts are showing that current, planned, and proposed mining projects worldwide are insufficient to meet the long-term mineral requirements of the energy transition. Second, China is the world's leading supplier of critical minerals and Russia is another leading supplier.

Projected Supply Shortfall

Baseline forecasts imply the supply of minerals may fall short of what is needed to achieve net-zero emissions by the mid-century. According to the IEA's latest mineral report published July 2023, in a scenario consistent with the Paris Agreement, minerals used in batteries will see the largest demand growth, with demand increasing nearly 9-fold for lithium, 8-fold

15 International Energy Agency, "The Role of Critical Minerals in Clean Energy Transitions" (May 2021), p8. https://www.iea.org/reports/the-role-of-critical-minerals-in-clean-energy-transitions. Accessed July 19, 2023.

16 Jason Burton, Alex Demas, and Steven Fortier, "U.S. Geological Survey Releases 2022 List of Critical Minerals," United States Geological Survey (February 22, 2022). https://www.usgs.gov/news/national-news-release/us-geological-survey-releases-2022-list-critical-minerals. Accessed July 19, 2023.

for both nickel and graphite, and 3-fold for cobalt by 2030.[17] Minerals used in electricity networks, such as copper and aluminum, will also see a substantial boost in demand growth as increasing electrification is key to decarbonizing the electricity and transportation sectors. The IEA estimates that investment spending in critical minerals development globally grew sharply by 30% in 2022. The boost in investment spending could help moderate the forecast supply gap of the energy transition's mineral requirements, but the IEA estimates the current growth trajectory is still insufficient to reach net-zero emissions by the mid-century. Additionally, much of the growth in investment spending on new minerals development came from Chinese companies.[18]

According to a 2022 forecast from Benchmark Mineral Intelligence, a leading mineral industry group, even when accounting for current, planned, probable, and possible supply, a significant shortfall in lithium supply is expected through 2040.[19] The projected mineral supply gap through 2040 could slow the pace of the energy transition, given the long lead time to bring online new mineral production. According to analysis from the IEA, developing mining projects, from discovery to production, has taken on average more than 16 years.[20] Therefore, if a company decides to pursue production at a mine in 2023, it's unlikely that it will start first production before 2039. In addition, a decline in higher ore quality in several operational mines worldwide is increasing both production costs and carbon dioxide (CO2) emissions as more energy is required during extraction, according to the IEA.[21]

Questions of whether existing reserves are adequate to meet future mineral requirements have driven countries and companies to consider unconventional locations, such as mining the seabed and beneath melting

17 International Energy Agency, "Critical Minerals Market Review 2023" (July 2023), p6-7. https://www.iea.org/reports/critical-minerals-market-review-2023. Accessed August 16, 2023.

18 Ibid.

19 George Miller, "Challenges and Opportunities for Advanced Air Mobility Raw Materials," Benchmark Mineral Intelligence (June 9, 2022). https://aam-cms.marqui.tech/uploads/aam-portal-cms/originals/4971dc04-b516-4957-b291-9be2e863d9c7.pdf. Accessed July 19, 2023.

20 International Energy Agency, "The Role of Critical Minerals in Clean Energy Transitions" (May 2021), p12. https://www.iea.org/reports/the-role-of-critical-minerals-in-clean-energy-transitions. Accessed July 19, 2023.

21 EY Americas, "Critical Minerals Supply and Demand Challenges Mining Companies Face" (April 25, 2022). https://www.ey.com/en_us/mining-metals/critical-minerals-supply-and-demand-issues. Accessed July 19, 2023.

ice. Seabed mining—which involves extracting minerals and deposits from the ocean floor—is largely in the exploration phase and is occurring in some exclusive economic zones (EEZs) within 200 miles of a country and in international waters.[22] Seabed extraction within EEZs is governed by each respective government, but exploration and extraction in the high seas is governed by the International Seabed Authority (ISA). The ISA was established under the UN Convention on the Law of the Sea (UNCLOS), and therefore, the United States is not an ISA member because it is not a signatory to UNCLOS, though it is an observer nation. As of May 2023, the ISA had signed 15-year seabed mining exploration contracts with 22 companies and/or government entities from China, Japan, Canada, Russia, South Korea, India, and the United Kingdom (UK), among others.[23] However, extraction in the high seas is restricted until the ISA passes a Mining Code—a regulatory framework to govern seabed mining including environmental risks. Negotiations on the Mining Code, among the 169 members, including 168 member states and the European Union, have stalled due to debates over proper environmental protections.[24] It may be difficult for the United States to unilaterally approve seabed mining operations of a U.S. company in international waters without being a member of the ISA.[25]

Melting ice in the Arctic is attracting mining companies to explore for minerals, such as nickel and cobalt, needed for the energy transition,

22 The Ocean Foundation, "Deep Seabed Mining." https://oceanfdn.org/seabed-mining/. Accessed May 30, 2023, Fani Sakellariadou, Francisco J. Gonzalez, James R. Hein, Blanca Rincón-Tomás, Nikolaos Arvanitidis, and Thomas Kuhn, "Seabed mining and blue growth: exploring the potential of marine mineral deposits as a sustainable source of rare earth elements," *Pure and Applied Chemistry* 94, no. 3 (February 4, 2022), pp329-351. https://www.degruyter.com/document/doi/10.1515/pac-2021-0325/html?lang=en. Accessed July 19, 2023.

23 International Seabed Authority, "Exploration Contracts." https://www.isa.org.jm/exploration-contracts/. Accessed May 30, 2023.

24 Deepsea Conversation Coalition, "Deep–Sea Mining Negotiations ISA Tracker." https://www.savethehighseas.org/isa-tracker/ (accessed May 30, 2023); and World Ocean Initiative, "International Seabed Authority under pressure over deep-sea mining impacts" (August 15, 2019), https://ocean.economist.com/governance/articles/international-seabed-authority-under-pressure-over-deep-sea-mining-impacts (accessed July 19, 2023).

25 Jordan Wolman, "U.S. is sidelined in critical minerals push," Politico (July 26, 2022). https://www.politico.com/news/2022/07/26/us-sidelined-critical-minerals-push-00047799. Accessed July 19, 2023.

particularly in Greenland.[26] The Arctic Circle is believed to carry substantial resources of critical minerals, including rare earth elements (REE). According to a French-based think tank, the Russian Arctic potentially holds the second-largest amount of REE resources in the world.[27] However, given the frontier nature of these exploration projects, it's unlikely that a substantive amount of new mineral production from the Arctic, or seabed mining, will come online within the next decade.

China's Global Dominance

In a mineral market fraught with a tight supply outlook, China is best positioned to compete for resources and dominant export markets. China is responsible for mining and processing several critical minerals essential to low-carbon technologies (Figure 3). As of 2022, China accounted for 70% and 90% of REEs mined and processed, respectively, in the world. REEs are used to make permanent magnets used in wind turbines and EV motors. While China accounts for a moderate share of mined lithium worldwide, Chinese companies account for the world's largest share of lithium processing. Even lithium mined in the United States is sent to China for processing. Lithium is projected to see the largest growth in demand among all minerals due to its use in lithium-ion batteries for EVs.[28] The mining and/or processing of other battery metals—cobalt, nickel, graphite, and manganese—are also heavily concentrated in China. China's relatively lax environmental regulations, cheaper labor and energy costs, and decades of planning to develop a comprehensive minerals supply chain—from extraction, separation and processing, smelting facilities, and magnet

26 René Marsh, "Billionaires are funding a massive treasure hunt in Greenland as ice vanishes," CNN (August 8, 2022), https://amp.cnn.com/cnn/2022/08/08/world/greenland-melting-mineral-mining-climate/index.html (accessed July 19, 2023); and Matthew Hall, "A new Cold War: mining geopolitics in the Arctic circle," Mining Technology (December 10, 2020), https://www.mining-technology.com/analysis/a-new-cold-war-mining-geopolitics-in-the-arctic-circle/ (accessed July 19, 2023).

27 Mikaa Mered, "The Arctic: Critical Metals, Hydrogen and Wind Power for the Energy Transition," French Institute of International Relations (January 23, 2019). https://www.ifri.org/sites/default/files/atoms/files/mered_arctic_metals_2019.pdf. Accessed July 19, 2023.

28 International Energy Agency, "The Role of Critical Minerals in Clean Energy Transitions" (May 2021), p5. https://www.iea.org/reports/the-role-of-critical-minerals-in-clean-energy-transitions. Accessed July 19, 2023.

plants—have led to China's dominance.[29]

Figure 3. China's Global Share of Mining & Processing of Key Minerals

Mineral	Application	Global Share	Mineral	Application	Global Share
Rare earth elements	Permanent magnets for wind turbines and EV motors, CO_2 capture	70% mining 90% processing	Aluminum	Electricity networks, solar PV, wind turbines, CO_2 capture	58% smelter production
Lithium	Battery storage, nuclear, CO_2 capture	15% mining 50-70% processing	Copper	Electricity networks, wind, solar, nuclear, EV charging stations, bioenergy	9% mining 42% processing
Cobalt	Battery storage, CO_2 capture	50-70% processing	Zinc	Wind turbines	32% mining
Nickel (class 1)	Battery storage, hydrogen electrolyzers, geothermal, wind, nuclear	35% processing	Silicon metal	Conventional semiconductor (used in solar industry)	68% mining
Graphite	Battery storage, fuel cells, CO_2 capture	65% mining	Gallium	WBG semiconductor-based power electronics	98% mining
Manganese	Battery storage, CO_2 capture, wind	90% processing	Cadmium	Cadmium telluride (CdTe) solar cells	42% processing
Antimony	Lead acid batteries	55% mining	Tellurium	CdTe solar cells (thin film)	53% mining
Vanadium	Vanadium redox flow battery	66% mining	Zirconium	Hydrogen electrolyzers, nuclear, CO_2 capture	12% mining

Note: Table excludes Chinese mining operations overseas.
Sources: USGS Mineral Commodity Summaries (2023), IEA The Role of Critical Minerals in Clean Energy Transitions (2022), DOE Supply Chain Reports (2022), and The Oxford Institute for Energy Studies (2023).

Minerals deemed critical by DOI & USGS in red

China's global supply share of some minerals is likely higher than what is shown in Figure 3, as the data does not comprehensively include all Chinese mining operations overseas. China has ownership stakes in some of the largest lithium mines in Australia, Chile, and Argentina, cobalt mines in the Democratic Republic of Congo (DRC), and nickel mines in Indonesia.[30]

29 Avery Chen and Camille Erickson, "Clean energy transition to fuel growth for China's rare earths sector in 2022," S&P Global (February 3, 2022). https://www.spglobal.com/marketintelligence/en/news-insights/latest-news-headlines/clean-energy-transition-to-fuel-growth-for-china-s-rare-earths-sector-in-2022-68604096. Accessed July 19, 2023.

30 International Energy Agency, "The Role of Critical Minerals in Clean Energy Transitions" (May 2021), p8. https://www.iea.org/reports/the-role-of-critical-minerals-in-clean-energy-transitions (accessed July 19, 2023); Luca Maiotti and Benjamin Katz, "Interconnected supply chains: a comprehensive look at due diligence challenges and opportunities sourcing cobalt and copper from the Democratic Republic of the Congo," The OECD Secretariat (2019), https://mneguidelines.oecd.org/Interconnected-supply-chains-a-comprehensive-look-at-due-diligence-challenges-and-opportunities-sourcing-cobalt-and-copper-from-the-DRC.pdf (accessed July 19, 2023); Ryan C. Berg and T. Andrew Sady-Kennedy, "South America's Lithium Triangle: Opportunities for the Biden Administration," Center for Strategic and International Studies (August 17, 2021), https://www.csis.org/analysis/south-americas-lithium-triangle-opportunities-biden-administration (accessed July 19, 2023); Kenji Kawase, "Chinese investors jostle over Argentine lithium mines," Nikkei Asia (October 13, 2021), https://asia.nikkei.com/Business/Materials/Chinese-investors-jostle-over-Argentine-lithium-mines (accessed July 19, 2023).

China is also pursuing REE mining in multiple countries in Africa.[31]

Russia's Lesser but Significant Role

Russia is also an important supplier of some critical minerals, albeit much less so than China. Russia is the world's largest producer of palladium and battery-grade, class 1 nickel, and is among the top producers of platinum, cobalt, gallium, and silicon metal; it also holds the world's largest uranium enrichment capacity (Figure 4). Following Russia's invasion of Ukraine, prices for battery-grade nickel reached an 11-year high.[32] While Western sanctions have not directly targeted Russian nickel exports, market fears of sanctions or Russia curbing exports sent prices soaring. The 2021 top destinations of Russian battery-grade nickel, starting with the largest, were China, Netherlands, Germany, the United States, and India.[33]

Figure 4. Russia's Global Share of Mining and Processing of Key Minerals

Mineral	Application	Global Share
Uranium	Nuclear fuel	5% mining
		38% conversion capacity utilization
		46% enrichment capacity
Palladium	Catalytic converters to reduce emissions from automobiles	42% mining
Platinum	Hydrogen fuel cells, catalytic converters, wind, CO2 capture	11% mining (second largest producer, after S. Africa)
Nickel (class 1)	Battery storage, hydrogen electrolyzers, geothermal, wind, nuclear	17% production
Cobalt	Battery storage, CO2 capture	5% mining
Gallium	WBG semiconductor-based power electronics	1% mining (second largest producer, after China)
Silicon metal	Conventional semiconductor (used in solar industry)	7% mining (second largest producer, after China)
Aluminum	Electricity networks, solar PV, wind turbines, CO2 capture	5% production
Copper	Electricity networks, wind, solar, nuclear, EV charging stations, bioenergy	5% mining
		4% processing

Sources: World Nuclear Association, USGS Mineral Commodity Summaries (2023), IEA The Role of Critical Minerals in Clean Energy Transitions (2022), and DOE Supply Chain Reports (2022).

Minerals deemed critical by DOI & USGS in red

31 Russell Parman, "An elemental issue," U.S. Army (September 26, 2019). https://www.army.mil/article/227715/an_elemental_issue. Accessed July 19, 2023.

32 Camille Erickson, "Nickel price spike during Russia-Ukraine conflict could drive up EV costs," S&P Global (March 3, 2022). https://www.spglobal.com/marketintelligence/en/news-insights/latest-news-headlines/nickel-price-spike-during-russia-ukraine-conflict-could-drive-up-ev-costs-69130867. Accessed July 19, 2023.

33 Ibid.

Risks and Potential Implications

Competition to acquire critical minerals will present heightened energy security risks to the United States and allied countries over the course of the energy transition if U.S. adversaries continue to dominate critical minerals supply. Energy security was traditionally defined as adequate, reliable supplies at affordable prices. The definition has since expanded to better capture how energy security is often intertwined with foreign policy issues and geopolitics.

An expanded definition of energy security considers: (1) how increased tensions between a given importer and exporter can impact an importer's energy supply and prices, (2) how a large energy exporter may use its supplies coercively or as political leverage, (3) how energy import dependencies may limit foreign policy responses, and (4) how large suppliers use their energy revenue toward building military capabilities. Meghan L. O'Sullivan, a Harvard professor and an expert on the role of energy in geopolitics, offered a more sophisticated definition and description of energy security in her 2013 book *The Entanglement of Energy, Grand Strategy, and International Security.* O'Sullivan writes:

> …being energy secure means having access to affordable energy without having to contort one's political, security, diplomatic, or military arrangements unduly. Is a country really energy secure if obtaining adequate energy supplies is dependent on a particular expensive, high risk, and limiting (in terms of opportunity cost) posture in the world?[34]

The Russian invasion of Ukraine is an illustrative example of O'Sullivan's definition of energy security and reinforces that energy security is an important part of national security. In 2022, Russia substantially cut natural gas pipeline flows to Europe, in retaliation of Western sanctions and aid to Ukraine, causing energy prices to skyrocket in Europe and causing the closure of many factories and businesses in the region. Russia's role as a dominant energy supplier globally limited the West's ability to implement secondary sanctions, like the sanctions imposed on Iran and North Korea.

34 Meghan L. O'Sullivan, "The Entanglement of Energy, Grand Strategy, and International Security," Harvard's Belfer Center for Science and International Affairs (May 2013). https://www.belfercenter.org/publication/entanglement-energy-grand-strategy-and-international-security. Accessed July 19, 2023.

As a result, Russia's oil production increased by 2% and oil revenue by 20% in 2022, due to higher energy prices and increased imports from Asian countries taking advantage of price discounts.[35] Record gas prices in 2022 also caused Russia's gas revenue to increase by nearly 80% compared with 2021.[36] However, for the first five months of 2023, Russian gas revenues have dropped, while oil revenues were relatively unchanged.[37] Russia's oil revenue is much more valuable to the Kremlin than natural gas revenue. Before its invasion of Ukraine, oil revenue accounted for almost 80% of Russia's energy export revenue, far above natural gas.[38] New rounds of Western sanctions targeting Russia's energy exports took effect in late 2022, but the impact on Russian energy revenue will largely depend on the price of oil and gas and demand in Asian markets.

The expanded definition of energy security in the context of current events is a reminder that strengthening energy security requires strategic, long-term planning. Energy security planning must ensure that a nation state's energy import sources do not greatly limit its foreign policy options and/or place the nation-state in a vulnerable position, making it susceptible to coercion by an adversary. The window of opportunity for the United States and allied countries to strategically plan its supply chains and import sources for low-carbon fuels is now. Thus, by rushing the energy transition, the United States and its allies are locking in current supply chains dominated by China, and to a much lesser extent, Russia.

The competition for critical minerals to fuel the energy transition raises two energy security questions. First, given the tight supply forecast of several critical minerals and long project lead times, will the growing global critical minerals market be more or less cyclical than the global oil market and is there a way to reduce the cyclical nature? This question addresses concerns inherent in the traditional definition of energy security, which is

35 Anatoly Kurmanaev and Stanley Reed, "How Russia Is Surviving the Tightening Grip on Its Oil Revenue," *The New York Times* (February 7, 2023). https://www.nytimes.com/2023/02/07/business/russia-oil-embargo.html. Accessed July 19, 2023.

36 Ibid.

37 Editorial Dept, "Russia Sees Natural Gas Revenues Collapse," Oil Price (June 30, 2023). https://oilprice.com/Energy/Energy-General/Russia-Sees-Natural-Gas-Revenues-Collapse.amp.html. Accessed July 19, 2023.

38 International Monetary Fund, "Russian Federation: 2020 Article IV Consultation-Press Release; Staff Report," Country Report No. 2021/036 (February 9, 2021). https://www.imf.org/en/Publications/CR/Issues/2021/02/08/Russian-Federation-2020-Article-IV-Consultation-Press-Release-Staff-Report-50068. Accessed July 19, 2023.

adequate, reliable supplies at affordable prices. Long project lead times may prompt boom-bust investment cycles, like oil markets, as lead times for mining projects are currently even longer than oil and gas projects. New extraction technologies and techniques and streamlining regulations, especially in the United States, are both needed to shorten the time it takes to bring online new production. Transparent, detailed, and widely accessible market data on global mining operations can also help to improve market signaling for investors.

The second energy security question is: Would China restrict critical mineral supplies to the United States and/or allied countries if tensions between great powers intensified? China's use of economic sanctions and trade restrictions in recent years toward various countries—including South Korea, Australia, Japan, and Lithuania—demonstrates China is willing to pull economic levers to exert power and influence outcomes, at least to some extent. Most recently, in July 2023, China's Ministry of Commerce announced export restrictions on two minerals, gallium and germanium, for national security purposes. Gallium is a commonly used semiconductor material, which can be used in energy applications, such as solar panels and EVs, along with defense applications. Experts view China's actions as a retaliation against the United States, Netherlands, and Japan for restricting China's access to semiconductor manufacturing equipment.[39] According to the U.S. Geological Survey, China accounted for 98% of total gallium mined globally in 2022.[40]

U.S. officials and allies are also concerned China will one day restrict REE exports, as it has done in the past. In 2010, China limited REE exports to Japan for two months after a dispute over a fishing boat incident.[41] Chinese news sources denied Beijing cut REE exports to Japan for political reasons, stating that China had announced an overall global reduction in REE exports a few months prior to its spat with Japan due to increased

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39 Alexander Holderness, Nicholas Velazquez, Henry H. Carroll , and Cynthia Cook, "Understanding China's Gallium Sanctions," Center for Strategic and International Studies (July 7, 2023). https://www.csis.org/analysis/understanding-chinas-gallium-sanctions. Accessed July 19, 2023.

40 U.S. Geological Survey, *Mineral commodity summaries* 2023 (January 31, 2023). https://www.usgs.gov/publications/mineral-commodity-summaries-2023. Accessed July 19, 2023.

41 China Power, "Does China Pose a Threat to Global Rare Earth Supply Chains?" Center for Strategic and International Studies. https://chinapower.csis.org/china-rare-earths/. Accessed May 30, 2023.

Chinese demand.[42] Ten years later, concerns about China cutting REE exports resurfaced after China passed its export control law in late 2020, which places export controls on dual-use items. Following the passing of the export control law, China passed a draft Regulations on Rare Earth Management, confirming that the export control law was applicable to REEs.[43] Nonetheless, it is still somewhat unclear to what extent China would use its dominance of critical minerals coercively or as a foreign policy tool.

Growing tensions between the United States and China make the United States vulnerable to disruptions from China. Over the past five years, the United States has increasingly used tariffs, export controls, sanctions, divestment orders, and licensing denials toward China to reduce forced transfers of U.S. technology to China, curtail intellectual property theft, and deter unfair trade practices and human rights violations (Figure 5).[44] Chinese retaliatory responses to U.S. trade and export restrictions have been comparatively moderate. However, the probability that China could aggressively impose trade and export restrictions on critical minerals should not be ruled out, especially in the face of a future escalatory incident. For example, in a scenario where China invades Taiwan and wishes to deter or limit U.S. military involvement, China may choose to weaponize its supply of critical minerals similar to how Russia has weaponized its natural gas supply to Europe.

42 Amy King and Shiro Armstrong, "Did China really ban rare earth metals exports to Japan?" East Asia Forum (August 18, 2013). https://www.eastasiaforum.org/2013/08/18/did-china-really-ban-rare-earth-metals-exports-to-japan/. Accessed July 19, 2023.

43 Qian Zhou and Sofia Brooke, "China Merges Three Rare Earths State-Owned Entities to Increase Pricing Power and Efficiency," China Briefing (January 12, 2022). https://www.china-briefing.com/news/china-merges-three-rare-earths-state-owned-entities-to-increase-pricing-power-and-efficiency/. Accessed July 19, 2023.

44 Yukon Huang, "The U.S.-China Trade War Has Become a Cold War," Carnegie Endowment for International Peace (September 16, 2021). https://carnegieendowment.org/2021/09/16/u.s.-china-trade-war-has-become-cold-war-pub-85352. Accessed July 19, 2023.

Figure 5. Selected Issues Shaping U.S.-China Economic Relations

U.S.- China Trade War	Partial Technological & Financial Decoupling	Growing Chinese Technology Independence & Competition	China's Export Control Law	U.S. Sanctions Targeting China's Forced Labor
Started in 2018, and truce announced in January 2020. Series of tit-for-tat import tariffs and quotas set on both sides, while allowing some exemptions. Trade data from 2022, showed flows between the two had not recovered.	Past two U.S. administrations have increased export controls on technology products, services, and inputs to and from China, along with divestment orders, licensing denials, visa bans, sanctions, and tariffs. Beijing is pursuing decoupling from U.S. dollar and financial system.	China's dependence on U.S. technologies has declined substantially over the past decade as Chinese R&D and innovation capacity has increased. U.S.-China technology competition is rising as China strives to attain global technological leadership.	Took effect December 1, 2020. Allows Chinese authorities to restrict exports of "controlled items" deemed a threat to state security. Sparked concerns in the West that the law could be applied to Chinese exports of rare earth elements given military applications.	The U.S. imposed sanctions against Chinese companies believed to be using forced labor in the Xinjiang region, including a major Chinese company producing polysilicon for solar panels.

Sources: U.S. China Trade War,[45] Partial Technological & Financial Decoupling,[46] Growing Chinese Technology Independence & Competition,[47] China's Export Control Law,[48] U.S. Sanctions Targeting China's Forced Labor[49]

45 Chad P. Bown and Yilin Wang, "Five years into the trade war, China continues its slow decoupling from US exports," Peterson Institute for International Economics (March 16, 2023). https://www.piie.com/blogs/realtime-economics/five-years-trade-war-china-continues-its-slow-decoupling-us-exports. Accessed July 19, 2023.

46 Jon Bateman, *U.S.-China Technological "Decoupling": A Strategy and Policy Framework*, Carnegie Endowment for International Peace (April 25, 2022), https://carnegieendowment.org/2022/04/25/u.s.-china-technological-decoupling-strategy-and-policy-framework-pub-86897 (accessed July 19, 2023); and Diana Choyleva and Dinny McMahon, *China's Quest for Self-Reliance: How Beijing Plans to Decouple from the Dollar-Based Global Trading and Financial System*, Wilson Center (August 2022). https://www.wilsoncenter.org/publication/chinas-quest-self-reliance-how-beijing-plans-decouple-dollar-based-global-trading-and (accessed July 19, 2023).

47 Pengfei Han, Wei Jiang, and Danqing Mei, *Mapping U.S.-China Technology Decoupling and Dependence*, Stanford's Center on China's Economy and Institutions (2022), https://sccei.fsi.stanford.edu/china-briefs/mapping-us-china-technology-decoupling-and-dependence (accessed July 19, 2023); Efekan Bilgin and Alphonse Loh, "Techno-nationalism: China's bid for global technological leadership," LSE Blog (September 28, 2021), https://blogs.lse.ac.uk/cff/2021/09/28/techno-nationalism-chinas-bid-for-global-technological-leadership/ (accessed July 19, 2023); and EU Science Hub, "China is on track to achieve its objective of global industrial and technological leadership in key sectors by 2049," https://joint-research-centre.ec.europa.eu/jrc-mission-statement-work-programme/facts4eufuture/china-challenges-and-prospects-industrial-and-innovation-powerhouse/china-track-achieve-its-objective-global-industrial-and-technological-leadership-key-sectors-2049_en (accessed July 19, 2023).

48 Sofia Baruzzi, "China's Export Control Law Explained," China Briefing (November 9, 2020), https://www.china-briefing.com/news/chinas-export-control-law-explainer-china-briefing-news/ (accessed June, 2023); and Sohrab Darabshaw, "Rare Earth Elements About to Get Even Rarer," Metal Miner (May 5, 2022), https://agmetalminer.com/2022/05/05/rare-earth-elements-about-to-get-even-rarer/ (accessed June 2023).

49 Nichola Groom and Richard Valdmanis, "Exclusive: U.S. solar panel imports from China grow, alleviating gridlock, officials say," Reuters (March 6, 2023). https://www.reuters.com/business/energy/us-solar-panel-imports-china-grow-alleviating-gridlock-officials-say-2023-03-06/. Accessed July 19, 2023.

Chinese Dominance of Low-Carbon Manufacturing

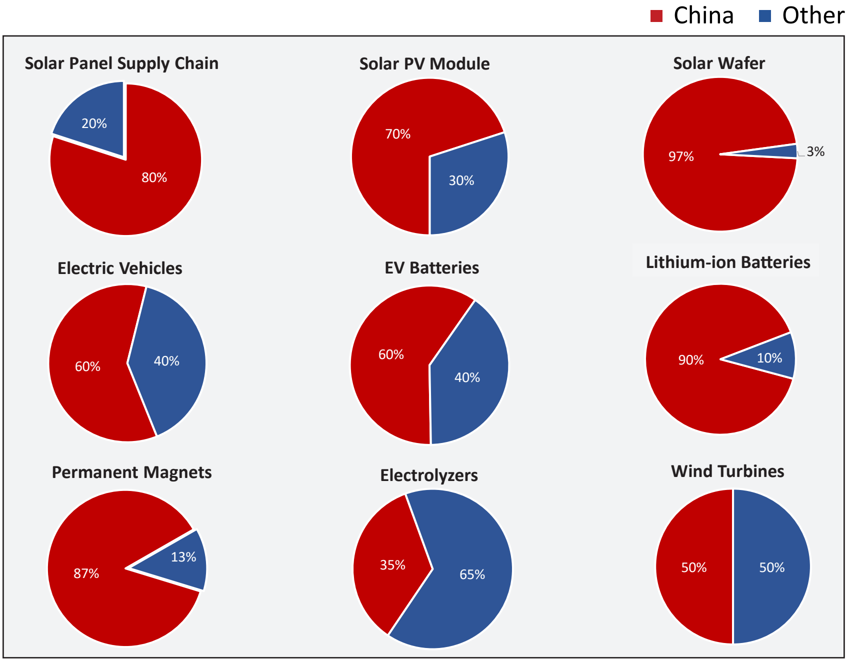
China is the leading manufacturer and exporter of low-carbon energy technologies (Figure 6). It is the world's single largest manufacturer of solar panels, wind turbines, lithium-ion batteries, and EVs. Chinese state-owned companies have been able to scale up manufacturing relatively quickly, having government-backed financial support, ambitious domestic renewable targets and policies stimulating demand, comparatively lower labor rates and energy costs, and the availability of raw material. International buyer concerns about Chinese manufacturing quality have largely subsided, and many Chinese solar brands are considered among the best value and quality.[50] China accounts for more than 80% of the manufacturing of solar panel inputs globally.[51] China is also a dominate supplier of solar power system components. For instance, components to make solar inverters—such as semiconductor, passive, and electronic components—are largely made in China and other parts of Asia.[52]

50 SolarReviews, "Chinese solar panels: Are they any good?" SolarReviews Blog (April 24, 2023), https://www.solarreviews.com/blog/sourcing-solar-are-chinese-solar-panels-any-good (accessed May 30, 2023); and Regen Power, "Solar Panels, which is good for the home solar system?" https://regenpower.com/articles/chinesesolarpanels-vs-germansolarpanels/ (accessed May 30, 2023).

51 International Energy Agency, "Special Report on Solar PV Global Supply Chains" (August 2022). https://www.iea.org/reports/solar-pv-global-supply-chains. Accessed June 2023.

52 U.S. Department of Energy, Solar Photovoltaics: Supply Chain Deep Dive Assessment, U.S. Department of Energy Response to Executive Order 14017, "America's Supply Chains" (February 24, 2022). https://www.energy.gov/sites/default/files/2022-02/Solar%20Energy%20Supply%20Chain%20Report%20-%20Final.pdf. Accessed June 2023.

Figure 6. China's Manufacturing of Low-Carbon Energy Technologies, Global Share



Sources: Energy Intelligence (2022), International Energy Agency (2022, 2023), U.S. White House (2022), and Wood Mackenzie (2022)
Notes: (1) The data captures activity in 2021 and 2022. (2) Data on China's solar market share excludes Chinese solar investments in Southeast Asia.

Wind Manufacturing

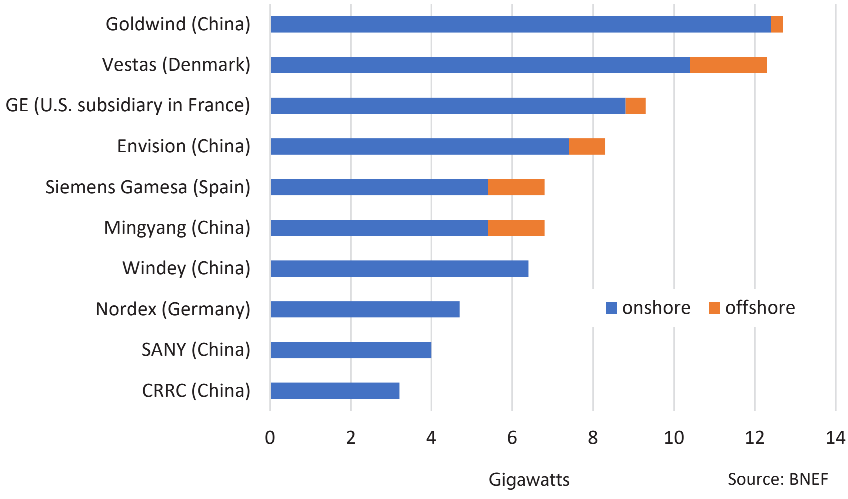
While China's dominance in solar markets is well documented, China's share of global onshore and offshore wind manufacturing, exports, and installations are also on the rise. Some industry sources believe Chinese companies are well-positioned to supplant Western companies, which have traditionally dominated the wind industry but are struggling to remain profitable. Chinese companies are setting targets to increase global market share, and Chinese wind turbines are becoming more cost competitive.[53]

The ExWorks costs (total amount needed to produce a wind turbine and

53 Sha Hua, "Chinese Wind-Turbine Companies Seek Global Growth as Western Rivals Struggle," *The Wall Street Journal* (May 14, 2022). https://www.wsj.com/articles/chinese-wind-turbine-companies-seek-global-growth-as-western-rivals-struggle-11652520781. Accessed July 19, 2023.

tower) for Western companies is around $650,000–800,000 per megawatt (MW) for onshore wind, depending the market, compared with $342,328-411,107 per MW for Chinese companies, partly due to lower labor rates and raw material availability.[54] Chinese companies also enjoy government subsidies and a low-cost supply chain for turbines, including China's steel industry, which is the largest in the world. In 2022, China's Goldwind was the world's largest global wind turbine supplier, overtaking Denmark's Vestas (Figure 7)—though nearly 90% of Goldwind's turbines were sold in the Chinese market.[55] But international orders for Chinese wind components are expected to rise.

Figure 7. Top 10 Wind Turbine Makers. 2022



54 Philip Totaro, "Chinese wind turbine makers in a better place than ever to start displacing Western OEMs," RECHARGE (April 8, 2022). https://www.rechargenews.com/wind/chinese-wind-turbine-makers-in-a-better-place-than-ever-to-start-displacing-western-oems/2-1-1196826. Accessed July 19, 2023.

55 Will Gusick, "Goldwind and Vestas in Photo Finish for Top Spot as Global Wind Power Additions Fall," Bloomberg New Energy Finance (March 23, 2023). https://about.bnef.com/blog/goldwind-and-vestas-in-photo-finish-for-top-spot-as-global-wind-power-additions-fall/. Accessed July 19, 2023.

Global demand for offshore wind components is growing as governments worldwide, including the United States, have set offshore wind targets to take advantage of higher speed winds. In late 2021, the Biden administration set a target for offshore wind to generate 30 gigawatts (GW) of electricity by 2030, enough to power more than 10 million homes.[56] At the start of 2023, the United States had two operating offshore wind farms, representing less than 1% of the 2030 target.[57] The United States has relied on European companies for wind components, but private U.S. companies might turn to Chinese companies to source some offshore wind components as European companies are struggling to compete economically. In February 2022, CEOs of top European wind companies wrote a letter to the president of the European Commission warning that they are losing ground to Chinese companies in Europe and abroad.[58] Rapidly growing offshore wind deployment in China, driven by domestic provincial targets, has led to a boost in Chinese manufacturing of offshore wind components and positioned Chinese companies to compete globally. In 2022, China's Mingyang became the first Chinese company to supply wind turbines to the European market to build the first offshore wind farm in the Mediterranean Sea, and in 2023, Mingyang became the first Chinese company to provide wind turbines for an offshore wind farm in Japan.[59]

56 Melissa Manno, "Biden Wants to Increase U.S. Offshore Wind Energy. Can He Do It?" Council on Foreign Relations (November 23, 2021). https://www.cfr.org/in-brief/biden-wants-increase-us-offshore-wind-energy-can-he-do-it. Accessed July 19, 2023.

57 Michael E. Webber and Hugh Daigle, "Next US energy boom could be wind power in the Gulf of Mexico," The Conversation (August 16, 2022) https://theconversation.com/next-us-energy-boom-could-be-wind-power-in-the-gulf-of-mexico-188326. Accessed July 19, 2023.

58 Wind Europe, "Re: European wind energy supply chain struggling, Green Deal at risk," letter to Ursula von der Leyen, President of the European Commission (February 22, 2022). https://windeurope.org/wp-content/uploads/files/policy/position-papers/20220222-WindEurope-letter-to-President-von-der-Leyen.pdf. Accessed July 19, 2023.

59 Zheng Xin, "Mingyang ships China's first offshore wind turbines to Japan," *China Daily* (March 30, 2023). https://www.chinadaily.com.cn/a/202303/30/WS6425815fa31057c47ebb77cc.html. Accessed July 19, 2023.

Lithium-ion Batteries

Figure 8. Market Share of Battery Supply Chain

1st Stage: Extraction			
	China	U.S.	EU
Nickel	31%	1%	5%
Cobalt	1%	0%	<1%
Graphite	68%	0%	1%
Lithium	14%	<11%	<1%
Manganese	6%	0%	0%
2nd Stage: Chemical Processing			
	China	U.S.	EU
Nickel	68%	1%	10%
Cobalt	73%	0%	15%
Graphite	100%	0%	0%
Lithium	59%	4%	0%
Manganese	93%	0%	5%
3rd Stage: Cathode and Anode Production			
	China	U.S.	EU
Cathode	80%	<1%	<1%
Anode	89%	<1%	0%
4th Stage: Lithium ion battery cell manufacturing			
	China	U.S.	EU
Cells	79%	7%	7%

Source: Benchmark Mineral Intelligence, 2022

https://aam-cms.marqui.tech/uploads/aam-portal-cms/originals/4971dc04-b516-4957-b291-9be2e863d9

Note: The data differences in figure 8 compared with figure 3 reflect estimates from different data sources absent an authoritative data source for China, along with differences in accounting for domestic and/or overseas activities.

China accounts for around 79% to 90% of global manufacturing of lithium-ion batteries, depending on the industry source (Figure 8). While lithium-ion battery cell manufacturing is increasing in Europe and in the United States, China is still projected to account for most of world's planned capacity growth. About 75% of the 136 new lithium-ion battery plants planned by 2029 were expected to be based in China, based on projections made in 2020.[60] Although the invention of lithium-ion batteries has its roots with U.S. scientists, over the past two decades U.S. companies have

60 John Xie, "How China Dominates Global Battery Supply Chain," VOA News (September 1, 2020). https://www.voanews.com/a/silicon-valley-technology_how-china-dominates-global-battery-supply-chain/6195257.html (accessed July 19, 2023); and Vivas Kumar, "Lithium-ion battery supply chain technology development and investment opportunities," Benchmark Mineral Intelligence, Presentation to Carnegie Mellon University – Battery Seminar (June 2020). https://wp-admin.benchmarkminerals.com/app/uploads/20200608-Vivas-Kumar-Carnegie-Mellon-Battery-Seminar-V1.pdf (accessed July 19, 2023).

outsourced battery manufacturing to East Asia.[61] Currently, U.S. companies get almost all lithium-ion batteries from China, followed by South Korea and Japan. China's dominance stems from strategic industrial policies, targeting the entire supply chain from minerals to the battery pack, government incentives to support domestic EV demand and manufacturing, and limiting foreign market access via its battery certification program.[62]

Electric Vehicles (EVs)

China's growing EV market has helped domestic battery cell manufacturers scale up, and conversely, links to local battery cell manufacturers have helped Chinese EV makers. Since 2009, the Chinese government has provided generous subsidies for EV purchases, including battery EVs, plug-in hybrids, and fuel cell EVs, helping China to become the largest EV market in the world.[63] Growing EV demand in China has attracted overseas companies, such as U.S.-based Tesla, to open manufacturing plants in China, although Chinese EV companies have proven difficult to compete with in China as their brands have gained popularity domestically and are designed with local preferences.[64] Chinese EV makers are opening

61 Francis Wang, "A 100-Day Look at U.S. Battery Supply Chain Challenges," Power Magazine (April 2, 2021), https://www.powermag.com/blog/a-100-day-look-at-u-s-battery-supply-chain-challenges/ (accessed July 19, 2023); Paul Boisvert, "'Founding Father' of lithium-ion batteries helps solve 40-year problem with his invention," Oak Ridge National Laboratory (July 27, 2021), https://neutrons.ornl.gov/content/%E2%80%98founding-father%E2%80%99-lithium-ion-batteries-helps-solve-40-year-problem-his-invention (accessed July 19, 2023); and Bryan Lynn, "US Inventor's Battery Could Change the World… Again," Voice of America (May 3, 2017). https://learningenglish.voanews.com/a/inventor-john-goodenough-battery-breakthrough-could-change-the-world-again/3835846.html (accessed July 19, 2023).

62 U.S. Department of Energy, Executive Summary: National Blueprint for Lithium Batteries 2021-2030 (June 2021), https://www.energy.gov/sites/default/files/2021-06/FCAB%20National%20Blueprint%20Lithium%20Batteries%200621_0.pdf. Accessed July 19, 2023.

63 Giulia Interesse, "China Considers Extending its EV Subsidies to 2023 (updated)," China Briefing (September 29, 2022). https://www.china-briefing.com/news/china-considers-extending-its-ev-subsidies-to-2023/. Accessed July 19, 2023.

64 Clemens Dabelstein, Philip Schäfer, Dennis Schwedhelm, Jingbo Wu, and Ting Wu, "Winning the Chinese BEV market: How leading international OEMs compete," McKinsey & Company (May 4, 2021), https://www.mckinsey.com/industries/automotive-and-assembly/our-insights/winning-the-chinese-bev-market-how-leading-international-oems-compete (accessed July 19, 2023); and Norihiko Shirouzu, "Global automakers face electric shock in China," Reuters (May 26, 2022), https://www.reuters.com/business/autos-transportation/global-automakers-face-electric-shock-china-2022-05-25/ (accessed July 19, 2023).

sales offices in Europe to get an early start in the growing EV market.[65] In 2021, China was the top origin of EV exports, sending almost 500,000 EVs abroad, mainly to Europe and Southeast Asia, and EVs manufactured in China accounted for 60% of the world's EV production.[66]

UHV Technology

China is leading the world in developing and installing ultra-high voltage (UHV) transmission lines. UHV lines are long-distance power lines that send electricity at very high-capacity levels, reducing costs and minimizing power losses. UHV lines operate at 800 kilovolts (kV) or greater for direct current lines and 1,000 kV or greater for alternating current lines.[67] China deployed its first UHV line domestically in 2009 and since has commissioned over 30 UHV lines to date.[68] The largest UHV line commissioned is a 1,100 kV UHV DC Changji-Guquan line of 2,046 miles in length, similar in distance from Finland to France, demonstrating China's ability to deploy UHV lines at the continental scale.[69] The UHV lines transmit electricity sourced from resource rich areas, including solar and wind, in Northern and Western China to cities with high energy demand in Eastern China. Long-distance, high-capacity transmission lines help to decrease the cost of renewable energy to consumers as remote areas tend to have high concentrations of wind and solar resources, and thus, are important for decarbonization efforts across

65 Automotive News Europe, "China's EV makers make their move on Europe" (September 30, 2021). https://europe.autonews.com/automakers/chinas-ev-makers-make-their-move-europe. Accessed July 19, 2023.

66 Takashi Kawakami, Yohei Muramatsu, and Saki Shirai, "China led world with 500,000 electric car exports in 2021," Nikkei Asia (March 8, 2022). https://asia.nikkei.com/Spotlight/Electric-cars-in-China/China-led-world-with-500-000-electric-car-exports-in-2021. Accessed July 19, 2023.

67 Shang Qianming, "Ultra-High Voltage System Supercharges Energy Revolution," *China Today* (February 26, 2021). http://www.chinatoday.com.cn/ctenglish/2018/ln/202102/t20210226_800237464.html (Accessed July 19, 2023); and Bin Li and Yuping Zheng, *Protection Technologies of Ultra-High-Voltage AC Transmission Systems* (Amsterdam: Elsevier Inc, 2020). https://www.sciencedirect.com/topics/engineering/uhv-power-transmission. Accessed July 19, 2023).

68 Andries Wantenaar, "China's UHV transmission to more than double by 2025 to 105 GW," Rethink Technology Research (January 6, 2022), https://rethinkresearch.biz/articles/chinas-uhv-transmission-to-more-than-double-by-2025-to-105-gw/ (accessed July 19, 2023); and Nils Feldmann, "Advancing climate goals with ultra-high voltage power lines," nextrends Asia (August 8, 2022), https://nextrendsasia.org/advancing-climate-goals-with-ultra-high-voltage-power-lines/ (accessed July 19, 2023).

69 Bloomberg News, "World's Biggest Ultra-High Voltage Line Powers Up Across China" (January 1, 2019). https://www.bloomberg.com/news/articles/2019-01-02/world-s-biggest-ultra-high-voltage-line-powers-up-across-china#xj4y7vzkg. Accessed July 19, 2023.

the world. China has installed UHV lines in Brazil and Pakistan. In Brazil, the Chinese built-UHV lines transmit electricity from its resource-rich north to southern parts of the country.[70] China has also completed high voltage transmission projects in multiple countries around the world, including in Africa, Western and Eastern Europe, Asia, and Latin America.[71]

Risks and Potential Implications

China's dominance of low-carbon technology manufacturing presents energy security risks for the United States and allied countries. This will tilt the balance of power in the energy domain toward China as a dominant supplier of the energy transition. If gone unrivaled, China's dominance as a supplier can strengthen its global influence via trade, finance, construction, investment, and acquisition deals; create multi-decadal ties and dependencies; expand Chinese economic statecraft tools, and support China's broader foreign policy initiatives, such as the Belt and Road Initiative (BRI), Global Energy Interconnection (GEI), and technological standard setting.

Major fossil fuel exporters like Saudi Arabia, Russia, and even OPEC have gained political clout because of the world's dependence on their energy resources. China historically has been an energy consumer and hasn't contributed much to the world's supply. But this has changed, and China is now the Saudi Arabia of the renewable energy markets. China's dominance in low-carbon energy manufacturing will likely present more opportunities for its BRI, the main instrument of Beijing's economic statecraft. As countries worldwide seek to fulfill climate commitments and build massive infrastructure projects to bring online low-carbon energy and expand electrification, many will likely turn to China to help finance and construct projects. The scale of construction and costs needed to accomplish the global transition to net-zero emissions are immense, and China is re-aligning its BRI objectives to fill this gap. While Beijing's goal to help developing countries buildout "green" energy infrastructure—as stated

70 Ministry of Foreign Affairs of the People's Republic of China, "China's State Grid: Linking North and South of Brazil" (August 29, 2022). https://www.fmprc.gov.cn/mfa_eng/topics_665678/zggcddwjw100ggs/xsd/202208/t20220829_10757157.html. Accessed July 19, 2023.

71 Electric Energy Online, "State Grid, a Contributor to the Belt and Road Initiative" (October 9, 2019). https://electricenergyonline.com/article/energy/category/general/90/793205/state-grid-a-contributor-to-the-belt-and-road-initiative.html. Accessed July 19, 2023.

by Chinese President Xi Jinping in his September 2021 pre-recorded speech to the UN General Assembly[72]—bodes well for climate goals, it presents a conundrum for the United States and allies contending with the expansion of Chinese political and economic influence. This potential expansion of Chinese influence through new opportunities offered by the energy transition could lead later to favorable foreign policy outcomes for Beijing on hot topics contended on the international stage.

Even before the concept of the energy transition, China has played a noticeable role in financing energy projects abroad. Over the past few decades, several countries have turned to China to increase their power generation either with coal-fired power plants or hydroelectric. As of 2021, data from Boston University shows that China's policy banks lent $32.5 billion for overseas hydropower projects and associated transmission infrastructure to build 32 GW of hydro generation capacity.[73] Chinese companies are involved in overseas energy projects either through direct investments; mergers and acquisitions (M&A);[74] financing via Chinese development banks and financial institutions; as engineering, procurement, and construction (EPC) contractors; and/or as equipment and/or technology suppliers. Chinese state development banks and financial institutions include China Export-Import Bank (China Exim Bank), Chinese Development Bank (CDB), Sinosure, Industrial and Commercial Bank of China (ICBC), and Bank of China (BoC). These Chinese financial institutions likely often practice "tied financing" with Chinese overseas investors, requiring them to use Chinese EPC contractors and procure equipment and technologies

72 David Stanway and Joe Brock, "China's overseas coal power retreat could wipe out $50 bln of investment," Reuters (September 22, 2021). https://www.reuters.com/business/energy/chinas-overseas-coal-power-retreat-could-wipe-out-50-bln-investment-2021-09-22/. Accessed July 19, 2023.

73 Cecilia Springer, "Going green? Chinese policy banks' changing role in global energy development," China Dialogue (April 27, 2022). https://chinadialogue.net/en/energy/going-green-chinese-policy-banks-changing-role-global-energy-development/. Accessed July 19, 2023.

74 Stuart Penson, "China's CTG buys renewables assets in Europe and Middle East," Carbon Economist (August 23, 2021), https://pemedianetwork.com/transition-economist/articles/renewables/2021/china-s-ctg-buys-renewables-assets-in-europe-and-middle-east/ (accessed July 19, 2023); Clifford Chance, "Clifford Chance advises China Three Gorges Europe on acquisition of 181 MW portfolio of operating windfarms in Spain" (November 17, 2021), https://www.cliffordchance.com/news/news/2021/11/clifford-chance-advises-china-three-gorges-europe-on-acquisition.html (accessed July 19, 2023); Clifford Chance, "Clifford Chance advises China Three Gorges Spain on its acquisition of a 619MW renewables portfolio in Spain from Nexwell Power" (June 14, 2022), https://www.cliffordchance.com/news/news/2022/06/clifford-chance-advises-china-three-gorges-spain-on-its-acquisit.html (accessed July 19, 2023); and International Energy Agency, Chinese Companies Energy Activities in Emerging Asia (April 2019), https://www.iea.org/reports/chinese-companies-energy-activities-in-emerging-asia (accessed July 19, 2023).

from Chinese providers.[75] Chinese financial institutions have become a major source of energy project financing globally. From 2007 to 2016, China's two main policy banks, China Exim Bank and CDB, issued energy loans equivalent to the combined amount lent out by major Western-backed multilateral banks, which was $196.7 billion.[76]

Belt and Road Initiative (BRI)

President Xi launched BRI in 2013, and China's National Development and Reform Commission, Ministry of Foreign Affairs, and Ministry of Commerce released an action plan in 2015.[77] In the action plan, China framed BRI as a means to promote economic prosperity, regional cooperation and trade, world peace and development, and connectivity among the Asian, African, and European continents. Since the action plan, the Chinese Communist Party added BRI to its constitution in 2017; Beijing has held two international BRI forums to drum up participation; and BRI outreach has extended beyond those three continents to the Americas and Middle East. The first major BRI summit, formerly known as the Belt and Road Forum (BRF), was held in May 2017 and was attended by 29 world leaders and official representatives from 30 additional countries.[78] The second was held in April 2019 and was attended by leaders from 37 countries and representatives from over 150 countries in total.[79] As of December 2022, 147 countries have signed a general cooperation agreement with China

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75 Rasmus Lema, Padmasai Lakshmi Bhamidipati, Cecilia Gregersen, Ulrich Elmer Hansen, and Julian Kirchherr, "China's investments in renewable energy in Africa: Creating co-benefits or just cashing-in?" World Development 141 (May 2021), https://doi.org/10.1016/j.worlddev.2020.105365 (accessed July 19, 2023); and International Energy Agency, *Chinese Companies Energy Activities in Emerging Asia.*

76 Chuyu Liu and Johannes Urpelainen, "Why the United States should compete with China on global clean energy finance," Brookings (January 7, 2021). https://www.brookings.edu/research/why-the-united-states-should-compete-with-china-on-global-clean-energy-finance/. Accessed July 19, 2023.

77 The State Council of the People's Republic of China, "Full text: Action plan on the Belt and Road Initiative," (March 30, 2015). http://english.www.gov.cn/archive/publications/2015/03/30/content_281475080249035.htm. Accessed July 19, 2023.

78 Shannon Tiezzi, "What Did China Accomplish at the Belt and Road Forum?" *The Diplomat* (May 16, 2017). https://thediplomat.com/2017/05/what-did-china-accomplish-at-the-belt-and-road-forum/. Accessed July 19, 2023.

79 Matthew P. Goodman and Jonathan E. Hillman, "China's Second Belt and Road Forum," Center for Strategic and International Studies (April 24, 2019). https://www.csis.org/analysis/chinas-second-belt-and-road-forum.

under BRI.[80] This includes high-and-low-income countries in Africa, Asia, Latin America, the Middle East, and Europe, including several EU members.

While the momentum of BRI has slowed in recent years, the energy transition will likely open new investment opportunities for BRI, as China is best positioned to invest, finance, and build low-carbon infrastructure abroad given it is the largest manufacturer, exporter, and investor of renewable energy equipment and technologies. If global pressure to reach net-zero emissions by the mid-century intensifies, middle- and low-income countries will likely look to China to help finance, invest, and build energy infrastructure projects.

Energy projects have been a major focus of BRI. Since BRI's inception in 2013 to 2022, energy projects made up the largest share of total BRI investment and construction projects at about 40%, according to reporting from the Chinese-based Green Finance and Development Center (GFDC), which bases its data on the China Global Investment Tracker, a database from the American Enterprise Institute in addition to GFDC's own research.[81] In recent years, the data has shown a decline in new BRI projects, which many analysts have attributed to various reasons, spanning from quality issues with construction projects that are turning countries away, to Chinese companies losing interest in undertaking BRI projects. BRI projects, in terms of both monetary value and number of projects, have fallen from the peak during 2015 to 2018, for both energy and other projects; however, Chinese overseas non-financial direct investment (purchases of ownership stakes in non-financial companies) has actually increased in terms of value, according to Chinese data collected by the Council on Foreign Relations.[82] Furthermore, according to GFDC, in 2022 the monetary value of Chinese overseas investment deals under BRI exceeded the value of Chinese construction projects overseas. Chinese technology investments overseas experienced the largest growth by far compared with other sectors largely due to battery production investments by CATL—China's state-owned

80 Christoph Nedopil, *China Belt and Road Initiative (BRI) Investment Report 2022*, Green Finance & Development Center, FISF Fudan University, Shanghai (January 2023). https://greenfdc.org/wp-content/uploads/2023/02/Nedopil-2023_China-Belt-and-Road-Initiative-BRI-Investment-Report-2022.pdf. Accessed July 19, 2023.

81 Ibid., and American Enterprise Institute, "China Global Investment Tracker," AEI Database. https://www.aei.org/china-global-investment-tracker/. Accessed May 12, 2023.

82 Nadia Clark, "The Rise and Fall of the BRI," Council on Foreign Relations Blog Post (April 6, 2023). https://www.cfr.org/blog/rise-and-fall-bri. Accessed July 19, 2023.

battery manufacturer and global leader in lithium-ion batteries.[83] Chinese companies are also purchasing ownership stakes in renewable energy and mining companies overseas.

While fossil fuel projects represent most of BRI's energy engagements (investment and construction), solar and wind projects as a share of total BRI's energy engagements have increased—from an average of 6% from 2013 to 2015 to an average of 23% from 2020 to 2022. China's overseas investments in oil and gas are long known to be a part of its energy security strategy. China only produces a fraction of the oil and gas it consumes and is largely dependent on imports. China's oil and gas investments abroad largely represent a strategy to secure long-term volumes. On the contrary, investments in clean energy projects overseas are disconnected from Chinese energy security goals and are more similar to Chinese overseas coal investments. Just as China is among the top manufactures of coal fired-power plants, China is the largest producer of clean energy mineral inputs, equipment, and technologies. Before President Xi's 2021 announcement that China would stop building new coal power plants overseas, China was the world's largest public financier of overseas coal plants.[84] However, despite President Xi's announcement, new overseas coal power plant and mining projects were announced in 2022.[85]

The massive investments, financing, and construction needed worldwide to transform energy systems and power grids will likely create more opportunities for BRI. China is planning to host a third global BRI forum in 2023,[86] four years since the last forum in 2019, possibly to energize

83 Christoph Nedopil, *China Belt and Road Initiative (BRI) Investment Report 2022.*

84 Xinyue Ma and Kevin P. Gallagher, "Who Funds Overseas Coal Plants? The Need for Transparency and Accountability," BU Global Development Policy Center, GCI Policy Brief 008 (July 2021), https://www.bu.edu/gdp/files/2021/07/GCI_PB_008_FIN.pdf (accessed July 19, 2023); and David Stanway and Joe Brock, "China's overseas coal power retreat could wipe out $50 bln of investment," Reuters (September 22, 2021), https://www.reuters.com/business/energy/chinas-overseas-coal-power-retreat-could-wipe-out-50-bln-investment-2021-09-22/ (accessed July 19, 2023).

85 Christoph Nedopil, *China Belt and Road Initiative (BRI) Investment Report 2022*, Green Finance & Development Center, FISF Fudan University, Shanghai (January 2023), https://greenfdc.org/wp-content/uploads/2023/02/Nedopil-2023_China-Belt-and-Road-Initiative-BRI-Investment-Report-2022.pdf (accessed May 12, 2023); and American Enterprise Institute, "China Global Investment Tracker," AEI Database, https://www.aei.org/china-global-investment-tracker/ (accessed May 12, 2023).

86 Xue Gong, "The Belt and Road Initiative Is Still China's 'Gala' but Without as Much Luster," Carnegie Endowment for International Peace (March 3, 2023). https://carnegieendowment.org/2023/03/03/belt-and-road-initiative-is-still-china-s-gala-but-without-as-much-luster-pub-89207. Accessed July 19, 2023.

interest in BRI in the post-COVID world and mark BRI's 10th anniversary. According to GFDC, the removal of COVID-related travel restrictions that affected Chinese developers may lead to growth in BRI engagement.[87]

China's Economic Statecraft

Literature on Beijing's economic statecraft provides insights into how the energy transition and China's dominance of the current suite of commercial low-carbon energy technologies can support Beijing's economic statecraft. The energy transition will present more opportunities for BRI, and by extension support Beijing's economic statecraft. This could potentially support Beijing's soft power and international perceptions of China, path dependencies particularly in terms of technology, and lend Beijing credibility in its efforts to lead climate diplomacy within the Group of 77 (G-77) alliance, which is made up of developing countries. Ultimately, a boost in Beijing's economic statecraft could potentially lead to favorable foreign policy outcomes over the long-term as countries grow more dependent on Chinese companies for the critical energy systems. BRI[88] investments are largely directed by the state. BRI is a state operation—it is incorporated into the Chinese Communist Party (CPP) constitution, advertised by President Xi, and dominated by Chinese state-owned companies.[89] In March 2022, China's main policy body, the National Development and Reform Commission (NDRC), issued new guidance for BRI, announcing that the Chinese government will commit to green development overseas, deepen cooperation on clean energy, including solar, wind, advanced nuclear power, smart grids, and hydrogen energy, and encourage Chinese solar and wind

87 Ibid. and American Enterprise Institute, "China Global Investment Tracker," AEI Database. https://www.aei.org/china-global-investment-tracker/. Accessed May 12, 2023.

88 While the BRI project data used in the paper is specifically designated as BRI, differentiating between BRI and non-BRI projects can be challenging. Nonetheless, overseas investment, financing, and construction projects by state-owned Chinese companies, whether designated BRI or not, can serve the same purpose, and thus, the distinction is often trivial.

89 Thomas Hale, Chuyu Liu, and Johannes Urpelainen, *Belt and Road Decision-making in China and Recipient Countries: How and To What Extent Does Sustainability Matter?* ISEP & BSG Report (April 2020), https://sais-isep.org/wp-content/uploads/2020/04/ISEP-BSG-BRI-Report-.pdf (accessed July 19, 2023); and Gabriel Wagner, "Grand Narrative, Fragmented Reality: The Belt and Road Initiative in Heilongjiang Province," *Inquiries Journal* 13, no. 9 (2021), http://www.inquiriesjournal.com/a?id=1909 (accessed July 19, 2023).

companies to “go global.”[90]

What is economic statecraft?

Economic statecraft is a strategy used by wealthier countries to use economic power to influence foreign policy outcomes. There are different types of economic statecraft tools, which can be used to either influence other countries through coercion or influence through economic benefits and attraction. Robert Blackwill and Jennifer Harris identify seven tools of economic statecraft: trade policy, cross-border investments, sanctions, state-sponsored cyberattacks, economic aid, monetary policies like currency manipulation, and exercising control over commodity or energy flows.[91] Sanctions, cyberattacks, and control of commodity or energy flows are tools used negatively for coercion, while economic aid and investments are intended to influence behavior through attraction and tangible benefits. Pippa Morgan, in an article on Chinese soft power in Africa, notes that trade policies can be used either to coerce or attract, depending on if they are discriminatory or preferential.[92]

Priscilla Roberts describes Beijing’s economic statecraft as the use of economic resources and leverage to pursue political, economic, and strategic objectives.[93] Throughout the 21st century, China has used economic statecraft tools, mainly foreign aid, access to its domestic market, and trade policies, to mitigate Western sanctions and/or to influence positive perceptions of China in the developing world. China’s use of economic statecraft became more prominent in the 1990s and onwards as its economic growth began to soar. Roberts also notes that in the 1990s

90 National Development and Reform Commission, People’s Republic of China, “China to boost green development of Belt and Road,” press release (March 31, 2022). https://en.ndrc.gov.cn/news/pressreleases/202203/t20220331_1321483.html. Accessed July 19, 2023.

91 Robert Blackwell and Jennifer Harris, *War by Other Means: Geoeconomics and Statecraft* (Belknap Press, 2017); and Kalyanaraman, “War by Other Means: Geoeconomics and Statecraft by Robert D. Blackwill and Jennifer M. Harris,” *Strategic Analysis* 41, no. 6, pp591-594 (2017), https://doi.org/10.1080/09700161.2017.1377897 (accessed July 19, 2023).

92 Pippa Morgan, “Can China’s Economic Statecraft Win Soft Power in Africa? Unpacking Trade, Investment and Aid,” *Journal of Chinese Political Science* 24 (December 17, 2019), pp387–409. https://doi.org/10.1007/s11366-018-09592-w. Accessed July 19, 2023.

93 Priscilla Roberts, “Economic Statecraft with Chinese Characteristics: Strange, New, and Different, or Old Wine in New Bottles?” *Journal of Current Chinese Affairs* 50, no. 3) (November 2021), pp267–293. https://doi.org/10.1177/18681026211061750. Accessed July 19, 2023.

and early 2000s, China "amassed trillions of dollars in foreign currencies" and "its overtly expressed regional and global objectives became commensurately more ambitious."[94] During that period, China boosted its foreign aid and overseas investments in Africa, Asia, the Middle East, Latin America, and some European countries. According to Roberts, "China sought to position itself as the leader of the developing world, to assume an ever more prominent role in existing international organizations to which it belonged, and to establish new institutions and global infrastructure networks."[95]

In 1999, China launched the "going global" strategy to secure global resources for domestic consumption and to increase Chinese companies' business opportunities globally.[96] After his accession as the leader of the CPP, President Xi boosted "going global" efforts, mounting an even more assertive and ambitious form of economic statecraft through the creations of BRI and the Asian Infrastructure Investment Bank (AIIB) based in Beijing. AIIB was created by China in 2015 and was the first international, multilateral development bank based in Asia, independent of the World Bank and International Monetary Fund. The AIIB has over 100 members, including European countries like the UK, France, Germany, and Italy. China is by far AIIB's largest shareholder with the largest voting power.[97]

Zhang Xiaotong and James Keith describe China's economic statecraft under Xi as aspiring to transform its national wealth into power to influence new international rules, including in global finance and commerce, challenge the United States' leading role in multilateral institutions, and assert leadership on global commerce, trade, and investments.[98] The authors note that BRI, along with the Chinese-led AIIB and the Chinese-headquartered BRICS Development Bank, are means for China to convert wealth to power,

94 Ibid.

95 Ibid.

96 China Policy, *China Going Global between ambition and capacity* (April 2017), https://policycn.com/wp-content/uploads/2017/05/2017-Chinas-going-global-strategy.pdf (accessed July 19, 2023); and Tristan Kenderdine and Han Ling, "International Capacity Cooperation—Financing China's Export of Industrial Overcapacity," *Global Policy* 9, no. 1 (October 20, 2017), https://doi.org/10.1111/1758-5899.12509 (accessed July 19, 2023).

97 Martin A. Weiss, "Asian Infrastructure Investment Bank," Congressional Research Service Report (May 4, 2023). https://crsreports.congress.gov/product/pdf/IF/IF10154. Accessed July 19, 2023.

98 Zhang Xiaotong and James Keith, "From Wealth to Power: China's New Economic Statecraft," *The Washington Quarterly* 40, no. 1 (April 2017), pp185-203. https://doi.org/10.1080/0163660X.2017.1302746. Accessed July 19, 2023.

engage in economic diplomacy, and gain influence. Karl Yan also describes BRI as a form of economic statecraft, and President Xi and other state leaders' role as "global salesmen" who establish bilateral agreements, such as memorandum of understandings, with other state leaders to help facilitate business opportunities for Chinese companies abroad.[99] Xiaotong and Keith assert that Beijing's economic statecraft is a strategy used to challenge U.S. hegemony and influence, especially in Asia.[100]

Vida Macikenaite points out "the growth of China's economic capabilities" led to a dramatic rise in Chinese official foreign aid and outbound foreign direct investment (FDI) starting in the early 2000s, which has increased interdependence between China and other countries while also tilting "the power asymmetries in favor of China in most of its interactions with other states."[101] Macikenaite highlights instances of Beijing's use of economic statecraft to exert influence—such as the creation of AIIB, the spread of BRI, and China's increased use of unilateral sanctions since 2010—and concludes "China is likely to be increasingly able to translate its economic power into actual influence."[102]

Based on the descriptions of Chinese economic statecraft above, this paper assesses that China's global dominance of critical minerals and clean energy technologies likely bolsters Beijing's economic statecraft through three channels: (1) improving the image and attractiveness of Chinese overseas investments, (2) creating multi-decadal dependencies via Chinese acquisitions of assets, and (3) expanding and strengthening Beijing's economic statecraft tools.

Public Image of Chinese Investments

China's public announcements to increase energy and infrastructure investments abroad that support global climate and Paris Agreement goals likely increases the attractiveness of Chinese investments. Likewise,

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99 Karl Yan, "The Railroad Economic Belt: Grand strategy, economic statecraft, and a new type of international relations," *The British Journal of Politics and International Relations* 23, no. 2 (2021), pp262–279. https://doi.org/10.1177/1369148120940938. Accessed July 19, 2023.

100 Zhang Xiaotong and James Keith, "From Wealth to Power: China's New Economic Statecraft."

101 Vida Macikenaite, "China's economic statecraft: the use of economic power in an interdependent world," *Journal of Contemporary East Asia Studies* 9, no. 2, (November 2020), pp108-126. https://doi.org/10.1080/24761028.2020.1848381. Accessed July 19, 2023.

102 Ibid.

China's dominance of clean energy supply chains, relatively low-cost products, and financing options help to counter and possibly outweigh general wariness toward Chinese investment—as the energy transition requires high upfront capital costs. The growth of "green" projects in BRI's portfolio could improve the attractiveness of China as an economic partner for countries looking to meet their climate goals under the Paris Agreement.

In recent years, Beijing has struggled to build positive perceptions internationally, likely a reflection of the mixed results of Chinese economic statecraft. Analysts have criticized China as "a rogue donor that is propping up pariah states, gobbling up African land, resettling Chinese laborers across the continent," as placing debt burdens on least developing countries, interfering with global efforts to promote good governance, and exacerbating environmental and social problems.[103] Some European countries have become wary of Chinese investments after Chinese state-owned companies purchased large shareholdings in European companies.[104]

Global public opinion polling on China has generated mixed results. In 2019, a poll conducted in 34 countries by the Pew Research Center showed general opinions on China were split. A median of 41% of people surveyed across the 34 countries had an unfavorable view of China and 40% had a favorable view.[105] On the contrary, in a different question focused on economic benefits, survey results showed that most people viewed China's growing economy as beneficial to their own country. A median of 55% of people surveyed across 18 countries, including the United States, viewed China's economic growth as mutually beneficial, especially in Africa, Latin America, and the Middle East, while a median of 30% viewed it as negative, largely in India.

In a 2019 Pew Research Center survey asking 16 countries across Asia, the Middle East, Africa, and Latin America if Chinese investment was good

103 Xue Gong, "A Critique of China's Economic Statecraft: Challenges ahead in Myanmar," Nanyang Technological University, Singapore (2016), https://www.semanticscholar.org/paper/A-Critique-of-China%E2%80%99s-Economic-Statecraft%3A-ahead-in-Gong/bb90f092665ae8e6944983b198756e49e08a0c29 (accessed July 19, 2023); and Hisham Aidi, "China's Economic Statecraft in Africa," Policy Center for the New South, Policy Brief (August 6, 2018), https://www.policycenter.ma/publications/china%E2%80%99s-economic-statecraft-africa (accessed July 19, 2023).

104 Frank Mouritz and Adéla Šelepová, *China's Economic Statecraft in Europe*, George C. Marshall European Center for Security Studies (2020). https://www.marshallcenter.org/sites/default/files/files/2020-10/pC_V10N3_en-2_Mouritz.pdf. Accessed July 19, 2023.

105 Laura Silver, Kat Devlin, and Christine Huang, "Attitudes toward China," Pew Research Center (December 5, 2019). https://www.pewresearch.org/global/2019/12/05/attitudes-toward-china-2019/. Accessed July 19, 2023.

because it created jobs or bad because it gave China influence, the results largely were dependent on the region. Asian countries were more suspicious of Chinese investment, while the Middle East, Africa, and Latin America had more positive response, with 50% or more people viewing Chinese investment favorably.[106] The response was similar to survey results from Afrobarometer, given in 2019-2020 across 18 African countries, showing 59% of respondents perceived China's economic and political influence in Africa as somewhat positive or very positive, while only 15% perceived it as negative.[107]

Beijing's ability and eagerness to help finance overseas clean energy infrastructure projects via BRI, coupled with its cost-competitive manufacturing equipment and technologies, could improve its image and the attractiveness of Chinese investments in developing countries seeking to both increase access to electricity and make progress toward climate goals. Beijing's rebranding of BRI as a conduit to assist countries to achieve their climate goals through clean energy likely helps to revive its economic statecraft efforts through this channel and build a defense against critics.

Creating Multi-Decadal Ties & Dependencies

There is consensus among experts that BRI is a key tool of economic statecraft for Beijing, and as stated earlier, energy sector projects are the largest sector for BRI projects worldwide. The energy and mining sectors have been the first and second largest areas of BRI investments since 2013 to 2022 on average, respectively, not including construction projects.[108] In 2022, however, technology investments edged out the mining sector for the second spot largely due to overseas battery manufacturing investments made by China's CATL. In other words, Chinese companies are more likely to invest and acquire ownership stakes in overseas projects and companies in the energy, mining, and technology sectors compared with other sectors like

106 A more recent survey from the Pew Research Center released in June 2022 shows unfavorable views about China have grown in the United States and some European countries since 2019. However, the poll does not include Africa, the Middle East, and Latin America; therefore, this paper uses the 2019 polling results.

107 Josephine Appiah-Nyamekye Sanny and Edem Selormey, "Africans regard China's influence as significant and positive, but slipping," Afrobarometer Dispatch 407 (November 17, 2020). https://www.afrobarometer.org/wp-content/uploads/2022/02/ad407-chinas_perceived_influence_in_africa_decreases-afrobarometer_dispatch-14nov20.pdf. Accessed July 19, 2023.

108 Christoph Nedopil, *China Belt and Road Initiative (BRI) Investment Report 2022*.

transportation, health, agriculture, and chemicals where Chinese companies are more likely to engage in construction.[109]

Over the past decade, Chinese state-owned companies—State Grid Corporation of China (known as State Grid), China Southern Power Grid, and China Three Gorges Corporation—have acquired ownership stakes in electrical grid companies in Brazil, Peru, Chile, Australia, Philippines, Greece, Italy, Portugal, and Oman (Figure 9). State Grid is one of the world's largest utility companies. These Chinese state-owned companies are also constructing massive electrical infrastructure projects in these countries and in others across the world. China's partial ownership of sensitive, critical infrastructure, and superior expertise on electrical equipment and maintenance relative to locals, likely cements China's longevity in these countries. In Brazil and Pakistan, where China has built UHV transmission lines, it's unlikely that maintenance and operations can be conducted absent Chinese presence. China is the world's top builder of UHV transmission lines, which are key to bringing abundant renewable energy sources from remote areas to demand centers.

109 Ibid.

Figure 9. China's State-Owned Companies' Acquisitions of Overseas Electric Companies

Country	Company	Acquired Year	Ownership Share[2]	Chinese Acquirer	Significance
Australia	ElectraNet	2012	46.56%	China State Grid	Australian transmission company
	SPI Australia Assets (Jemena)	2013	60%	China State Grid	Australian electricity and gas distribution assets
Brazil	CPFL Energia SA	2017	83.7%	China State Grid	Brazil's largest power distributor
	CEEE-T	2021	66%	China State Grid	Electric power transmission company of Rio Grande do Sul State
Chile	Transelec	2018	27.79%	China Southern Power Grid	Chile's largest electric transmission system
	Chilquinta Energía S.A. and Tecnored S.A.	2020	100%	China State Grid	Chile's third largest power distribution company
	CGE	2021	96%	China State Grid	Chile's largest distribution and second-largest transmission network
Greece	ADMIE	2017	24%	China State Grid	Greece's power grid operator
Italy	CDP RETI	2014	35%	China State Grid	Energy grid holding company
Laos	Électricité du Laos Transmission Company	2021	Majority share	China Southern Power Grid	Manages Laos' power grid under 25-year agreement
Luxembourg	Encevo Group	2018	24.92%	China Southern Power Grid	Provides energy supply, grid operations, and related services to Luxembourg, Germany, France, Belgium and the Netherlands
Oman	Oman Electricity Holding Company	2020	49%	China State Grid	Held a 95% market share in Oman's power sector (as of 2017)
Peru	Luz del Sur	2020	83.6%	China Yangtze Power	Largest electric company in Peru
	Enel Distribucion Peru (EDP)	TBD[1]	83.15%	China Southern Power Grid	Power distribution and supply company
	Enel X Peru	TBD[1]	100%	China Southern Power Grid	Advanced energy services provider
Philippines	National Grid Corporation	2009	40%	China State Grid	Owner of Philippines' national grid
Portugal	EDP	2011	21.08%	China Three Gorges	Portugal's main utility
	Redes Energeticas Nacionais (REN)	2012	25%	China State Grid	Portugal's national power grid

Source: Company websites and multiple news articles
Note: [1]The agreement was made in 2023, but it has not been finalized. [2]The ownership share reflects the current ownership share, and in some cases is different from the original share acquired.

China's state-owned companies' acquisition of ownership shares in overseas electricity companies aligns with Beijing's greater ambitions under its Global Energy Interconnection (GEI) Initiative. President Xi first announced plans to establish a global grid at the 2015 UN Sustainable Development Summit. Shortly after, GEI was created. GEI's objective is to build global and regional grid connections across continents to expand the balancing area to integrate massive amounts of renewable energy, increase electrification, and progress decarbonization goals. GEI is run by the Global Energy Interconnection Development and Cooperation Organization (GEIDCO) and implemented by State Grid. GEIDCO is promoting GEI as a global emissions reduction plan to achieve climate goals under the Paris Agreement.[110] GEI has support from the United Nations Framework Convention on Climate Change (UNFCCC), the UN 2030 Agenda for Sustainable Development, the Clean Energy Ministerial, the African Union, and the Gulf Cooperation Council (GCC). UN Secretary General António Guterres has also publicly praised GEI.[111] While progress on GEI has been slow, GEIDCO is actively meeting with various governments and hosted a seminar at COP27 in November 2022 in Egypt.[112] State Grid's partial acquisition of overseas electricity companies over time may be a part of its strategy to slowly progress GEI, as being a partial owner of a company makes it easier to influence decisionmaking on future projects.

Chinese companies are also purchasing ownership stakes in renewable energy companies globally. Most noteworthy, in 2020, China's Silk Road Fund (SRF), a financing arm of BRI in which Export-Import Bank of China and the Chinese Development Bank are shareholders,[113] acquired a 49%

110 Global Energy Interconnection Development and Cooperation Organization, "Global Energy Interconnection: An Innovative Global Solution for Implementing Paris Agreement," presented to United Nations Framework Convention on Climate Change (November 24, 2018), https://unfccc.int/news/global-energy-interconnection-is-crucial-for-paris-goals (accessed July 19, 2023) and https://unfccc.int/sites/default/files/resource/121_Global%20Energy%20Interconnection%20An%20Innovative%20Global%20Solution%20for%20Implementing%20Paris%20Agreement_GEIDCO_RCSD.pdf (accessed July 19, 2023).

111 Edmund Downie, *Powering the Globe: Lessons From Southeast Asia for China's Global Energy Interconnection Initiative*, Columbia's Center on Global Energy Policy (April 2020). https://www.energypolicy.columbia.edu/wp-content/uploads/2020/04/GEI_CGEP-Report_111722.pdf. Accessed July 19, 2023.

112 Global Energy Interconnection Development and Cooperation Organization, "GEIDCO Chief Cooperation Officer Held Talks with Eskom Acting Group CEO," press release (May 12, 2023). https://m.geidco.org.cn/category/19?lang=en. Accessed July 19, 2023.

113 International Energy Agency, *Chinese Companies Energy Activities in Emerging Asia.*

stake in Saudi Arabia's ACWA Power Renewable Energy Holding, giving SRF ownership stake in power generation and desalination assets in Saudi Arabia and other countries in the Middle East and North Africa (MENA).[114] In 2021, China Three Gorges South Asia Investment, a subsidiary of China Three Gorges, acquired 100% of Dubai-based Alcazar Energy Partners, giving China ownership of multiple solar and wind project assets in Egypt and Jordan.[115] Acquiring ownership in some of the largest renewable energy companies in the MENA region will likely give Chinese companies advantage in developing and operating additional renewable assets in the region. In late 2020, China's State Power Investment Corp (SPIC) acquired 100% of Mexico's largest independent renewable power company, Zuma Energia.[116]

China also has partial ownership of some of the largest lithium mines in Australia, Chile, and Argentina, cobalt mines in the DRC, and nickel mines in Indonesia. Through a joint venture, China's Tianqi Lithium partially owns the Greenbushes lithium mine, the world's largest lithium mine reserve located in Australia.[117] Chinese miners have successfully made inroads into South America's Lithium Triangle—spanning Chile, Argentina, and Bolivia—which contains nearly 60% of the world's lithium resources.[118] China's Tianqi Lithium is the second-largest shareholder in Sociedad Química y Minera (SQM), the largest lithium mining company in Chile and as of 2019, the

114 Robert Mogielnicki, "China Strengthens its Presence in Gulf Renewable Energy," The Arab Gulf States Institute in Washington (June 10, 2020). https://agsiw.org/china-strengthens-its-presence-in-gulf-renewable-energy/. Accessed July 19, 2023.

115 Sean Rai-Roche, "China Three Gorges acquires projects totaling 411MW from Alcazar Energy," PV Tech (August 23, 2021). https://www.pv-tech.org/china-three-gorges-acquires-projects-totalling-411mw-from-alcazar-energy/. Accessed July 19, 2023.

116 Muyu Xu and Florence Tan, "China's SPIC buys Mexican renewable power firm Zuma Energia," Reuters (November 19, 2020), https://www.nasdaq.com/articles/chinas-spic-buys-mexican-renewable-power-firm-zuma-energia-2020-11-19-0 (accessed July 19, 2023); and Justin Villamil, "China Power Giant Makes Foray Into Mexican Renewables With Zuma," Bloomberg (November 19, 2020), https://www.bloomberg.com/news/articles/2020-11-19/china-power-giant-makes-foray-into-mexican-renewables-with-zuma#xj4y7vzkg (accessed July 19, 2023).

117 Tom Daly, "China's Tianqi Lithium inches nearer to Australian stake sale close," Reuters (June 21, 2021), https://www.reuters.com/business/energy/chinas-tianqi-lithium-inches-nearer-australian-stake-sale-close-2021-06-21/ (accessed July 19, 2023); and Ernest Scheyder, "Albemarle expresses interest in Tianqi's stake in Greenbushes lithium mine," Reuters (May 7, 2020), https://www.reuters.com/article/us-albemarle-tianqi-lithium/albemarle-expresses-interest-in-tianqis-stake-in-greenbushes-lithium-mine-idUSKBN22J2AV (accessed July 19, 2023).

118 Elizabeth Gonzalez, "Explainer: Latin America's Lithium Triangle," Americas Society/Council of the Americas (February 17, 2021). https://www.as-coa.org/articles/explainer-latin-americas-lithium-triangle. Accessed July 19, 2023.

fourth largest in the world.[119] China's Ganfeng Lithium, the world's largest lithium miner as of 2019,[120] is a majority stakeholder of one of Argentina's largest lithium mine operations under construction, the Caucharí-Olaroz lithium carbonate brine operation.[121] Furthermore, Ganfeng announced in 2022 it would acquire Lithea Inc, which owns two lithium salt lakes in Argentina.[122]

In Bolivia, the state-owned lithium company Yacimientos de Litio Bolivianos (YLB) announced in 2019 that it selected Xinjiang TBEA Group Co Ltd., a Chinese consortium, to hold a 49% stake in a joint venture to develop lithium mines.[123] Although Bolivia is a large lithium resource holder, it does not produce commercial quantities of lithium.[124] That may change in the next five to 10 years, however, as Bolivia's YLB signed a $1 billion agreement with three Chinese companies in January 2023 to start exploring lithium deposits.[125] A Chinese company and Russia's Uranium One Group, owned by Russia's state-owned nuclear corporation Rosatom, are also partnering with YLB to build lithium processing plants in Bolivia.[126] In the DRC, Chinese companies owned eight of the 14 largest cobalt miners,

119 John Xie, "How China Dominates Global Battery Supply Chain," Voice of America (September 1, 2020), https://www.voanews.com/a/silicon-valley-technology_how-china-dominates-global-battery-supply-chain/6195257.html (accessed July 19, 2023); and James Murray, "Profiling the top five largest lithium mining companies in the world," NS Energy (February 18, 2021), https://www.nsenergybusiness.com/features/largest-lithium-mining-companies/# (accessed July 19, 2023).

120 Ibid.

121 Lithium Americas, "Corporate Presentation" (May 2023). https://www.lithiumamericas.com/_resources/presentations/corporate-presentation.pdf. Accessed July 19, 2023.

122 Dominique Patton, "China's Ganfeng Lithium to buy Lithea Inc for $962 million," Reuters (July 11, 2022). https://www.reuters.com/markets/deals/chinas-ganfeng-lithium-buy-lithea-inc-962-mln-2022-07-11/. Accessed July 19, 2023.

123 Daniel Ramos, "Bolivia picks Chinese partner for $2.3 billion lithium projects," Reuters (February 6, 2019). https://www.reuters.com/article/us-bolivia-lithium-china/bolivia-picks-chinese-partner-for-2-3-billion-lithium-projects-idUSKCN1PV2F7. Accessed July 19, 2023.

124 Ibid.

125 Joseph Bouchard, "In Bolivia, China Signs Deal For World's Largest Lithium Reserves," *The Diplomat* (February 10, 2023). https://thediplomat.com/2023/02/in-bolivia-china-signs-deal-for-worlds-largest-lithium-reserves/. Accessed July 19, 2023.

126 Mining Technology, "Bolivia's YLB signs lithium agreements with Russian and Chinese companies" (June 30, 2023). https://www.mining-technology.com/news/ylb-lithium-russian-chinese/. Accessed July 19, 2023.

according to a 2019 OECD report.[127] China's overseas investments in energy transition minerals are likely akin to China's traditional overseas oil and gas investments—China needs these raw materials and energy sources to supplement its domestic supply and secure long-term supply sources.

Strengthening China's Statecraft Toolkit

China's dominance of clean energy technology supply chains likely strengthens China's economic statecraft toolkit. As mentioned above, Blackwill and Harris identified seven tools of economic statecraft: trade policy, cross-border investments, sanctions, state-sponsored cyberattacks, economic aid, monetary policies like currency manipulation, and exercising control over commodity or energy flows. For China, five of the seven economic statecraft tools will likely benefit the most.

Cross-border investments: As explained in the previous section on BRI, demand among BRI countries for renewable energy is set to grow, presenting opportunities for Chinese state companies. As of 2019, a think tank estimated that total investment in wind and solar power could reach $644 billion from 2020-2030 in BRI countries, based on their renewable energy and climate targets.[128] BRI likely does not seek to force unwanted investments on recipient countries, but rather find mutually beneficial opportunities, furthering Chinese business opportunities while addressing customer demands.[129] China's past overseas investments in coal-fired power plants and hydropower reflected growing demand from recipient countries, particularly growing demand for coal power in South and Southeast Asia and for hydropower in South America and sub-Saharan Africa. Likewise, BRI's switch to focusing on "green" investments by President Xi is also partly driven by growing demand worldwide for solar and wind, underpinned by

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127 Luca Maiotti and Benjamin Katz, *Interconnected supply chains: a comprehensive look at due diligence challenges and opportunities sourcing cobalt and copper from the Democratic Republic of the Congo*, The OECD Secretariat (2019). https://mneguidelines.oecd.org/Interconnected-supply-chains-a-comprehensive-look-at-due-diligence-challenges-and-opportunities-sourcing-cobalt-and-copper-from-the-DRC.pdf. Accessed July 19, 2023.

128 Han Chen, Jessica Norris, Lily Hartzell, and Feng Xiaochang, "Greener Power Projects for the Belt & Road Initiative (BRI)," Natural Resources Defense Council (April 22, 2019). https://www.nrdc.org/experts/han-chen/greener-power-projects-belt-road-initiative-bri. Accessed July 19, 2023.

129 International Energy Agency, *Chinese Companies Energy Activities in Emerging Asia;* Bo Kong and Kevin Gallagher, "Chinese development finance for solar and wind power abroad," Boston University's Global Development Policy Center, GCI Working Paper 009 (January 2020), https://www.bu.edu/gdp/files/2020/02/WP9-Kong-Bo-inc_abstract.pdf (accessed July 19, 2023).

climate commitments. Recipient countries likely turn to China because of financing options and lower cost Chinese-made solar and wind equipment, which China has been able to achieve because of its expansion of renewable energy domestically, reducing equipment and technology costs via economies-of-scale manufacturing.

Trade Policy: According to China's Ministry of Commerce, China participates in more than a dozen free trade agreements (FTAs), most of which are bilateral FTAs and two multilateral FTAs—the China-Association of Southeast Asian Nations (ASEAN) FTA and the recently signed Regional Comprehensive Economic Partnership (RCEP).[130] RCEP, the largest FTA in history, was signed in November 2020 by five regional partners (China, Japan, South Korea, Australia, and New Zealand) and members of ASEAN. RCEP represents the first FTA between China and Japan. Metals are among the top five categories of Chinese exports to Japan and South Korea and are included in the schedules of China and Japan as a category that both will gradually reduce tariffs over the next 20 years, in alignment with the RCEP timeline.[131]

Experts believe that the ratification of RCEP could potentially lead to progress on the trilateral China-Japan-South Korea FTA negotiations, which have been ongoing since 1999, thereby further integrating the East Asian economies.[132] China is also negotiating FTAs with the Gulf Cooperation Council, Norway,[133] South Korea (second phase of FTA), and Israel,[134] among others.[135] In September 2021, China applied to join the

130 Ministry of Commerce People's Republic of China, "China FTA Network," http://fta.mofcom.gov.cn/english/fta_qianshu.shtml. Accessed June 1, 2023.

131 Zoey Zhang, "Developing Your China Trade with Japan and South Korea Under RCEP," China Briefing (June 28, 2021). https://www.china-briefing.com/news/developing-your-china-trade-with-japan-and-south-korea-under-rcep/. Accessed July 19, 2023.

132 Peter A. Petri and Michael Plummer, "RCEP: A new trade agreement that will shape global economics and politics," Brookings (November 16, 2020). https://www.brookings.edu/blog/order-from-chaos/2020/11/16/rcep-a-new-trade-agreement-that-will-shape-global-economics-and-politics/. Accessed July 19, 2023.

133 U.S. Department of Commerce, "Norway Country Commercial Guide," Trade Agreements (September 9, 2022). https://www.trade.gov/country-commercial-guides/norway-trade-agreements. Accessed July 19, 2023.

134 Ralph Jennings, "China, Israel free-trade deal, Beijing's first in Middle East, in 'last stages' amid troubles with US," *South China Morning Post* (September 8, 2022). https://www.scmp.com/economy/china-economy/article/3191828/china-israel-free-trade-deal-beijings-first-middle-east-last. Accessed July 19, 2023.

135 Ministry of Commerce People's Republic of China, "China FTA Network," http://fta.mofcom.gov.cn/english/fta_qianshu.shtml. Accessed June 1, 2023.

Comprehensive and Progressive Agreement for Trans-Pacific Partnership (CPTPP)—a free trade agreement ratified by 11 countries in the Americas and Asia-Pacific representing 13% of global GDP. The United States is not included. The requirements to join CPTPP are more cumbersome than RCEP, requiring economic reforms such as increasing transparency of state-owned enterprises, and implementing changes to subsidies, labor and environmental standards, intellectual property protections, digital trade practices, and the Chinese requirement that most foreign investors have domestic partners.[136] Therefore, China's ability to meet CPTPP's requirements by implementing sensitive reforms are in question.

China's long-term economic integration with others through bilateral and multilateral FTAs bodes well for Beijing's strategic influence, as countries become more dependent on Chinese goods and are given access to the world's second-largest economy to sell goods. China's rising leadership in innovating and manufacturing new technologies,[137] including clean energy technologies, might give Beijing leverage and influence when negotiating an FTA or applying to enter an existing trade agreement, like CPTPP. Some experts fear China may use its economic power and leverage to pressure or persuade CPTPP members to allow exceptions and lower its entrance requirements, though that would require an agreement among all existing members.[138]

Control over Energy "Flows": China's dominance of critical mineral production, processing, and exports gives it the power to exercise control over the trade of key clean energy inputs. Blackwill and Harris assessed a country was better endowed structurally to effectively execute economic statecraft if it was a large consumer or producer having the ability to direct or control commodities such as energy flows. China's rise as a large exporter of cost competitive renewable equipment and technologies and critical mineral inputs present Beijing with a new role as prominent producer

136 Carla Freeman, "How Will China's Bid to Join a Trans-Pacific Trade Pact Affect Regional Stability?" United States Institute of Peace (October 7, 2021). https://www.usip.org/publications/2021/10/how-will-chinas-bid-join-trans-pacific-trade-pact-affect-regional-stability. Accessed July 19, 2023.

137 Rob Garver, "Experts Warn US Is Falling Behind China in Key Technologies," Voice of America (September 17, 2022). https://www.voanews.com/amp/experts-warn-us-is-falling-behind-china-in-key-technologies/6751392.html. Accessed July 19, 2023.

138 Jeffrey J. Schott, "Which countries are in the CPTPP and RCEP trade agreements and which want in?" Peterson Institute for International Economics (April 3, 2023). https://www.piie.com/research/piie-charts/which-countries-are-cptpp-and-rcep-trade-agreements-and-which-want. Accessed July 19, 2023.

and exporter in global energy markets, increasing the degree of economic statecraft it can yield.[139]

A 2018 report from the European Parliament (EP) examining the use of energy resources as a foreign policy tool by authoritarian nations assessed energy can be used either as a defensive or offensive tool of foreign policy.[140] The EP paper explains that a more commonly used defensive strategy is to cultivate commercial and political relationships with neighbors and/or important global actors, opening the door for an energy-rich country to exert political influence and/or making it challenging for the international community to exert pressure on it. The 2018 report focuses mostly on Russia and determines,

> Russia has similarly developed deep economic and political relations with key consuming countries, particularly in Europe. This has prevented European states from supporting stringent sanctions aimed at Russia's energy sector following Russia's annexation of Crimea and its intervention in Eastern Ukraine.

The EP report notes "an effective defensive policy, or the perception of one, may also embolden the authoritarian state in question to be more assertive in its foreign policy. This increased willingness to take risk, either diplomatically or militarily, can then precipitate instability of conflict." Applying the 2018 EP assessment to current events, one could assess Russia's massive energy resources and growing export markets beyond Europe contributed to the Kremlin's risk calculus of invading Ukraine in February 2022, and in terms of anticipating limited pressure from parts of the international community.

In terms of energy resources being used as an offensive tool—"to punish or coerce"—the authors of the EP report note that this is less common

139 Robert Blackwell and Jennifer Harris, *War by Other Means: Geoeconomics and Statecraft* (Cambridge, MA: Belknap Press, 2017); and S. Kalyanaraman, "War by Other Means: Geoeconomics and Statecraft by Robert D. Blackwill and Jennifer M. Harris," *Strategic Analysis* 41, no. 6 (2017), pp591-594, https://doi.org/10.1080/09700161.2017.1377897 (accessed July 19, 2023).

140 Fernando Garces De Los Fayos and Krzysztof Bartczak, *Energy as a tool of foreign policy of authoritarian states, in particular Russia*, European Parliament (April 2018). https://www.europarl.europa.eu/RegData/etudes/STUD/2018/603868/EXPO_STU(2018)603868_EN.pdf. Accessed July 19, 2023.

but most prevalent with Russia.[141] Russia has used its energy resources to punish or pressure countries that have sought or demonstrated an openness for closer ties to the EU and NATO, and also to deter or persuade countries from taking actions against Russian aggression, sometimes through carrots such as energy price discounts. The 2018 EP study highlighted more than 20 examples since 1993 of Russia using its energy resources to exert political power, such as curtailing gas supplies, raising gas prices for buyers, and building pipelines to bypass traditional transit countries. Often, Russia cites technical, economic, or financial reasons for the curtailment, such as payment disputes or infrastructure maintenance. Even after Russia's invasion of Ukraine, Russia gave technical and commercial excuses to conceal its weaponization of energy resources. For example, in mid-2022, when Russia curtailed gas flows from the Nord Stream 1 gas pipeline to Europe, Gazprom claimed it was due to ongoing technical issues with gas turbines.

Applying the EP framework of defensive versus offensive tools, China's control of key clean energy inputs and dominance of cost-competitive manufacturing are likely currently in China's defensive toolkit—widening the door for China to attract more support globally for BRI and to cultivate commercial and political relationships that could make it difficult to rally the international community to apply pressure. One example of this are recent unilateral U.S. actions taken against the Chinese company Hoshine Silicon Industry Co. Ltd., located in Xinjiang. In June 2021, the United States ordered the U.S. Customs and Border Protection to detain solar shipments containing metallurgical-grade silicon (MGS) supplied by Chinese company Hoshine Silicon Industry Co. Ltd. and its subsidiaries, "based on information reasonably indicating that Hoshine used forced labor to manufacture silica-based products," according to the White House.[142] MGS is used to make polysilicon, a key input for solar modules. Companies purchasing MGS from Hoshine and its subsidiaries, including those outside

141 Ibid.

142 The White House, "FACT SHEET: New U.S. Government Actions on Forced Labor in Xinjiang," Statements & Releases (June 24, 2021). https://www.whitehouse.gov/briefing-room/statements-releases/2021/06/24/fact-sheet-new-u-s-government-actions-on-forced-labor-in-xinjiang/. Accessed July 19, 2023.

of China, accounted for around 90% of the polysilicon global market in 2020.[143]

Screening solar modules imported into the United States for traces of MGS connected to Hoshine resulted in a significant slowdown of solar installations in the United States. A survey of the U.S. solar industry in 2022 found that 318 utility-scale solar projects were being delayed or cancelled in the United States.[144] However, the U.S. has since provided clearer guidance to U.S. customs, resulting in an increase in solar imports in early 2023.[145]

Despite recognition among G7 countries that Hoshine was using forced labor in Xinjiang, the United States was the only country to impose an import ban. Following Russia's invasion of Ukraine and subsequent gas disruptions, Europe ramped up solar module imports from Asia, including those likely containing MGS from Hoshine, in order to reduce their future reliance on Russian energy in a manner consistent with climate goals. EU lawmakers announced in September 2022 a general proposal to ban imports made with forced labor from any country, but as of June 2023, it is still unclear when it will be enacted.[146] The lack of participation from Western counterparts underscores that China's control of energy "flows" via supply chains and cost-competitive manufacturing of clean energy components gives it a defensive foreign policy tool. Despite evidence of forced labor and human rights abuses, China's new role as an energy supplier can somewhat shield it from international condemnation.

Many are wondering to what extent China would use its dominance of clean energy supply chains offensively to punish or coerce in a peace, crisis, or wartime scenario. As mentioned earlier in the paper, in July 2023, China's

143 Johannes Bernreuter, "What the U.S. ban on Hoshine Silicon means for the PV industry," Bernreuter Research (June 25, 2021). https://www.bernreuter.com/newsroom/polysilicon-news/article/what-the-u-s-ban-on-hoshine-silicon-means-for-the-pv-industry/. Accessed July 19, 2023.

144 Solar Energy Industries Association, "Tariff Case Cuts Solar Deployment Forecasts Nearly in Half, 100,000 Jobs at Risk," SEIA press release (April 27, 2022). https://www.seia.org/news/tariff-case-cuts-solar-deployment-forecasts-nearly-half-100000-jobs-risk. Accessed July 19, 2023.

145 Nichola Groom and Richard Valdmanis, "Exclusive: U.S. solar panel imports from China grow, alleviating gridlock, officials say," Reuters (March 6, 2023). https://www.reuters.com/business/energy/us-solar-panel-imports-china-grow-alleviating-gridlock-officials-say-2023-03-06/. Accessed July 19, 2023.

146 Camilla Naschert, "Solar imports set for scrutiny as EU takes aim at human rights in supply chains," S&P Global (February 22, 2022). https://www.spglobal.com/marketintelligence/en/news-insights/latest-news-headlines/solar-imports-set-for-scrutiny-as-eu-takes-aim-at-human-rights-in-supply-chains-68810066. Accessed July 19, 2023.

Ministry of Commerce announced export restrictions on two minerals, gallium and germanium, for national security purposes, likely in retaliation of the West restricting China's access to some semiconductor equipment. In 2010, when China curtailed REE exports to Japan, many analysts believed this was an example of China using its control of resources to punish Japan for arresting a Chinese fisherman in disputed waters. However, it ultimately resulted in Japan investing in REE mining overseas and reducing its reliance on REE imports from China from 85% in 2009 to 58% in 2018.[147] Thus, when an energy supplier uses its resources as an offensive tool, it risks being pegged as an unreliable supplier and customers diversifying supply sources over time. To try and mitigate this, energy suppliers will often attempt to use commercial or technical justifications for the curtailment to conceal strategic intentions.

State-sponsored cyberattacks: China's ambitions under the GEI initiative and China's acquisition of ownership stakes in national grid companies worldwide have prompted concerns about cybersecurity. These ventures likely give Chinese actors access to critical supervisory control and data acquisition (SCADA) systems—used to monitor substations, transformers, and other electrical assets—where Chinese companies typically use Huawei technology.[148] Experts believe State Grid, the Chinese-stated owned company implementing GEI, has direct ties to China's military and intelligence services, which makes its international ventures problematic. In 2019, the Philippine's National Transmission Corporation (TransCo) warned it believed China could remotely shut down its power transmission grid; State Grid has owned a 40% stake in the Philippines' National Grid Corporation since 2009.

This paper lacks evidence to assert China will use Chinese-built grid infrastructure as a means to conduct cyberattacks in the future. However, China's access and/or partial control of sensitive electrical infrastructure, and the looming uncertainty of China's ability to disrupt a country's

147 Tobias Gehrke and Mart Smekens, "Preventing the Critical Minerals Crisis," Egmont Royal Institute for International Relations, Egmont Policy Brief 277 (May 2022). https://www.egmontinstitute.be/content/uploads/2022/05/TobiasGehrke_MartSmekens_PolicyBrief277.pdf?type=pdf. Accessed July 19, 2023.

148 James Griffiths, "China can shut off the Philippines' power grid at any time, leaked report warns," CNN (November 26, 2019), https://www.cnn.com/2019/11/25/asia/philippines-china-power-grid-intl-hnk/index.html (accessed July 19, 2023); and Karen Lema, "Philippines steps up security to shield power grid from foreign control," Reuters (February 3, 2020), https://www.reuters.com/article/philippines-china-power/philippines-steps-up-security-to-shield-power-grid-from-foreign-control-idUSL4N2A333F (accessed July 19, 2023).

electricity flows, provides China with opportunities for reconnaissance, along with leverage in times of peace, crisis, and conflict.

Sanctions: In recent years, China has turned more to using economic coercion tools, such as unilateral sanctions and trade restrictions, to pressure or punish countries, and China's dominance of clean energy supply chains likely increases its economic coercive ability and tools. According to a 2022 report from the National Bureau of Asian Research, "As China dramatically increased its overall export volumes at the beginning of the 21st century and took on an increasingly central role in critical supply chains, it began to gain the clout it needed to leverage effective sanctions."[149] A 2022 report from the European Parliamentary Research Service also notes an uptick in cases of economic coercion since President Xi came into power, including trade restrictions, tourism restrictions, boycotts, bans, and empty threats, among others.[150]

China likely perceives sanctions and restrictions as a means to signal its displeasure of a country or entity that is undermining Beijing's interests, and display nationalistic strength at home by countering foreign pressure.[151] According to a 2023 report by the Australian Strategic Policy Institute (ASPI), China's use of diplomatic coercion and threats have increased since a decade ago, and it is heavily relying on trade and investment restrictions as a means of coercing other nations.[152] ASPI notes that much of China's diplomatic coercion is economic coercion—"the weaponization of interdependence in goods and services, trade and investment."

Most past examples of Chinese restrictions are curbing imports from feuding countries or restricting access to the Chinese market, but there are some examples, though fewer, of China restricting exports. For example, Chinese sanctions imposed on South Korea in retaliation of deploying the

149 Yukon Huang, "China's Sanctions Strategy and Its Implications," The National Bureau of Asian Research, Interview with Yukon Huang (July 26, 2022). https://www.nbr.org/publication/chinas-sanctions-strategy-and-its-implications/. Accessed July 19, 2023.

150 Marcin Szczepański, "China's economic coercion evolution, characteristics and countermeasures," European Parliamentary Research Service (November 15, 2022). https://www.europarl.europa.eu/thinktank/en/document/EPRS_BRI(2022)738219. Accessed July 19, 2023.

151 Yukon Huang, "China's Sanctions Strategy and Its Implications."

152 Fergus Hunter, Daria Impiombato, Yvonne Lau, and Adam Triggs, "Countering China's coercive diplomacy," Australian Strategic Policy Institute, Policy Brief 68 (February 2023). https://www.aspi.org.au/report/countering-chinas-coercive-diplomacy. Accessed July 19, 2023.

Terminal High-Altitude Area Defense (THAAD) system in 2017 restricted Korea's business access to China's domestic market, including banning sales of certain products from Korea to China, closing Korean supermarkets in China, restricting Chinese tourism to Korea, and limiting Korean movies and shows available in China.[153] In 2012, China curbed auto imports from Japan and banana imports from Philippines for separate policy disputes over the Senkaku/Diaoyu Islands and the South China Sea, respectively.[154] Since 2020, China has imposed tariffs or trade restrictions toward imports of roughly a dozen Australian goods—all in retaliation of Australia's call for an investigation into the origins of COVID-19, Australia's ban on Huawei building a 5G network, and other political disagreements.[155] In 2022, China cut its imports from Lithuania by nearly 90% after it opened a Taiwanese representative office in November 2021.[156] There are a couple of notable examples of China restricting exports, as mentioned earlier in this paper, including REE exports in 2010 and gallium and germanium in 2023.

In a crisis or conflict scenario over Taiwan or the South China Sea, China would likely use economic coercion to deter other countries from publicly scrutinizing Beijing's actions. China might also reach for its economic coercion toolkit, or the threat of it, to fend off international actions or condemnation against its actions in Xinjiang, Hong Kong, and/or Tibet. Beijing's dominance of critical minerals and clean energy material exports adds to the existing goods and services that the world is dependent on China for. Countries grappling with the high costs of the energy transition

153 Haneul Lee, "Rising Anti-China Sentiment in South Korea Offers Opportunities To Strengthen US-ROK Relations," Center for American Progress (August 2, 2022). https://www.americanprogress.org/article/rising-anti-china-sentiment-in-south-korea-offers-opportunities-to-strengthen-us-rok-relations/. Accessed July 19, 2023.

154 Chia-Chien Chang and Alan H. Yang, "Weaponized Interdependence: China's Economic Statecraft and Social Penetration against Taiwan," *Orbis* 64, no. 2 (2020), pp312-333. https://doi.org/10.1016/j.orbis.2020.02.002. Accessed July 19, 2023.

155 Ye Xue, "China's economic sanctions made Australia more confident," Lowy Institute (October 22, 2021), https://www.lowyinstitute.org/the-interpreter/china-s-economic-sanctions-made-australia-more-confident (accessed July 19, 2023); and Shiro Armstrong, "Learning the right lessons from Chinese sanctions on Australian imports," East Asia Forum (April 16, 2023), https://www.eastasiaforum.org/2023/04/16/learning-the-right-lessons-from-chinese-sanctions-on-australian-imports/#:~:text=From%20May%202020%20Beijing%20blocked,(US%2413.4%20billion)%20annually. (accessed July 19, 2023).

156 Marcin Szczepański, "China's economic coercion evolution, characteristics and countermeasures," European Parliamentary Research Service (November 15, 2022). https://www.europarl.europa.eu/thinktank/en/document/EPRS_BRI(2022)738219. Accessed July 19, 2023.

will likely be reticent to publicly condemn a country in which they receive cost-competitive, energy-related supplies from.

China's Policy Objectives

The purpose of economic statecraft is to use one's economic power to further policy objectives. If China's dominance of clean energy supply chains provides a boost to Beijing's economic statecraft, coincidingly, what are related policy objectives that it may help to further? There are five main policy goals that it either directly or indirectly supports:

- boost domestic economic goals
- become a global technology superpower and standard setter
- challenge western influence in developing countries
- reduce international condemnation on Taiwan and South China Sea claims
- influence global climate strategies

Boost to Domestic Economic Goals: China's role as a leading global supplier of clean energy inputs and technologies creates business opportunities for Chinese companies abroad and an outlet to monetize excess domestic manufacturing capacity. China's revenue from solar photovoltaic exports was $52 billion in 2022, up from $32 billion in 2021, according to a Western consultant.[157] Furthermore, BRI helps Chinese companies expand into new markets to absorb domestic excess capacity of goods and services.[158] Chinese companies can scale up manufacturing and services rapidly amid government support and favorable industrial policies, but sometimes face issues with excess capacity as domestic demand growth slows or plateaus. For example, a slowdown in investments and installations of coal-fired power plants and hydropower development in China correlated with an increase in Chinese coal plants and hydropower projects

157 Wood Mackenzie, "China's solar exports booming, up 64% in 2022 despite global trade tensions," News Release (May 23, 2023). https://www.woodmac.com/press-releases/chinas-solar-exports-booming-up-64-in-2022-despite-global-trade-tensions/. Accessed July 19, 2023.

158 Bo Kong and Kevin Gallagher, "Chinese development finance for solar and wind power abroad," Boston University's Global Development Policy Center, GCI Working Paper 009 (January 2020), https://www.bu.edu/gdp/files/2020/02/WP9-Kong-Bo-inc_abstract.pdf (accessed July 19, 2023); and International Energy Agency, *Chinese Companies Energy Activities in Emerging Asia* (April 2019), https://iea.blob.core.windows.net/assets/f165f18e-bc05-4cee-8c18-3941799c0a47/Chinese_Companies_Energy_Activities_in_Emerging_Asia.pdf (accessed July 19, 2023).

overseas.[159] For non-hydro renewable energy, signs of excess solar and wind manufacturing capacity in China first emerged in 2009 and persisted through 2012, causing two of China's largest solar firms at the time to file for bankruptcy and eventually prompting the deputy director general of the New Energy Department of China's National Energy Administration to call for more Chinese financing toward renewable energy projects abroad.[160] Chinese state financing is often conditional on the use of Chinese EPC contractors and equipment suppliers,[161] helping to open up access to new markets for absorbing excess capacity of Chinese labor as well.

Global technology superpower and standard setting: Over the past two decades, China has made significant progress transforming from a reverse engineering, manufacturing hub to an innovator, though the lines between the two dichotomies are often blurred. In the World Intellectual Property Organization's (WIPO) Global Innovation Index (GII), China has climbed up the ranks over the past decade. In 2022, China overall ranked 11th, though still behind the United States at second place.[162] According to the previous 2021 report,

> Since 2013, China has moved up the GII ranks consistently and steadily, establishing itself as a global innovation leader and getting closer to the top 10 every year. The performance of China is at the frontier of achievement, notably in innovation outputs. For instance, China's levels of patents by origin, scaled by GDP, are higher than those of Japan, Germany, and the United States, and are even more impressive when considered in absolute terms.[163]

159 Ibid.

160 Ibid.

161 Ibid.

162 Soumitra Dutta, Bruno Lanvin, Lorena Rivera León, and Sacha Wunsch-Vincent, *Global Innovation Index 2022: What is the future of innovation-driven growth?* World Intellectual Property Organization, 15th edition (2022). https://www.wipo.int/edocs/pubdocs/en/wipo-pub-2000-2022-en-main-report-global-innovation-index-2022-15th-edition.pdf. Accessed July 19, 2023.

163 Soumitra Dutta, Bruno Lanvin, Lorena Rivera León, and Sacha Wunsch-Vincent, *Global Innovation Index 2021: Tracking Innovation through the COVID-19 Crisis*, World Intellectual Property Organization, 14th Edition (2021). https://www.wipo.int/edocs/pubdocs/en/wipo_pub_gii_2021.pdf. Accessed July 19, 2023.

China's aspirations to become a technological leader and rival the United States on innovation stems back decades ago. In 2006, China announced its 15-year science and technology (S&T) innovation plan titled "The National Medium- and Long-Term Program for Science and Technology," which was a national strategy to enhance its indigenous innovation capability, compete internationally, and leapfrog innovation in priority areas linked to economic growth and national security by hastening technological breakthroughs.[164] Energy was one of multiple priority areas identified. Energy goals in the plan included: developing ingenious capability to build nuclear energy technology; experiencing breakthroughs in renewable technologies including wind energy (onshore and offshore), solar energy, biomass energy, and associated scale application; developing fast and reliable power transmission and distribution technologies; and advancing research and development of energy storage, batteries, fuel-cell engines, solar-cell materials, advanced nuclear energy, and hydrogen to advance new clean energy technologies.

China's more recent national strategies also include energy innovation and manufacturing as priorities. China's 2016 National Innovation Development Strategy includes nuclear energy as one of four main advanced technology and equipment areas to "go global" or export, and as a strategic task includes "accelerate the development of technology and equipment for, and large scale application of, clean and new energy sources such as nuclear energy, solar energy, wind energy and biomass energy; and conquer the key technologies for large-scale supply/demand interaction, energy storage and grid connection."[165]

In China's 14th Five-Year Plan's (FYP) section on developing strategic and emerging technologies, new energy—including hydrogen and energy storage—and new energy vehicles are included as strategic and emerging industries that Beijing seeks to develop during the FYP's duration of

164 The State Council of the People's Republic of China, *The National Medium- and Long-Term Program for Science and Technology Development (2006-2020): An Outline* (2006). https://www.itu.int/en/ITU-D/Cybersecurity/Documents/National_Strategies_Repository/China_2006.pdf. Accessed July 19, 2023.

165 The Central Committee of the Communist Party of China (CPC) and the State Council, "Outline of the National Innovation-Driven Development Strategy Issued by the CPC Central Committee and the State Council." Translated by Georgetown's Center for Security and Emerging Technology on December 11, 2019 (May 19, 2016). https://cset.georgetown.edu/publication/outline-of-the-national-innovation-driven-development-strategy/. Accessed July 19, 2023.

2021-2025.[166] China's 14th FYP, which was approved by the National People's Congress in March 2021, also includes Beijing's most ambitious environmental goals of peaking carbon dioxide emissions before 2030 and reaching carbon neutrality before 2060, along with promoting low-carbon development. Under the 14th FYP, China seeks to expand domestic innovation capacity in manufacturing and high technology, and to increase research and development (R&D) spending by at least 7% annually.[167] The plan also states Beijing's intent to dominate supply chains, including in new energy and electricity. China's Vision 2035 plan, also approved by the National People's Congress in March 2021 alongside the 14th FYP, states that China will become a global leader in technology innovation by 2035 and consolidate its great power status.[168]

Thus, China's dominance in clean energy supply chains and technologies can be categorized under broader goals: becoming the global leader in innovation, maintaining prominence in manufacturing, strengthening domestic supply chains, and peaking carbon dioxide emissions before 2030 and reaching carbon neutrality before 2060, as stated in its 14th FYP.

Another broader goal that is bolstered by China's prominence in clean energy technologies is standard setting. The China Standards 2035 strategy, introduced in 2018, encompasses Beijing's goals to influence the creation of technological and product standards (specifications) globally, to push the internationalization of Chinese standards, and ultimately to establish itself as a competitor and contender in technological innovation. There are also economic advantages of setting technical standards, as they can be proprietary and for profit and create dependencies for future products, which can help with capturing a greater market share. The focus

166 The National People's Congress of the People's Republic of China, "Outline of the People's Republic of China 14th Five-Year Plan for National Economic and Social Development and Long-Range Objectives for 2035." Translated by Georgetown's Center for Security and Emerging Technology on May 12, 2021 (March 12, 2021). https://cset.georgetown.edu/publication/china-14th-five-year-plan/. Accessed July 19, 2023.

167 The State Council of the People's Republic of China, "14th Five-Year Plan of the People's Republic of China—Fostering High-Quality Development." Translated by Asian and Pacific Energy Forum (March 2021). https://policy.asiapacificenergy.org/node/4432. Accessed July 19, 2023.

168 Yun Sun, "An examination of the 2035 Vision for China-Africa Cooperation," Brookings (December 27, 2021), https://www.brookings.edu/blog/africa-in-focus/2021/12/27/an-examination-of-the-2035-vision-for-china-africa-cooperation/ (accessed July 19, 2023); and Jon Taylor, "China 2035: Achieving Socialist Modernization Basically," China Today (June 25, 2021), http://www.chinatoday.com.cn/ctenglish/2018/commentaries/202106/t20210625_800250626.html (accessed July 19, 2023).

is on new technologies associated with critical infrastructure, such as cloud computing, big data, 5G, artificial intelligence (AI), and UHV transmission lines.

According to a CPP document released in October 2021 titled "National Standardization Development Outline," translated by Georgetown University's Center for Security and Emerging Technology,

> China will establish a number of world-class comprehensive and professional standardization research institutions, a number of national quality standards laboratories, and more than 50 national technological standards innovation bases, forming a national quality infrastructure system that integrates standards, metrology, certification, accreditation, inspection, and testing, fundamentally meeting the demands of economic and social development in the standardized service industry.[169]

China is also actively participating in global standard setting bodies. From the mid-2000s to 2018, Chinese presence and participation in technical committees and sub-committees at the International Organization for Standardization (ISO)—a global network of national standards bodies consisting of over 160 members, including the American National Standards Institute (ANSI)—grew by about 40%, exceeding participation by the United States in those committees.[170]

A key area of focus for standardization is UHV technology. China likely wants to set global technological standards for UHV lines to continue to dominate bilateral and multilateral discussions, including at the United Nations, about building a global grid to meet global climate goals. Since 2021, China has influenced standards on UHV technology at the International Electrotechnical Commission (IEC), a global standard setting body recognized by the World Trade Organization and including members

169 The Chinese Communist Party Central Committee and the State Council, "National Standardization Development Outline." Translated by Georgetown's Center for Security and Emerging Technology on October 10, 2021 (November 8, 2021). https://cset.georgetown.edu/publication/the-chinese-communist-party-central-committee-and-the-state-council-publish-the-national-standardization-development-outline/. Accessed July 19, 2023.

170 John Seaman, *China and the New Geopolitics of Technical Standardization*, Ifri and Policy Center for the New South (January 2020). https://www.ifri.org/sites/default/files/atoms/files/seaman_china_standardization_2020.pdf. Accessed July 19, 2023.

such as the United States, several countries in the European Union, and China,[171] along with the Institute of Electrical and Electronics Engineers (IEEE), the world's largest technical professional organization. China has created an IEC standard for UHV Alternating Current Transmission Systems and IEEE standard for Medium Frequency (less than 12 MHz) Power Line Communications for Smart Grid Applications, and China also recently initiated a program that would create a new IEEE standard that helps sample and evaluate the status of running electric meters.[172]

Challenging Western Influence in Developing Countries: China's rise as a cost-competitive global supplier of clean energy technology and world's largest investor of "green" projects adds to Beijing's toolkit of strategies it can employ to try to counter American hegemony and influence developing countries. It adds to the economic and political leverage that China has on countries dependent on Chinese loans and investments. China's economic investments in developing countries has helped it to forge or further positive relations, such as with Venezuela, Pakistan, some Central Asian countries, and several countries in the Middle East and Africa. While U.S. friends, such as Saudi Arabia, will strive to balance their relations with the United States and China rather than completely turn to one superpower, many of these countries might be reluctant to join the United States in condemning China for any given actions, such as an invasion of Taiwan.

For example, after Beijing passed the national security law in Hong Kong, 53 countries, all developing nations, supported the security law, while 23 countries, mostly European countries, Australia, and Japan, condemned it at the UN Human Rights Council.[173] Many of the developing countries

171 International Electrotechnical Commission (IEC) Members – National Committees. https://www.iec.ch/national-committees. Accessed June 3, 2023.

172 Ma Aiping, "New UHV Transmission Standard Approved, Empowering Chinese Technology and Equipments Go Aboard," Science and Technology Daily (October 13, 2021), http://finance.people.com.cn/n1/2021/1013/c1004-32251551.html (accessed July 19, 2023); and State Administration for Market Regulation, "To Empower the development of New Electric Power Systems with Electricity Measurement" (May 26, 2022), https://gkml.samr.gov.cn/nsjg/xwxcs/202205/t20220526_347329.html/ (accessed July 19, 2023).

173 Dave Lawler, "The 53 countries supporting China's crackdown on Hong Kong," Axios (July 2, 2020), https://www.axios.com/2020/07/02/countries-supporting-china-hong-kong-law (accessed July 19, 2023); and Eleanor Albert, "Which Countries Support the New Hong Kong National Security Law?" *The Diplomat* (July 6, 2020), https://thediplomat.com/2020/07/which-countries-support-the-new-hong-kong-national-security-law/ (accessed July 19, 2023).

supportive of Beijing are recipients of Chinese loans and/or investments. According to the Council on Foreign Relations,

> BRI has its conditions—whether explicit or implicit—and increases China's political sway in loan-recipient countries. For instance, countries that have signed on to BRI have refrained from criticizing China's detention of over one million Muslims in reeducation camps. In fact, after signing on to BRI projects, Pakistan Prime Minister Imran Khan praised "China's effort in providing care to its Muslim citizens," and Cameroon lauded China for "fully protect[ing] the exercise of lawful rights of ethnic minority populations."[174]

Gain Support on Taiwan and SCS: If China's dominance of clean energy technologies does indeed increase the attractiveness of BRI investments for recipients needing competitive financing options to build the infrastructure necessary to meet climate goals, then that could expand China's leverage to try and get support for any future actions concerning Taiwan and in the South China Sea. According to Kalyanaraman, China has leveraged foreign direct investment to induce "nine African countries within a period of five years to reverse their diplomatic recognition of Taiwan and adhere to the One-China policy."[175] According to the Council on Foreign Relations, "Experts worry that BRI gives China additional leverage to influence countries with claims to the South China Sea, many of which have already accepted BRI loans."[176]

Influence Global Climate Strategies: China seeks to influence and define globally acceptable strategies to tackle climate issues to gain support for China's preferred strategies and reduce criticism of China's preferred path. China prefers a climate strategy that upholds the principle of Common but Differentiated Responsibilities and Respective Capabilities (CBDR-RC)

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174 Council on Foreign Relations, "Tools of Foreign Policy: What Is Economic Statecraft?" World 101. https://world101.cfr.org/foreign-policy/tools-foreign-policy/what-economic-statecraft. Accessed June 3, 2023.

175 S. Kalyanaraman, "War by Other Means: Geoeconomics and Statecraft by Robert D. Blackwill and Jennifer M. Harris," *Strategic Analysis* 41, no. 6 (2017), pp591-594. https://doi.org/10.1080/09700161.2017.1377897. Accessed July 19, 2023.

176 Council on Foreign Relations, "Tools of Foreign Policy: What Is Economic Statecraft?" World 101. https://world101.cfr.org/foreign-policy/tools-foreign-policy/what-economic-statecraft. Accessed June 3, 2023.

between developed and developing countries; links biodiversity and climate issues and emphasizes nature-based solutions and restoration of the ecosystem; and increases the focus of climate adaptation at international forums like the United Nations Framework Convention on Climate Change (UNFCC).[177] According to Jianfeng Jeffrey Qi and Peter Dauvergne,

> …strong alliances with other developing countries enhances China's capacity to protect its economic interests, challenge Global North discourses, and advance its climate change agenda, including the CBDR-RC principle, the flexible implementation of mitigation targets, and the critical need for adaptation.[178]

China seeks to unite developing countries around these issues through various forums like the G77 + China and the Like Minded-Group of Developing Countries and align itself with developing countries' calls for more emphasis on climate adaptation and related finance. Qi and Dauvergne note that financing from developed countries favors mitigation strategies, such as emissions reduction, while developing countries want a greater focus on adaptation strategies. China is providing financial support to developing countries for nature-based solutions, also known as ecosystem-based adaptation or restoration, mainly through its South-South Climate Cooperation Program.[179]

China's preferences, as mentioned in the paragraph above, are apparent in President Xi's October 2021 speech at the 16th G20 Leaders' Summit:

> The G20 needs to uphold the principle of common but differentiated responsibilities, push for the full implementation of the Paris Agreement on climate change, and support a successful COP26 to the United Nations Framework Convention

177 Grantham Research Institute on Climate and the Environment, "How is China tackling climate change?" The London School of Economics and Political Science (July 25, 2022), https://www.lse.ac.uk/granthaminstitute/explainers/how-is-china-tackling-climate-change/ (accessed July 19, 2023); and Jianfeng Jeffrey Qi and Peter Dauvergne, "China's rising influence on climate governance: Forging a path for the global South," *Global Environmental Change* 73 (March 2022), https://doi.org/10.1016/j.gloenvcha.2022.102484 (Accessed July 19, 2023).

178 Ibid.

179 Ibid.

> on Climate Change and COP15 to the Convention on Biological Diversity. Developed countries need to lead by example on emissions reduction, fully accommodate the special difficulties and concerns of developing countries, deliver on their commitments of climate financing, and provide technology, capacity-building and other support for developing countries.[180]

President Xi likely also perceives clean energy investment projects via BRI as a vehicle to influence governance on these topics and lead climate diplomacy among developing countries, based on Xi's statements in a series of speeches in 2016 and 2017.[181] In 2018, Miquel Muñoz Cabré, Kevin P. Gallagher, and Zhongshu Li calculated renewable energy investment globally potential at $1.0 trillion, based on goals in countries' nationally determined contributions (NDCs).[182] They write,

> China is uniquely poised to be a leader in global renewable energy finance because of the competitive advantage of its renewable energy companies and the unique financing models practiced by China's two overseas policy banks, the China Development Bank (CDB) and the Export–Import Bank of China (CHEXIM).[183]

While Western media reports have speculated that China wants to become a global leader of climate governance, Qi and Dauvergne note that narrative is likely false because Beijing does not want to shoulder responsibility that may affect economic growth.[184] Instead, China is seeking

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180 Xinhua, "Full text: Remarks by Xi Jinping at Session I of the 16th G20 Leaders' Summit" (October 30, 2021). http://www.news.cn/english/2021-10/30/c_1310280299.htm Accessed July 19, 2023.

181 Jianfeng Jeffrey Qi and Peter Dauvergne, "China's rising influence on climate governance: Forging a path for the global South," *Global Environmental Change* 73 (March 2022). https://doi.org/10.1016/j.gloenvcha.2022.102484 (Accessed August 23, 2023).

182 Miquel Muñoz Cabré, Kevin P. Gallagher, and Zhongshu Li, "Renewable Energy: The Trillion Dollar Opportunity for Chinese Overseas Investment," *China & World Economy* 26, no. 6 (November 13, 2018), pp27-49. https://doi.org/10.1111/cwe.12260. Accessed July 19, 2023.

183 Ibid.

184 Jianfeng Jeffrey Qi and Peter Dauvergne, "China's rising influence on climate governance: Forging a path for the global South."

to become the climate leader of developing countries, not globally. China may also be hesitant to assume the leadership role, given that China does not want to undermine its domestic energy security, as it takes a measured, slower approach to reduce fossil fuel consumption in the long term. Additionally, claiming the climate leadership role could lead to more international pressure for China to curtail its high coal consumption.

Race to Lead Nuclear Energy Exports

The energy transition has ignited a worldwide search for a low-carbon energy source that is affordable, scalable, and reliable, and some argue nuclear power is the leading solution for the energy transition. Nuclear energy is a baseload source of electricity, meaning it generates power at a constant rate. It is also considered a low-carbon form of energy because it does not directly emit CO2 when electricity is generated. While solar and wind are cost-competitive, clean energy sources that will play a major role in the energy transition, they are still intermittent, variable sources, and require baseload energy or energy storage to fill in gaps when demand exceeds solar and wind supply. Grid-scale energy storage, derived from renewable energy, and that is of long duration (more than 10 hours), is needed to support wind and solar and to decarbonize the grid; however, these technologies either are not commercial at scale or have exorbitant costs.[185] Other sources of emerging low-carbon technologies, such as renewable-based hydrogen and hydrogen produced from fossil fuels using carbon capture technologies are also not commercially developed yet, and thus their future price competitiveness are unknown.

Public sentiment towards nuclear power has wavered over history, particularly following major nuclear accidents at Three Mile Island in the United States in 1979, Chernobyl in Soviet-era Ukraine in 1986, and the Fukushima-Daiichi nuclear plant in Japan in 2011 following an earthquake and tsunami. According to data from the U.S. Energy Information Administration, worldwide nuclear generation peaked in 1995-1996, accounting for 18% of global electricity generation, but has fallen to 10%, as of 2020.[186] Nuclear accidents have undermined public trust in nuclear safety and has led to fewer nuclear capacity additions over the past decade. Shortly after the Fukushima incident, some countries, such as Germany, enacted policies phasing out or reducing their long-term use of nuclear power. The nuclear industry has also been plagued with high up-front capital costs, cost overruns, and persistent project delays, often at least doubling construction times.

185 U.S. Department of Energy, "Long Duration Storage Shot." https://www.energy.gov/eere/long-duration-storage-shot. Accessed June 3, 2023.

186 U.S. Energy Information Administration, "World Electricity Generation Data." https://www.eia.gov/international/data/world/electricity/electricity-generation. Accessed June 3, 2023.

However, in search of low-carbon baseload power, several countries have recently either scaled back plans to phase out nuclear energy and/or have increased their nuclear energy targets in their long-term energy strategies.[187] Countries with plans to bring online substantive amounts of new nuclear reactors include China, France, India, Poland, and the UK, and several developing countries across Latin America, Africa, and the Middle East have expressed interest in bringing online nuclear power plants in the future.[188] Some advanced economies, such as the United States, Canada, the UK, and France, are also directing financial support toward advancing small modular reactors (SMRs)—small nuclear power plants with a capacity of 300 megawatt-electric (MWe) or less. In general, SMRs are believed to require less upfront capital costs to build compared with traditional, large nuclear power plants, have shorter construction times, can be built in a factory, and can be co-located at the demand site—but SMR designs vary widely and most SMR designs are still years away from being built.

If nuclear is to play a notable role in the energy transition, new nuclear power plant builds must increase substantially. According to 2020 estimates from UxC LLC, a global nuclear analysis consultancy, 640 gigawatt-electric (GWe) of new build requirements over the coming 30 years are required to reach the 840-GWe nuclear capacity needed by 2050 to achieve global carbon mitigation goals, based on the Intergovernmental Panel on Climate Change's (IPCC) 2019 report.[189] The estimate accounts for new builds needed to offset the retirements of aging nuclear power plants; as of 2021, 63% of nuclear power plants worldwide are over 30 years old, according to the IEA.[190] This presents commercial opportunities for nuclear technology exporters, including the United States, Russia, and China. For example, UxC estimated,

187 Phil Chaffee, "Appetite for New Nuclear Gets Energy Security Boost," Energy Intelligence (October 3, 2022). https://www.energyintel.com/00000183-9d7c-d66b-a5a7-9d7ce6490004. Accessed July 19, 2023.

188 International Energy Agency, *Nuclear Power and Secure Energy Transitions* (June 2022), p7. https://www.iea.org/reports/nuclear-power-and-secure-energy-transitions. Accessed July 19, 2023.

189 UxC, LLC (UxC), *Global Nuclear Market Assessment Based on IPCC Global Warming of 1.5° C Report*, (July 2020). https://www.nei.org/CorporateSite/media/filefolder/resources/reports-and-briefs/UxC-NEI-(IPCC-2050-Nuclear-Market-Analysis-PUBLIC)-2020-07-01.pdf. Accessed July 19, 2023.

190 International Energy Agency, *Nuclear Power and Secure Energy Transitions,* p7.

> …the 30-year cumulative total for U.S. nuclear market revenues could range between $1.3 trillion and $1.9 trillion. U.S. suppliers will have numerous opportunities to expand their market presence, including in new reactor construction projects (large, small modular, and advanced designs), maintaining and fueling the global fleet of reactors, as well as decommissioning aging reactors.[191]

Advanced economies, such as the United States and Western Europe, are losing market share in reactor design and construction. According to a June 2022 IEA report, 27 of 31 reactors worldwide that started construction from 2017 to mid-2022 are Russian and Chinese designs, and the IEA expects China will be the top producer of nuclear energy by 2050.[192] Russia is currently the dominant exporter of nuclear technologies (Figure 10), and China is hoping to become a major exporter. Prior to Russia's invasion of Ukraine, Russia fulfilled 60% of reactor sales worldwide,[193] and according to its state-owned nuclear company Rosatom, it has reactors operating or under construction in Armenia, Bangladesh, Belarus, Bulgaria, China, Czechia, Egypt, Finland, Hungary, India, Iran, Russia, Slovakia, Ukraine, and Turkey.[194] Russia tends to offer cheaper options and competitive financing packages, with loans backed by Russian government subsidies, and Rosatom provides the full fuel cycle services.[195] Even after its invasion of Ukraine, Russia started building Egypt's first nuclear power plant in June

191 UxC, LLC (UxC), *Global Nuclear Market Assessment Based on IPCC Global Warming of 1.5° C Report*.

192 International Energy Agency, *Nuclear Power and Secure Energy Transitions,* p7.

193 David Yellen, "The trade war we want China to win: China's nuclear exports can challenge Russian dominance," Atlantic Council (February 26, 2020). https://www.atlanticcouncil.org/blogs/energysource/the-trade-war-we-want-china-to-win-chinas-nuclear-exports-can-challenge-russian-dominance/. Accessed July 19, 2023.

194 Rosatom, "Projects." https://rosatom.ru/en/investors/projects/#:~:text=ROSATOM%20holds%20first%20place%20in,abroad%20at%20various%20implementation%20stages).&text=Project%20specifications%3A%20Construction%20of%20two,capacity)%20launched%20in%20December%202017. Accessed January 2023.

195 Névine Schepers, "Russia's Nuclear Energy Exports: Status, Prospects and Implications," EU Non-Proliferation and Disarmament Consortium, Non-Proliferation and Disarmament Papers 61 (February 2019), https://www.sipri.org/sites/default/files/2019-02/eunpdc_no_61_final.pdf (accessed July 19, 2023); and Viet Phuong Nguyen 1 and Man-Sung Yim, "Nonproliferation and Security Implications of the Evolving Civil Nuclear Export Market," *Sustainability* 11, no. 7 (March 2019), p1830. https://doi.org/10.3390/su11071830 (accessed July 19, 2023).

2022—though the original contracts were signed years prior[196]—and has signed new contracts with Turkey to continue the construction of nuclear plants there.[197] Western governments have not enacted any noteworthy sanctions on Rosatom and continue to import nuclear fuel and services from Russia. In 2022, U.S. civilian power owners and operators purchased 12% of its uranium supply from Russia and relied on Russia for 24% of their purchases of enrichment services.[198] Europe relies on Russia for about 24% of uranium conversion services and 25% of enrichment services, based on 2020 data.[199] Nonetheless, Russia's ability to fulfill its work orders and finance new reactor builds in third countries is in question, given its war in Ukraine and Western sanctions targeting the Kremlin's financial coffer. As of 2019, Russia had more than $133 billion in work orders over the subsequent 10 years, mostly for the construction of nuclear power plants, according to Rosatom.[200]

196 Enerdata, "Russia's Rosatom starts building Egypt's first nuclear power reactor," (July 22, 2022). https://www.enerdata.net/publications/daily-energy-news/russias-rosatom-starts-building-egypts-first-nuclear-power-reactor.html. Accessed July 19, 2023.

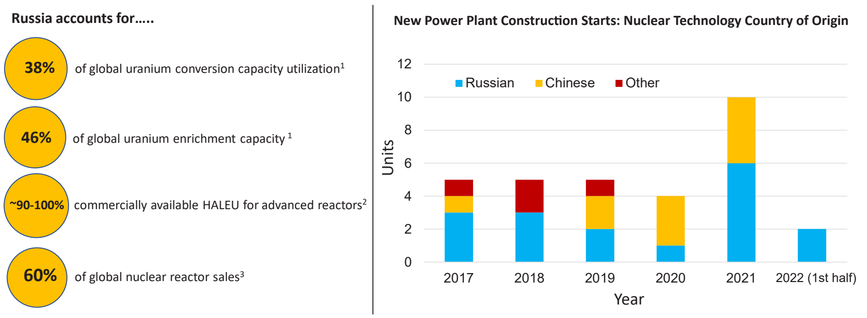
197 Can Sezer and Ezgi Erkoyun, "Russia's Rosatom signs new construction contract for Turkish nuclear plant," Reuters (July 30, 2022). https://www.reuters.com/business/energy/russias-rosatom-signs-new-construction-contract-turkish-nuclear-plant-2022-07-30/. Accessed July 19, 2023.

198 U.S. Energy Informational Administration, "Uranium Marketing Annual Report," Tables 3 and 16 (June 13, 2023). https://www.eia.gov/uranium/marketing/. Accessed July 19, 2023.

199 International Energy Agency, *Nuclear Power and Secure Energy Transitions* (June 2022). https://www.iea.org/reports/nuclear-power-and-secure-energy-transitions. Accessed July 19, 2023.

200 Rosatom, "Russia and China signed the contract for Russian-designed NPP construction on the new site," press release (June 5, 2019). https://www.rosatom.ru/en/press-centre/news/russia-and-china-signed-the-contract-for-russian-designed-npp-construction-on-the-new-site/. Accessed July 19, 2023.

Figure 10. Russia's Role in the Global Nuclear Power Market



Notes: [1]Data is as of 2020. [2]While Russia is the main global supplier of HALEU, Chinese vendors can produce HALEU. A HALEU demonstration plant is also under construction in Ohio. [3]Data varies among sources and timeframes. Different estimates include Russia accounting for 60% of reactor sales (as cited in 2017 in think tank and media reports), 55% of nuclear designs under construction worldwide (as cited in June 2022 by the IEA), and 23 of 31 reactor export orders with sites specified globally from 2009 to 2018 (as cited here: https://doi.org/10.1016/j.enpol.2018.06.036).

Sources: IEA's Nuclear Power and Secure Energy Transitions 2022 (right chart); World Nuclear Association, Third Way, and Nuclear Energy Institute.

China is attempting to start competing with Russia and gain market share in the global nuclear power market. In its 2020 report, UxC estimated China would supply 43 of 107 new reactors globally slated for completion by 2030, which includes new builds in China and abroad, while Russia would supply 29 reactors, and other reactor providers, like France, India, and South Korea, would supply the remainder.[201] UxC projections were made prior to Russia's invasion of Ukraine, and currently, Russia's ability to finance nuclear reactor builds abroad and expand its work orders are in question. If Russia faces difficulties in doing so and such a gap ensues, then China is well positioned to take advantage considering its ability and experience with providing state-backed financing options for large infrastructure projects, its existing economic and investment relationships with countries through BRI, its near self-sufficiency in reactor design, construction, and parts of the fuel cycle, and its ambition to be a dominant player in the global nuclear marketplace. Since China's first domestic nuclear power plant came online in 1991, its nuclear fleet has expanded substantially with the bulk of the

201 Kyle Sallee, "Regaining American Competitiveness in the Global Nuclear Power Market," American University's Center for Security, Innovation, and New Technology (February 5, 2021). https://www.american.edu/sis/centers/security-technology/regaining-american-competitiveness-in-the-global-nuclear-power-market.cfm. Accessed July 19, 2023.

increase occurring between 2011 and 2019.[202] As of September 2022, China operated 53 reactors total and had over 20 nuclear reactors under construction.[203] According to China's 14th five-year plan, China is targeting 70 GW of installed nuclear energy capacity by 2025 compared with 52 GW as of 2021.[204] While nuclear power generation made up 5% of China's total power generation, as of 2021,[205] the IEA expects China will be the top producer of nuclear energy by 2050. [206]

The state-owned China National Nuclear Corporation (CNNC), which is the country's largest nuclear enterprise, announced in 2016 its goal of building 30 nuclear reactors across 40 BRI countries.[207] According to Chinese experts, Boqiang Lin, Nuri Bae, and François Bega, since 2016, China has signed preliminary nuclear cooperation agreements with Algeria, Brazil, Bulgaria, Cambodia, Czechia, Egypt, Ghana, Indonesia, Iran, Jordan, Kazakhstan, Kenya, Poland, Romania, Saudi Arabia, South Africa, Sudan, Thailand, Turkey, Uganda, and the United Arab Emirates.[208] To date, outside of China, Pakistan is the only country that hosts Chinese-built nuclear power plants, but that could soon change. In February 2022, CNNC signed a $8.3 billion deal with Argentina to build a 1,200 MW nuclear power plant, with plans for CNNC to finance 85% of the cost, though the project's timeline is uncertain.[209] In Bangladesh, Chinese companies have lobbied and held

202 Jane Nakano, "The Changing Geopolitics of Nuclear Energy: A Look at the United States, Russia, and China," Center for Strategic and International Studies (March 12, 2020). https://www.csis.org/analysis/changing-geopolitics-nuclear-energy-look-united-states-russia-and-china. Accessed July 19, 2023.

203 Zheng Xin, "Nation pushes nuclear power to ensure supply, reach carbon goals," *China Daily* (September 16, 2022). https://www.chinadaily.com.cn/a/202209/16/WS6323dc25a310fd2b29e7808f.html. Accessed July 19, 2023.

204 Michal Meidan, Philip Andrews-Speed, and Yan Qin, "Key issues for China's 14th Five Year Plan," The Oxford Institute for Energy Studies (March 2021). https://a9w7k6q9.stackpathcdn.com/wpcms/wp-content/uploads/2021/03/Key-issues-for-Chinas-14th-Five-Year-Plan.pdf. Accessed July 19, 2023.

205 U.S. Energy Information Administration, International Electricity Generation Data. https://www.eia.gov/international/data/world. Accessed July 19, 2023.

206 International Energy Agency, *Nuclear Power and Secure Energy Transitions,* (June 2022). https://www.iea.org/reports/nuclear-power-and-secure-energy-transitions. Accessed July 19, 2023.

207 Boqiang Lin, Nuri Bae, and François Bega, "China's Belt & Road Initiative nuclear export: Implications for energy cooperation," *Energy Policy* 142 (July 2020). https://doi.org/10.1016/j.enpol.2020.111519. Accessed July 19, 2023.

208 Ibid.

209 Eliana Raszewski, "Argentina wants China to fully fund $8.3 bln nuclear plant amid cash shortfall," Reuters (April 5, 2022). https://www.reuters.com/business/energy/argentina-wants-china-fully-fund-83-bln-nuclear-plant-amid-cash-shortfall-2022-04-05/. Accessed July 19, 2023.

talks with Bangladeshi officials in the past to potentially build a nuclear power plant.[210] In the UK, state-owned China General Nuclear (CGN) owns one-third ownership stake in the Hinkley Point C nuclear power plant, which is under construction, as of June 2023. In 2022, the UK's nuclear regulator approved CGN's Hualong One reactor design for construction, giving it a nod of confidence that may make other countries more comfortable about the safety of the Chinese nuclear design. However, due to public and political opposition over China's involvement, it's unlikely that CGN will construct the reactor in the UK.[211] The shift in the UK government's desire for Chinese involvement in its nuclear sector—from enthusiasm for Beijing's involvement in UK's planned nuclear expansion over five years ago to its current hesitation—is indicative of Western countries' growing ambivalence to Chinese involvement in critical infrastructure. Thus, while China is well-positioned to become a leading exporter of nuclear technologies, it is not guaranteed, and China might struggle to win contracts for new nuclear reactor builds across the globe at the rate it hopes.

The United States is currently the world's largest producer of nuclear energy, with 93 operable reactors—almost all built between 1967 and 1990—and one reactor under construction, as of April 2023.[212] Nuclear power accounts for nearly 20% of total generation in the United States, representing 30% of nuclear power generated worldwide.[213] The United States was once the world's leading exporter of nuclear energy technology but is no longer. After the 1979 accident at the Three Mile Island nuclear power plant in Pennsylvania, demand for new nuclear power plants declined in the United States, weakening the robustness and economic competitiveness of the U.S. nuclear supply chain.[214] Globally, the rate of

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210 BenarNews, "Chinese Companies Lobby for Contract to Build Bangladesh's Second Nuclear Plant," Radio Free Asia (May 2019). https://www.rfa.org/english/news/china/bangladesh-nuclear-05092019173654.html. Accessed July 19, 2023.

211 Julia Pamilih, "Briefing: China's Involvement in UK Nuclear," China Research Group (July 5, 2022). https://chinaresearchgroup.org/research/briefing-chinas-involvement-in-uk-nuclear-power. Accessed July 19, 2023.

212 World Nuclear Association, *World Nuclear Performance Report 2022,* Report No. 2022/003 (July 2022). https://www.world-nuclear.org/getmedia/9dafaf70-20c2-4c3f-ab80-f5024883d9da/World-Nuclear-Performance-Report-2022.pdf.aspx. Accessed February 2023.

213 Ibid.

214 Jane Nakano, "The Changing Geopolitics of Nuclear Energy: A Look at the United States, Russia, and China," Center for Strategic and International Studies (March 12, 2020). https://www.csis.org/analysis/changing-geopolitics-nuclear-energy-look-united-states-russia-and-china. Accessed July 19, 2023.

new construction slowed and/or stagnated from late 1970s to the early 2000s as well, in part due to fears over safety stemming from nuclear accidents at Three Mile Island and Chernobyl, nuclear waste, and high upfront capital costs.[215] The bankruptcy of Westinghouse in 2017 and project delays and cost overruns with reactors under construction further undermined the U.S. role in the global nuclear marketplace. Private nuclear companies in the United States also have struggled to compete with state-owned enterprises in Russia and China, which offer attractive financing options that are backed by their respective governments.[216] Nonetheless, the U.S. government and companies are stepping up their focus on the development and deployment of SMRs. The U.S. government has ramped up international engagement with various countries to market its SMRs under a program it launched in 2021 known as Foundational Infrastructure for Responsible Use of Small Modular Reactor Technology (FIRST), as detailed in a CGSR 2022 report titled "Combating Climate Change while Promoting Non-Proliferation: Addressing New Challenges."[217]

Commercial competition among great power countries is heating up around the development and deployment of SMRs. As mentioned earlier, SMRs are defined as nuclear reactors with a capacity of 300 MWe per unit or less and designed in a modular fashion allowing for factory assembly.[218] Interest in deploying SMRs has increased as countries seek clean energy technology that is more affordable than traditional large nuclear power plants, can be located closer to demand centers, have shorter construction times, and can be installed into smaller grids or remotely off-grid.[219] SMRs are being developed by several countries, including the United States, China, Russia, South Korea, Japan, Canada, and Argentina. Russia was the first country to deploy an advanced SMR; in May 2020, Russia began

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215 World Nuclear Association, "Outline History of Nuclear Energy" (November 2020). https://www.world-nuclear.org/information-library/current-and-future-generation/outline-history-of-nuclear-energy.aspx. Accessed February 2023.

216 U.S. Department of Energy, *Restoring America's Competitive Nuclear Energy Advantage* (2020). https://www.energy.gov/articles/restoring-americas-competitive-nuclear-energy-advantage. Accessed July 19, 2023.

217 Edward Jenner, "Combating Climate Change While Promoting Nonproliferation: Addressing New Challenges," Center for Global Security Research (September 2022). https://cgsr.llnl.gov/content/assets/docs/SMR-FNPP-Risk_9.15.22_EJ_FINAL.pdf. Accessed July 19, 2023.

218 Joanne Liou, "What are Small Modular Reactors (SMRs)?" International Atomic Energy Agency (November 4, 2021). https://www.iaea.org/newscenter/news/what-are-small-modular-reactors-smrs. Accessed February 2023.

219 Ibid.

commercial production of SMRs abroad a floating nuclear power plant (FNPP), known as Akademik Lomonosov, in the Arctic. While the United States has not yet deployed a modern-day SMR, the U.S. company NuScale has designed one, and it was certified by the U.S. Nuclear Regulatory Commission in early 2023. NuScale has also signed a preliminary agreement with Romania to deploy a SMR there. In addition to NuScale, other U.S. companies are also developing SMR designs.

Risks and Potential Implications

The loss of U.S. leadership in the global nuclear marketplace presents geopolitical, energy security, proliferation, and commercial risks. If the United States is unable to contend in the race to lead nuclear-related exports over the course of the energy transition, then the United States and allied countries will become even more dependent on adversaries, U.S. adversaries will cement multi-decadal ties globally, and U.S. influence on global nonproliferation standards and practices will wane.

The geopolitical implications of the United States ceding power to Russia and China in the nuclear technology export industry have been well analyzed and documented. In 2020, the U.S. Department of Energy (DOE) released a report titled *Restoring America's Competitive Nuclear Energy Advantage: A Strategy to Assure U.S. National Security*, which highlighted that when countries (such as Russia and China) establish nuclear export agreements with other countries, they are effectively locking in economic partnerships potentially lasting up to 100 years, encompassing all stages of its lifecycle, from design to decommissioning.[220] The role as a long-term technology provider can give that country a geopolitical strategic advantage at cultivating a meaningful political relationship with the purchasing country. Another risk is to the energy security of the United States and its allies. Nuclear power accounts for nearly 20% of power generation in the United States. Thus, its dependence on an adversary for nuclear fuel places the United States at a vulnerable position, especially in times of crisis or war with its adversary. The same applies for U.S. allies.

The United States has been the leader of strong nonproliferation standards and practices, and as more countries are interested in nuclear

220 U.S. Department of Energy, *Restoring America's Competitive Nuclear Energy Advantage.*

energy, nonproliferation oversight and export controls will be needed. According to the 2020 DOE report,

> U.S. regulatory structures remain the international gold standard for safe operation of nuclear power facilities and adoption of stringent international safeguard and security measures. If U.S. industry is not poised to compete in the international market, America's ability to influence global non-proliferation, security, and safety standards is not credible. The strength of our non-proliferation and nuclear safety efforts must rest on a foundation of domestic nuclear industry credibility and government commitment.[221]

The increase in potential new nuclear energy customers spurred by the energy transition does present risks as it can pave an initial, albeit narrow gateway for a country to pursue nuclear weapons. This can also make it a target for non-state actors that seek nuclear material for harmful purposes.[222] The United States' ability to monitor, track, and mitigate those risks are limited if Russia and China lead nuclear exports and cooperation with nuclear newcomers.

The U.S. Department of Commerce projected that over the next 10 years the global nuclear reactor market will be valued at $500-740 billion, presenting a substantial commercial opportunity for those companies that can compete and a major loss for those that cannot.[223] The potential entry of new customers presents not only opportunities to bolster strategic geopolitical relations, but also tangible economic benefits. Revival of the U.S. leadership as a nuclear technology exporter has had broad bipartisan support, as it was a goal of the Trump administration and has carried into the Biden administration.

221 Ibid.

222 Edward Jenner, "Combating Climate Change While Promoting Nonproliferation: Addressing New Challenges."

223 U.S. Department of Energy, *Restoring America's Competitive Nuclear Energy Advantage.*

Trade and Finance Tensions between Developed and Developing Nations

There are notable differences between developed (namely, the United States and the EU) and developing countries on defining the energy transition, in terms of the role of fossil fuels, the pace of the transition, and the financing of fossil fuel projects. These differences have the potential to raise tensions with developing countries that do not plan to eliminate the use of fossil fuels, view natural gas as a low-carbon fuel option for the future, and are cautious about how higher energy prices might affect their economic development and growth trajectory. These differences are playing out through global economic mechanisms of trade and finance, including carbon border adjustment mechanisms and the financing of fossil fuel projects at multilateral development banks. These divisions can pave the way for greater opportunity for China and Russia to align more closely with developing countries and fill in gaps.

At COP26 in November 2021, 39 countries and institutions—including the United States and the European Investment Bank (EIB), the EU's lending institution—signed a public statement to stop new direct public financing for unabated fossil fuel projects globally by the end of 2022, except in limited circumstances compatible with the Paris Agreement.[224] Earlier that year in August 2021, the U.S. Treasury—the majority shareholder in major development banks like the World Bank—announced new guidance on fossil fuel energy financing for multilateral development banks. The guidance said it would oppose new direct investment in coal and oil projects, oppose upstream natural gas projects, and would provide support for midstream and downstream natural gas projects that met their criteria of having significant impact on energy access and security and in the absence of a

224 UN Climate Change Conference UK 2021, "Statement on International Public Support for Clean Energy Transition" (April 11, 2021). https://ukcop26.org/statement-on-international-public-support-for-the-clean-energy-transition/. Accessed February 2023.

clean energy alternative.[225] The EIB stopped financing unabated fossil fuel energy projects overseas, including natural gas, at the end of 2021.[226]

Developing countries have criticized the Western world's rush to limit financing for fossil fuel projects, particularly natural gas, and claim it could be detrimental to their economic development.[227] In response to the COP26 statement, the Senegalese president said it came at a "fatal cost" for emerging economies.[228] Over the next two decades, energy demand in Africa is projected to be 30% higher in 2040 compared with 2021—which threatens to outpace supply—and experts expect energy demand for fossil fuels will be strong.[229] Developing countries would like to use their domestic resources of fossil fuels to provide relatively cheaper energy to support their economic development and growth like Western countries did in the past. Several developing countries consider natural gas as a relatively clean fuel option to reduce their use of carbon-intensive fossil fuels, such as coal and oil; increase their energy access; and support incremental increases in renewable energy and infrastructure.

Some economic development scholars have also expressed concern with how international energy financing policies, being decided by developed countries and imposed on developing countries, might affect economic development prospects. Dr. Vijaya Ramachandran, an expert on energy and development issues, wrote in a November 2021 article:

> The idea that some of the poorest people on Earth will be using green hydrogen—possibly the most complex and expensive

225 U.S. Department of Treasury, "Treasury Announces Fossil Fuel Energy Guidance for Multilateral Development Banks," press release (August 16, 2021). https://home.treasury.gov/news/press-releases/jy0323. Accessed July 19, 2023.

226 European Investment Bank, "EIB energy lending policy at a glance: Supporting the energy transformation." https://www.eib.org/en/projects/sectors/energy/elp-at-a-glance/index.htm. Accessed February 2023.

227 David Pilling and Camilla Hodgson, "European Investment Bank resists pressure to fund gas projects," Financial Times (September 20, 2022). https://www.ft.com/content/b00ea2e5-78a0-46c5-b2b0-33e6a40b96af. Accessed July 19, 2023.

228 Joe Lo, "'Huge blow' – cuts to gas finance sparks West African backlash," Climate Home News (July 12, 2021). https://www.climatechangenews.com/2021/12/07/huge-blow-cuts-gas-finance-sparks-west-african-backlash/. Accessed July 19, 2023.

229 Acha Leke, Peter Gaius-Obaseki, and Oliver Onyekweli, "The future of African oil and gas: Positioning for the energy transition," McKinsey & Company (June 8, 2022). https://www.mckinsey.com/industries/oil-and-gas/our-insights/the-future-of-african-oil-and-gas-positioning-for-the-energy-transition. Accessed July 19, 2023.

> energy technology that exists—and building out "smart micro-grid networks" in just a few years at anywhere near the scale required is absurd. Not even solar energy or wind power—if it could be built out quickly enough—could fuel development in the global south without backup power using fossil fuels, of which gas is the cleanest by far. In sub-Saharan Africa, which has large gas fields offshore and includes many of the world's poorest countries, a ban on financing gas projects would practically end support for the critical energy infrastructure necessary to support economic development and raise living standards—including electricity for homes, schools, and factories; industrial heat for producing cement and steel; the carbon dioxide that is an essential component of synthetic fertilizer; and liquefied gas for transportation and cooking fuel.[230]

Some developing countries have also accused the United States and the EU of hypocrisy due to their support for fossil fuel projects in their home countries, and the EU's recent designation of domestic gas power plant projects as climate-friendly in its taxonomy to attract investments. Furthermore, developed countries failed to meet their 2009 pledge to provide a $100 billion annually by 2020 to developing nations toward climate mitigation and adaption.[231] If the developed world was not able to fulfill the $100 billion pledge, then how will it help developing countries build out entirely new energy systems? Narrowing the opportunity and options for developing, particularly poor countries, from obtaining financing necessary for energy and economic growth, while already falling short of climate finance commitments, could lead to a contentious global environment in the future if the developing world believes the West's energy transition policies are to blame for slower economic growth than expected.

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230 Vijaya Ramachandran, "Rich Countries' Climate Policies Are Colonialism in Green," *Foreign Policy* (November 3, 2021). https://foreignpolicy.com/2021/11/03/cop26-climate-colonialism-africa-norway-world-bank-oil-gas/. Accessed July 19, 2023.

231 Leia Achampong, "Where do things stand on the global US $100 billion climate finance goal?" Eurodad (September 7, 2022). https://www.eurodad.org/where_do_things_stand_on_the_global_100_billion_climate_finance_goal. Accessed July 19, 2023.

Similarly, another area triggering division and tension is climate-friendly trade policies. Carbon border adjustment mechanisms (CBAMs)—also known as border carbon adjustments (BCAs) or border tax adjustments (BTAs)—is a trade policy tool imposing a cost on foreign imports based on carbon emissions to equalize the carbon-emission costs placed on domestic producers. The EU's plan to fully implement its CBAM by 2026 has sparked questions and debate about the future of trade in a climate-conscious world. The EU's CBAM is slated to be the world's first carbon border adjustment scheme. The EU first presented a legislative proposal on CBAM in July 2021, which was presented as a part of the European Green Deal adopted in 2019. The purpose of CBAM is to reconcile the issue that several EU domestic producers have been subject to a carbon price through the EU's Emissions Trading System (ETS) since 2005, but they must still compete with foreign imports not subject to equivalent carbon prices by their respective countries. The ETS and CBAM are two mechanisms the EU is using to reduce its use of fossil fuels to achieve its commitment of carbon neutrality by 2050.

Under the ETS, the EU sets a cap on the amount of CO2 emissions companies operating in certain carbon-intensive industries are permitted to emit. Those companies must purchase or receive allowances for every ton of CO2 they are allowed to emit within one calendar year. Companies exceeding the cap can purchase allowances from companies emitting below the cap—a mechanism enabled through a cap-and-trade system—or face penalties. The EU has provided domestic producers with free allowances to help them compete with foreign producers and mitigate carbon leakage (the relocation of companies to countries with laxer emissions regulations).[232] When CBAM enters into force in 2026, importers will have to buy certificates linked to the weekly average ETS carbon price, which has been between 60 and 100 euros per ton of CO2. Thus, EU imports will be subject to an equivalent carbon price as EU domestic products.[233] If foreign products are already subject to a carbon price in their home country, then that will be accounted for in the final levy. CBAM will have a transitional period, which as of June 2023, is expected to run from October 2023 to

232 European Commission, "Carbon leakage." https://climate.ec.europa.eu/eu-action/eu-emissions-trading-system-eu-ets/free-allocation/carbon-leakage_en. Accessed March 2023.

233 Jennifer L, "EU Carbon Prices Surge to 100 Euros," Carbon Credits (February 21, 2023). https://carboncredits.com/eu-carbon-prices-surge-to-100-euros/. Accessed July 19, 2023.

December 2025.[234] During this transitional period, EU importers of relevant products will have to report emissions levels. Although the reporting burden falls on the EU importer, the emissions tracking burden also falls on the foreign producer. Imports of iron and steel, cement, fertilizers, aluminum, and electricity generation will initially fall under CBAM requirements, and by 2030, CBAM will extend to cover all products under the ETS.[235]

Since the EU's announcement of CBAM, several countries and organizations have expressed concern. Emerging nations Brazil, Russia, India, China, and South Africa (BRICS) have vocally stated their collective opposition to carbon border tariffs. In a May 2022 joint statement issued at the BRICS High-level Meeting on Climate Change, it stated,

> We oppose any measures to restrict trade and investment and setting up new green trade barriers with the pretext of addressing climate change, such as the imposition of Carbon Border Adjustment Mechanisms, which are incompatible with multilateral rules under the World Trade Organization.[236]

The Like Minded-Group of Developing Countries has also expressed opposition to carbon border adjustments.[237] The international development organization Oxfam International has accused the EU of forcing least developed countries—which are hardest hit with climate change impacts—to pay tariffs, as least developed countries are not exempt from CBAM.[238]

234 Jana Titievskaia, Henrique Morgado Simões, and Alina Dobreva, "EU carbon border adjustment mechanism: Implications for climate and competitiveness," European Parliament Members' Research Service (March 2023). https://www.europarl.europa.eu/RegData/etudes/BRIE/2022/698889/EPRS_BRI(2022)698889_EN.pdf. Accessed July 19, 2023.

235 PricewaterhouseCoopers International Limited, "EU Carbon Border Adjustment Mechanism (CBAM) – what do businesses in the Middle East need to know?" In brief (January 10, 2023). https://www.pwc.com/m1/en/services/tax/me-tax-legal-news/2023/eu-carbon-border-adjustment-mechanism.html. Accessed July 19, 2023.

236 Ministry of Ecology and Environment of the People's Republic of China, "Joint Statement issued at the BRICS High-level Meeting on Climate Change," BRICS 2022 China (May 24, 2022). http://brics2022.mfa.gov.cn/eng/hywj/ODMM/202205/t20220529_10694182.html. Accessed June 2023.

237 Silvia Weko, "The future for global trade in a changing climate," Chatham House (December 5, 2022). https://www.chathamhouse.org/2022/12/future-global-trade-changing-climate. Accessed July 19, 2023.

238 Jade Tenwick and Julia Manresa, "EU carbon border tariff passes the buck to the least responsible," Oxfam International (December 13, 2022). https://www.oxfam.org/en/press-releases/eu-carbon-border-tariff-passes-buck-least-responsible. Accessed July 19, 2023.

There is also a concern that carbon border adjustments will create a new administrative requirement on foreign exporters to the EU to monitor, calculate, report, and verify carbon emissions of certain goods, which will be harder for developing countries to fulfill. Concerns about the impact on developing countries have been underpinned by quantitative studies showing that carbon border adjustments have the potential to exacerbate income inequality between developed and developing countries.[239] A 2022 paper from Boston University sums up general concerns about carbon border taxes,

> There are concerns that a unilateral EU CBAM will not only distort international trade, but also shift the burden of addressing climate change to developing countries. Many lower-income developing countries are slow in transitioning toward low-carbon economies, and they often rely more on the exports of carbon-intensive products. Some developing countries are the major exporters of carbon-intensive goods. For example, China, India and Russia are the top carbon net exporters, while developed countries such as the U.S., UK, Japan and European countries are carbon net importers. Many fear that developing countries risk being disproportionally burdened by the CBAM or similar policies initiated by developed countries. It is believed that, in the worse scenarios, these policies may exacerbate global inequality.[240]

Supporters of CBAM argue carbon border adjustments have the potential to speed up decarbonization efforts by influencing companies worldwide to reduce their carbon footprint and compelling governments to establish carbon pricing domestically. Supporters also argue the actual effect on countries' economies will be low.[241] As of 2021, the industries initially

239 He Xiaobei, Zhai Fan, and Ma Jun, "The Global Impact of a Carbon Border Adjustment Mechanism: A Quantitative Assessment," Boston University's The Task Force on Climate, Development and the IMF (March 2022). https://www.bu.edu/gdp/files/2022/03/TF-WP-001-FIN.pdf. Accessed July 19, 2023.

240 Ibid.

241 Silvia Weko, "The future for global trade in a changing climate," Chatham House (December 5, 2022). https://www.chathamhouse.org/2022/12/future-global-trade-changing-climate. Accessed July 19, 2023.

covered under CBAM made up 3.2% of the EU's annual total imports.[242] However, if carbon border adjustments were adopted by other developed nations over time, and the covered industries extended, then the economic impacts on developing countries would increase, which is the underlying concern of those that oppose CBAM. A 2021 study by UNCTAD shows CBAM will likely result in a reduction of relevant imports from developing countries and an increase of relevant imports from developed countries with more carbon efficient production processes.[243] Based on the initial basket of products covered by CBAM, other studies have shown countries most impacted likely to be Russia, Ukraine, Turkey, China, and some African countries.[244] The impact on imports from Russia aligns with the EU's broader desire to reduce economic ties with Russia over its invasion of Ukraine, but the EU should be cautious of reducing trade ties to other developing countries, particularly those like Turkey and some African nations that are friendly with both Russia and the West.

In the United States, CBAM has provoked mixed reactions. After CBAM was announced in 2021, the U.S. government initially expressed concern with the potential serious implications for international trade and relationships. In 2021, the Biden administration's climate envoy John Kerry called it a "last resort" measure that should be used when all other options to reduce emissions have been exhausted.[245] Some U.S. policymakers oppose the EU's unilateral action with CBAM and believe the United States, Europe, and other like-minded countries should work

242 Muyu Xu and David Stanway, "EU's planned carbon border tax to impact Russia the most -study," Reuters (August 31, 2021). https://www.reuters.com/business/environment/eus-planned-carbon-border-tax-impact-russia-most-study-2021-09-01/. Accessed July 19, 2023.

243 Claudia Contreras, Robert Hamwey, and Graham Mott, et al., *A European Union Carbon Border Adjustment Mechanism: Implications for developing countries,* United Nations Conference on Trade and Development (July 14, 2021). https://unctad.org/system/files/official-document/osginf2021d2_en.pdf. Accessed July 19, 2023.

244 Andreas Goldthau and Karsten Neuhoff, "Why the war in Ukraine warrants a rethink of the EU carbon border tax," Euractv (July 28, 2022), https://www.euractiv.com/section/energy-environment/opinion/why-the-war-in-ukraine-warrants-a-rethink-of-the-eu-carbon-border-tax/ (accessed July 19, 2023); Mirela Petkova, "Weekly data: EU's CBAM to impact Russia, China and the UK the most," Energy Monitor (February 7, 2022), https://www.energymonitor.ai/policy/carbon-markets/eus-cbam-to-impact-russia-china/ (accessed July 19, 2023); and Samuel Pleeck, Fatima Denton, and Ian Mitchell, "An EU Tax on African Carbon – Assessing the Impact and Ways Forward," Center for Global Development Blog Post (February 10, 2022), https://cgdev.org/blog/eu-tax-african-carbon-assessing-impact-and-ways-forward (accessed July 19, 2023).

245 Leslie Hook, "John Kerry warns EU against carbon border tax," *Financial Times* (March 11, 2021). https://www.ft.com/content/3d00d3c8-202d-4765-b0ae-e2b212bbca98. Accessed July 19, 2023.

together to form a “climate club” or “carbon club” where a climate-friendly trade policy would be coordinated among the group to enhance mutual benefits. A central opposition among this group of U.S. policymakers is that the EU’s CBAM would not account for U.S. regulations, like the Clean Air Act, which reduce emissions and already impose additional costs on U.S. businesses to reduce emissions.[246] U.S. policymakers in favor of carbon border adjustments view it as a way to improve the United States’ trade competitiveness, especially with China, because the United States has production processes more carbon efficient than its competitors. For example, U.S. steel exports could be more competitive than Chinese steel in European markets under CBAM.[247] In June 2022, U.S. Senator Sheldon Whitehouse of Rhode Island introduced to Congress the Clean Competition Act, which includes a carbon border adjustment tax, similar to CBAM, but it exempts least developing countries.[248]

246 U.S. Senator Kevin Cramer, “The EU Goes Rogue on Climate Policy With CBAM,” press release (December 15, 2022). https://www.cramer.senate.gov/news/press-releases/icymi-sen-cramer-op-ed-the-eu-goes-rogue-on-climate-policy-with-cbam. Accessed June 2023.

247 Joseph Majkut, “The United States Should Learn to Live with EU CBAM,” Center for Strategic and International Studies (January 17, 2023). https://www.csis.org/analysis/united-states-should-learn-live-eu-cbam. Accessed July 19, 2023.

248 U.S. Senator Sheldon Whitehouse, “Whitehouse and Colleagues Introduce Clean Competition Act to Boost Domestic Manufacturers and Tackle Climate Change,” press release (June 8, 2022), https://www.whitehouse.senate.gov/news/release/whitehouse-and-colleagues-introduce-clean-competition-act-to-boost-domestic-manufacturers-and-tackle-climate-change (accessed July 19, 2023); and U.S. Senate of the United States, “A Bill: To amend the Internal Revenue Code of 1986 to create a carbon border adjustment based on carbon intensity, and for other purposes,” 117th Congress 2D Session, GAI22177 Y74 (2022),
https://assets.law360news.com/1501000/1501316/clean%20competition%20act.pdf (accessed July 19, 2023).

Risks and Potential Implications

Global economic mechanisms created by the West to compel other countries to reduce emissions, like carbon border adjustments and limiting financing of certain energy projects, run the risk of alienating developing countries and creating a diplomatic gap for China and/or Russia to fill, which might give China and Russia an advantage in the context of great power competition. The United States and allied countries should not discount the possibility of coordinated opposition from developing countries led by U.S. adversaries if the United States and allied nations continue to pursue and double down on these mechanisms.

Russia and China have been among the most vocally against CBAM, threatening to launch a complaint with the World Trade Organization (WTO). India has also openly opposed CBAM and is likely considering raising the issue with the WTO.[249] India likely believes if CBAM is expanded to cover additional industries in the future, like refined oil, chemicals, and textiles, it could have a significant economic impact on India.[250] Considering the widespread opposition to carbon border adjustment schemes by developing countries, in the future, countries could coalesce around this issue with China and Russia leading the momentum. Carbon border adjustments could trigger retaliatory trade measures by countries opposing the additional costs, such as the BRICS. For instance, if the United States joins the EU in creating a carbon border adjustment, coordinated opposition among developing countries could give way to new trading blocks and partnerships with China and Russia leading efforts.

These global trade and financing rules will further drive a wedge between developed and developing nations on how best to address climate change. Differences on how best to tackle climate change already exist between developed and developing nations. As mentioned in an earlier section, China and most developing nations uphold the principle of CBDR-RC. CBDR-RC acknowledges the common responsibility of nations to address climate change but promotes stricter standards and duties for developed nations

249 Manoj Kumar and Neha Arora, "India plans to challenge EU carbon tax at WTO," Reuters (May 16, 2023). https://www.reuters.com/world/india/india-plans-challenge-eu-carbon-tax-wto-sources-2023-05-16/. Accessed July 19, 2023.

250 Aishwarya Pathak, "Impact of carbon border adjustment mechanism on India," *Times of India* (January 28, 2023). https://timesofindia.indiatimes.com/readersblog/cosmopolitan/impact-of-carbon-border-adjustment-mechanism-on-india-49738/. Accessed July 19, 2023.

because they have been the world's largest emitters, have industrialized and economically developed while using fossil fuels, and currently have more technological and financial resources. Most developing nations also want a greater focus on climate adaptation, while developed nations have put a larger emphasis on climate mitigation. These new global trade and financing rules place the same strict standard on all countries regardless of their development status and do not align with the principle of CBDR-RC. Carbon border adjustments might also reduce developing countries' ability to focus on adaptation due to potential reallocation of state resources to help exporting businesses adapt to carbon border adjustments and tracking emissions. The EU's CBAM does not provide an exemption for least developed nations because exempting least developed nations might lead to carbon leakage, as some companies may relocate their operations to countries with exemptions.

The "Climate Club" proposed by Germany at the G7 Summit in June 2022 and created in late 2022 could also experience similar backlash that provides China and Russia with leverage to build strong diplomatic and trading relations with disgruntled developing nations. Germany and others have stated the club is open to all countries committed to global climate goals, including the Paris Agreement and the Glasgow Climate Pact, and to those countries ready to accelerate their actions.[251] However, given that the EU and the United States already have more carbon efficient production processes than developing countries, it would be much harder for developing countries to join such a climate club. If admission was given to developing countries that could not accelerate their actions as quickly as the EU and the United States, then there would not be much of a difference between the climate club and the UN's Conference of Parties (COPs). The formation of climate clubs, amid the current geopolitical climate and great power competition with China and Russia, would likely open opportunities for China and Russia to engage with countries that do not agree with the West's climate approach and potentially open doors to clubs excluding the West.

251 G7 Germany 2022, "G7 Statement on Climate Club" (June 28, 2022). https://www.g7germany.de/resource/blob/974430/2057926/43099dc0d5bba6a5cdefca66c9114ec6/2022-06-28-g7-climate-club-data.pdf?download=1. Accessed July 19, 2023.

Growing Risk of Cyber Threats due to Increased Electrification and Digitalization

The electricity sector is a major target for malicious cyberattacks, and the energy transition will increase the sector's vulnerability to cyberattacks in two ways. First, decarbonizing an economy calls for increased electrification to use renewable energy in the transportation and heating sectors. The electricity sector already has critical linkages to various parts of a country's economy and those linkages will expand during the energy transition. Therefore, in a future scenario in which the energy transition advances, a cyberattack that leads to an energy disruption would affect more parts of an economy, such as transportation. Secondly, the energy transition will increase cyber vulnerabilities because of increased digitalization and reliance on "smart" systems to support the integration of higher shares of variable renewable energy onto the electrical grid. DOE, along with public and private utilities, have taken measures to increase cybersecurity. However, increased digitalization, improved techniques by hackers, and persistent targeting of the aging U.S. grid by adversaries has exposed the existing cyber vulnerabilities of the U.S. grid.

The energy transition is electricity intensive, requiring massive increases in electrification to decarbonize different parts of an economy, including power, transport, and heat. Global electricity demand would need to grow by nearly 160% by 2050, compared with 2021, to meet the global net-zero goal while also meeting growing demand in developing countries due to population and economic growth.[252] The highest quality, most productive, and lowest costing renewable energy resources typically exist in remote areas. Therefore, long-distance, high-capacity transmission lines must be constructed to transport the high volumes of electricity to populated areas.

Advanced digital technologies and greater system automation are required for network operators to manage the complex, variable, and distributed nature of renewable energy, such as solar and wind energy, and to keep situational awareness of resource availability and demand-side

252 International Energy Agency, *World Energy Outlook 2022* (November 2022), p281. https://www.iea.org/reports/world-energy-outlook-2022. Accessed July 19, 2023.

responses.[253] Increased digitalization can also improve energy efficiency, save costs, and help cut outage times; however, it also increases cyber vulnerabilities in the system. As explained in DOE's 2018 Multiyear Plan for Energy Sector Cybersecurity,

> Energy owners and operators have integrated advanced digital technologies to automate and control physical functions to improve performance and adjust to a rapidly changing generation mix. This has created a larger cyberattack surface and new opportunities for malicious cyber threats.[254]

A 2020 IEA report on cyber resilience highlights this issue further:

> … the growth in connected devices and distributed energy resources—such as distributed generation, EVs, and behind-the-meter storage—is expanding the potential cyberattack surface of electricity systems. Increased connectivity and automation throughout the electricity system could also make them more vulnerable to cyberattacks.[255]

Greater automation in the electricity sector is likely occurring faster than cyber threats are understood. A 2019 report from the World Energy Council warns, "The pace of digitalization in the energy sector may potentially outpace cyber defense and digital management capabilities, resulting in greater exposure to risk."[256] A 2022 report written by the Royal United Services Institute (RUSI) for Defence and Security Studies in the UK identified areas in which cyber vulnerabilities will increase as the share

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253 International Energy Agency, *Power systems in transition: Challenges and opportunities ahead for electricity security* (October 2020). https://www.iea.org/reports/power-systems-in-transition/cyber-resilience. Accessed July 19, 2023.

254 U.S. Department of Energy, *Multiyear Plan for Energy Sector Cybersecurity*, Office of Electricity Deliver and Energy Reliability (March 2018). https://www.energy.gov/ceser/articles/doe-multiyear-plan-energy-cybersecurity. Accessed July 19, 2023.

255 International Energy Agency, *Power systems in transition: Challenges and opportunities ahead for electricity security*.

256 Lucy Nottingham, et al., *Cyber challenges to the energy transition*, World Energy Council Insights Brief (2019). https://www.worldenergy.org/assets/downloads/Cyber_Challenges_to_the_Energy_Transition_WEC_MMC_2019.pdf. Accessed July 19, 2023.

of renewable energy increases, including Supervisory Control and Data Acquisition (SCADA) systems, legacy technologies, supply chains, and lithium-ion batteries. [257]

SCADA is an industrial control system meant to control processes remotely or onsite, interact directly with industrial equipment, and monitor and analyze real-time data to increase the operators' awareness of the conditions of assets and overall operations. With renewable energy, SCADA systems monitor the amount of energy available given weather patterns. The use of SCADA systems to provide grid stability will increase as higher shares of variable renewable energy are integrated onto the grid. According to the 2022 RUSI report, "…as SCADA analyses data collected in Wi-Fi-enabled devices, such as smart energy meters, vulnerabilities in these devices could act as backdoors, allowing for unauthorized access to any operation that SCADA manages." The report continues, "the wide range of different devices connected through SCADA accompanying the shift to renewables will be more volatile and harder to control. This will require a much wider array of automated signals going across the grid which are potentially vulnerable to cyberattacks."[258]

The 2022 RUSI report also describes legacy technologies or "outdated and insecure grid technology" as a cyber risk for the energy transition, as renewable generation is distributed via older infrastructure.[259] Electric grids in various countries around the world are facing the challenge of having to modernize old electrical grids based on technologies developed decades ago. Even in the United States, 70% of transmission lines and 60% of the circuit breakers are at least 30 years old or more.[260]

Supply chains are another area of cyber risk. Electricity sector supply chains are growing and becoming more complex with increased global demand for digital and smart technologies. The growth of software and hardware components being sold by different vendors under various

257 Sneha Dawda, Chamin Herath, and Jamie MacColl, *Securing a Net-Zero Future: Cyber Risks to the Energy Transition*, Royal United Services Institute for Defence and Security Studies (January 2022). https://static.rusi.org/305-EI-Cyber-Risks.pdf. Accessed July 19, 2023.

258 Ibid.

259 Ibid.

260 Chuck Brooks, "3 Alarming Threats To The U.S. Energy Grid – Cyber, Physical, And Existential Events," Forbes (February 15, 2023). https://www.forbes.com/sites/chuckbrooks/2023/02/15/3-alarming-threats-to-the-us-energy-grid--cyber-physical-and-existential-events/?sh=45765e15101a. Accessed July 19, 2023.

standards around the world poses cyber risks as little may be known about the cybersecurity of certain components. The 2022 RUSI report also highlights lithium-ion batteries as a potential entry point for cyberattacks, which are increasingly being used to store renewable energy. According to RUSI, the battery management system of lithium-ion batteries "is a point of exposure and potential vulnerability" as "weaknesses in encryption, authorization, remote access and much more can pose as potential entry points into the control layer." Home car chargers pose similar intrusion point vulnerabilities. [261]

Nonetheless, it is difficult to speculate the types of cyberattacks or the magnitude of energy disruptions that might occur in the future. Broadly, cyberattacks typically are done by cybercriminals for financial gain. A high volume of cybercrimes are in the form of a ransomware attack, where hackers pose a ransom in exchange for decryption, with the objective of financial gain.[262] However, there is a growing threat from U.S. adversaries and state-sponsored actors that embark on cyber intrusions as an act of gray zone warfare, with the intention of stealing information, espionage, disrupting operations, or damaging infrastructure.[263] In terms of state-sponsored cyber threats, the countries that pose the greatest cyber threat to the United States are Russia, China, Iran, and North Korea and their surrogates, according to the 2021 Annual Threat Assessment (ATA) released by the U.S. Office of the Director of National Intelligence (ODNI).[264]

261 Sneha Dawda, Chamin Herath and Jamie MacColl, *Securing a Net-Zero Future: Cyber Risks to the Energy Transition*.

262 Charles Griffiths, "The Latest 2023 Ransomware Statistics," AAG (June 2023). https://aag-it.com/the-latest-ransomware-statistics/. Accessed July 19, 2023.

263 John Koon, "Power Grids Under Attack," Semiconductor Engineering (February 3, 2022). https://semiengineering.com/power-grids-under-attack/. Accessed July 19, 2023.

264 Office of the Director of National Intelligence, *Annual Threat Assessment of the US Intelligence Community* (April 9, 2021). https://www.odni.gov/files/ODNI/documents/assessments/ATA-2021-Unclassified-Report.pdf. Accessed July 19, 2023.

Risks and Potential Implications

Barring a wartime scenario, a prolonged or widespread disruption to electricity supplies is more likely to stem from a weather-related disruption, like prolonged severe hot or cold weather and major hurricanes, rather than a cyberattack from a U.S. adversary. Nevertheless, as tensions among great powers rise amid multiple geopolitical issues—like Russia's invasion of Ukraine and China's claim to Taiwan and islands in the South China Sea and East China Sea—the risk of cyberattacks increases, particularly as a gray zone confrontation below the threshold of war. An expansion of the cyberattack surface area and vulnerabilities in the electricity sector, amid existing cyber threats from U.S. adversaries, will present growing risks for private and public utilities as the energy transition advances in the future.

The ODNI's 2023 ATA assessed that China was most certainly capable of cyberattacks that could disrupt U.S. critical infrastructure, including oil and gas pipelines and rail systems, and: "If Beijing feared that a major conflict with the United States were imminent, it almost certainly would consider undertaking aggressive cyber operations against U.S. homeland critical infrastructure and military assets worldwide."[265] Russia is also identified as a top cyber threat as

> Russia is particularly focused on improving its ability to target critical infrastructure, including underwater cables and industrial control systems, in the United States as well as in allied and partner countries, because compromising such infrastructure improves and demonstrates its ability to damage infrastructure during a crisis.[266]

Iran is another growing cyber threat to the United States and its allies, as demonstrated by its capability to launch multiple cyberattacks against Israeli water facilities between April and July 2020. On North Korea, the

265 Office of the Director of National Intelligence, *Annual Threat Assessment of the US Intelligence Community* (February 6, 2023). https://www.dni.gov/files/ODNI/documents/assessments/ATA-2023-Unclassified-Report.pdf. Accessed July 19, 2023.

266 Office of the Director of National Intelligence, *Annual Threat Assessment of the US Intelligence Community* (February 2022), https://www.dni.gov/files/ODNI/documents/assessments/ATA-2022-Unclassified-Report.pdf (accessed July 19, 2023); Office of the Director of National Intelligence, *Annual Threat Assessment of the US Intelligence Community* (February 6, 2023).

ATA assessed "Pyongyang probably possesses the expertise to cause temporary, limited disruptions of some critical infrastructure networks and disrupt business networks in the United States." However, the type of critical infrastructure, whether that includes U.S. electricity infrastructure, is not specified in the unclassified ATA.

The threat of state-sponsored cyber operations targeting U.S. electricity systems has been ongoing for years. In June 2021, Energy Secretary Jennifer Granholm publicly stated that U.S. adversaries were capable of shutting down the U.S. electric grid through cyber means.[267] Granholm's statement follows multiple years of warnings from the U.S. government and grid regulators that U.S. adversaries had gained access into domestic energy systems. In 2018, the U.S. Department of Homeland Security (DHS) revealed a cyber campaign by the Russian government targeting the U.S. electrical grid, along with other U.S. critical infrastructure.[268] The Russian government-sponsored cyber actors gained remote access into energy sector networks, conducted network reconnaissance, moved laterally, and collected information pertaining to Industrial Control Systems, according to DHS.[269] That same year, DHS also announced Russian cyber actors had gained the ability to inflict power blackouts and disruptions after breaking into the control rooms of multiple U.S. electric utilities.[270] In 2019, the North American Electric Reliability Corporation (NERC), a U.S. grid regulator, revealed that a cyber hacking group with possible Russian ties "was conducting reconnaissance into the networks of electrical utilities," according to the Center for Strategic International Studies' Significant Cyber Incidents tracker.[271]

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267 Chandelis Duster, "Energy secretary says adversaries have capability of shutting down US power grid," CNN (June 6, 2021). https://www.cnn.com/2021/06/06/politics/us-power-grid-jennifer-granholm-cnntv/index.html. Accessed July 19, 2023.

268 U.S. Department of Homeland Security, "Russian Government Cyber Activity Targeting Energy and Other Critical Infrastructure Sectors," Alert (March 16, 2018). https://www.cisa.gov/news-events/alerts/2018/03/15/russian-government-cyber-activity-targeting-energy-and-other-critical. Accessed July 19, 2023.

269 Ibid.

270 Gavin Bade, "Russian hackers infiltrated utility control rooms, DHS says," Utility Dive (July 24, 2018). https://www.utilitydive.com/news/russian-hackers-infiltrated-utility-control-rooms-dhs-says/528487/. Accessed July 19, 2023.

271 CSIS' Strategic Technologies Program, "Significant Cyber Incidents." https://www.csis.org/programs/strategic-technologies-program/significant-cyber-incidents. Accessed March 2023.

In the case of China, almost a decade ago in 2014 the head of the U.S. Cyber Command and the director of the National Security Agency warned China was capable of conducting cyberattacks that could shut down the U.S. electrical grid.[272] Chinese and Russian government groups likely have conducted years of reconnaissance into U.S. critical infrastructure, including U.S. power systems, to either position themselves to potentially conduct an attack in the future and/or as a means of exercising multi-domain deterrence.

The 2023 U.S. Cybersecurity Strategy places the onus on the private sector to implement cybersecurity measures.[273] This extends to the electricity sector, as private sector companies own and provide most of the country's electricity generation, transmission, and distribution assets. Private-sector utilities and companies now face competing priorities: they are expected to accelerate the energy transition by hastening the construction and installation of new infrastructure and procuring equipment and materials from global supply chains with various vendors and standards while also being told to adopt measures to minimize cyber threats and incorporate cybersecurity and resilience. How will these private actors juggle these competing priorities?

272 Adam Segal, "China and the Power Grid: Hacking and Getting Hacked," Council on Foreign Relations Blog Post (December 3, 2014). https://www.cfr.org/blog/china-and-power-grid-hacking-and-getting-hacked. Accessed July 19, 2023.

273 Brandon Kirk Williams, "Biden to private sector: Cybersecurity is your responsibility—not the user's," *Bulletin of the Atomic Scientists* (May 1, 2023). https://thebulletin.org/2023/05/biden-to-private-sector-cybersecurity-is-your-responsibility-not-the-users/. Accessed July 19, 2023.

Energy-related Disinformation Campaigns from China and Russia

On different occasions, China and Russia have undertaken energy-related disinformation campaigns in an attempt to maintain, in the case of China, dominance of global REE processing, and in the case of Russia, dominance of natural gas exports to Europe. Both Chinese and Russian disinformation campaigns have targeted environmental advocates in Western societies, focusing on the potential and supposed environmental harms associated with the activity. While Russia has a richer history of conducting energy-related disinformation campaigns, disinformation campaigns from China have the potential to pose more problems for the energy transition, such as U.S. and allied plans to reduce China's global monopoly of REE processing.

China's energy-related disinformation

China is responsible for about 90% of REE processing globally and has been able to maintain that monopoly for decades. China is likely attempting to stifle competitors' attempts to reduce China's processing monopoly, as was done in the past with China's monopoly on REE mining. China's share of global REE mining has fallen from 98% in 2010 to 70% in 2022 due in part to diversification efforts by others.[274] China's REE export quota restrictions in 2010 prompted Japan to invest in mining with the Australian company Lynas Rare Earth, and mining also increased in Burma and the United States. Although countries were able to reduce their dependence on China for REE mining, about 90% of the world's raw REE, no matter where it is mined, is sent to China for processing. The only other major REE processing plant outside of China exists in Malaysia—which is the world's largest single REE processing plant and is operated by Lynas Rare Earth but is facing the threat of partial closure by the Malaysian government because of concerns over radioactive waste.[275] REEs are not only important for clean energy technologies like wind turbines and EVs, but they are also used in defense applications, like jet engines, precision-guided weapons, and the Virginia-

274 U.S. Geological Survey, *Mineral commodity summaries 2023* (January 31, 2023). https://pubs.usgs.gov/periodicals/mcs2023/mcs2023.pdf. Accessed July 19, 2023.

275 Lynas Rare Earths, https://lynasrareearths.com/ (accessed March 2023); and Tinzar Htun, "China's Consolidation of Rare Earth Elements Sector," The Payne Institute for Public Policy Commentary (May 1, 2023), https://repository.mines.edu/handle/11124/176887 (accessed July 19, 2023).

class submarine, electronics, like cellphones and flat-screen monitors, and medical equipment.[276]

In June 2022, a U.S. cybersecurity company revealed that a pro-China network behind a broad influence campaign called DRAGONBRIDGE posed as Americans on multiple social media platforms, launching a smear campaign against various new REE projects by Lynas, Canada's Appia Rare Earths & Uranium Corporation, and USA Rare Earth. The pro-China group posed as Texans against the processing facility that Lynas is building in Texas and called for protests. The group claimed the REE companies caused environmental harm to surrounding communities and warned Texan citizens of radiation poisoning, toxic waste, and serious health risks. The group had also promoted content criticizing America's passing of the Defense Production Act in March 2022 to spur domestic production of critical minerals.[277] An Australian think tank also investigating the disinformation believes that the group is backed by the CPP, and that it is a CPP information operation.[278]

Pro-China disinformation campaigns against REE processing facilities might increase over the next few years in an attempt to delay or halt the new separation facilities planned outside of China, or to preemptively reduce the probability of other countries undertaking new processing facilities. New REE processing facilities are planned in Australia, the UK, and the United States (Figure 11). The United States and its allies are also planning to bring online lithium processing sites to reduce their dependence on China, which accounts for about 50% to 70% of lithium processed globally. The United States currently mines about 1% of the world's lithium via its sole operational mine in Nevada and has limited processing capabilities. Efforts to expand lithium mining in the United States are underway, and the U.S. company Albemarle plans to build the first major lithium processing facility in America. The possibility of Chinese-linked disinformation campaigns targeting new lithium projects in the United States and allied countries should not be ruled out.

276 Maiya Clark and Ryan Williams, "Rare Earth Elements Aren't That Rare, but They're Vital to National Security," The Heritage Foundation (February 26, 2021). https://www.heritage.org/defense/commentary/rare-earth-elements-arent-rare-theyre-vital-national-security. Accessed July 19, 2023.

277 Mandiant Threat Intelligence, "Pro-PRC DRAGONBRIDGE Influence Campaign Targets Rare Earths Mining Companies in Attempt to Thwart Rivalry to PRC Market Dominance," Mandiant Blog (June 28, 2022). https://www.mandiant.com/resources/blog/dragonbridge-targets-rare-earths-mining-companies. Accessed May 2023.

278 Albert Zhang, "The CCP's information campaign targeting rare earths and Australian company Lynas," Australian Strategic Policy Institute (June 29, 2022). https://www.aspistrategist.org.au/the-ccps-information-campaign-targeting-rare-earths-and-australian-company-lynas/. Accessed July 19, 2023.

Figure 11. Planned Rare Earth Processing Facilities in the United States and Allied Countries

Location	Company	Year [1]	Notes
Australia	Lynas Rare Earth	2023	Building the Kalgoorlie rare earth processing plant
Australia	Iluka Resources	2025	Building a facility with the potential to supply 9% of the world's rare earth oxide market
United Kingdom	Pensana	2024	Building a facility to process rare earth from a mine it's developing in Angola
United States	MP Materials	NA	In 2020, the U.S. Department of Defense (DOD)[2] awarded MP Materials $9.6 million toward the construction of a light rare earth (LRE) facility at Mountain Pass California—America's sole commercial-scale rare earth mine, which sends its mined rare earth to China for processing and accounts for about 10-15% of the world supply of unseparated light rare earth oxides. In 2022, DOD also provided $35 million to build the heavy rare earth (HRE) facility at MP Materials' existing rare earth mine in Mountain Pass.
United States	Lynas Rare Earth	2025	In 2022, Australia's Lynas Rare Earth signed a $120 million contract with DOD to build a HRE separation facility in Texas. DOD will fund the full construction costs of the HRE facility and plans to fund half the cost for a Light Rare Earth (LRE) facility that Lynas also plans to build in same area. The rare earth for the HRE facility will come from mines in Australia.

Sources: Lynas Rare Earth's Kalgoorlie rare earth processing plant,[279] Iluka Resources' plant,[280] Pensana's facility in Angola,[281] MP Materials facilities in Mountain Pass,[282] and Lynas Rare Earth's facility in Texas[283]

Note: [1]"Year" reflects the expected start date or full-production capacity date of the facility. [2]Since 2019, the U.S. government has passed multiple Defense Production Acts and technology investment agreements to provide funds to private companies to build processing facilities in the United States.

279 Reuters Staff, "UPDATE 1-Rare-earths producer Lynas' Kalgoorlie facility faces labour shortages," Reuters (June 18, 2023), https://www.reuters.com/article/lynas-rare-kalgoorlie-idUKL4N38B063 (accessed July 19, 2023); Mary B. Powers, "Fluor Wins Rare Earths Plant Project as US, Australia Markets Expand," ENR (June 29, 2022), https://www.enr.com/articles/54374-fluor-wins-rare-earths-plant-project-as-us-australia-markets-expand (accessed July 19, 2023).

280 Sonali Paul and Harshita Swaminathan, "Backed by Australia, Iluka greenlights $750 mln rare earths refinery," Reuters (April 3, 2022). https://www.reuters.com/business/energy/backed-by-australia-govt-iluka-greenlights-750-mln-rare-earths-refinery-2022-04-04/. Accessed July 19, 2023.

281 Heidi Vella, "Diversifying rare earths: Inside Pensana's Angolan and Yorkshire projects," Mining Technology (May 2, 2022). https://www.mining-technology.com/features/rare-earths-diversity-supply/. Accessed July 19, 2023.

282 U.S. Department of Defense, "DoD Awards $35 Million to MP Materials to Build U.S. Heavy Rare Earth Separation Capacity," News Release (February 22, 2022), https://www.defense.gov/News/Releases/Release/Article/2941793/dod-awards-35-million-to-mp-materials-to-build-us-heavy-rare-earth-separation-c/ (accessed July 19, 2023); and U.S. Department of Defense, "DoD Awards $35 Million to MP Materials to Build U.S. Heavy Rare Earth Separation Capacity," News Release (February 22, 2022), https://www.defense.gov/News/Releases/Release/Article/2941793/dod-awards-35-million-to-mp-materials-to-build-us-heavy-rare-earth-separation-c/ (accessed July 19, 2023).

283 Lynas Rare Earths Ltd, "Lynas awarded $120M contract to build commercial HRE facility," press release (June 14, 2022), https://wcsecure.weblink.com.au/pdf/LYC/02531153.pdf; and Lynas Rare Earths Ltd, "Lynas Rare Earths: USA FAQs," FAQs (September 2022), https://lynasrareearths.com/wp-content/uploads/2022/09/Lynas-USA-Fact-Sheet-Sept-2022.pdf (accessed July 19, 2023).

Russia's energy-related disinformation

Russia has disseminated disinformation via social media platforms, its state-run news outlet RT, and environmental activist groups in an attempt to influence energy policies in Europe and the United States. Russian disinformation targeting Europe has mainly focused on amplifying concerns around domestic natural gas production and hydraulic fracturing—a method known as fracking and entails extracting oil and gas from shale rock—with the intent of rallying public protest against European gas production, thereby, leaving the region dependent on Russian gas.

A 2016 report from Wilfried Martens Center for European Studies, which received funding from the European Parliament, cited information obtained from experts that the Russian government provided $95 million to NGOs advocating against shale gas production in Europe, as shale gas production in Europe would undermine Russia's gas exports to the region.[284] During his term as NATO chief, Anders Fogh Rasmussen publicly stated in June 2014,

> I have met allies who can report that Russia, as part of their sophisticated information and disinformation operations, engage actively with so-called non-government organizations—environmental organizations working against shale gas—obviously to maintain European dependence on imported Russian gas.[285]

From 2011 to 2021, several countries in Europe announced bans or moratoriums on fracking, halting project plans by oil and gas companies.[286] Some European countries even considered banning imported gas that was

284 Vladislava Vojtíšková, Vít Novotný, Hubertus Schmid-Schmidsfelden, and Kristina Potapova, *The Bear in Sheep's Clothing: Russia's Government-Funded Organisations in the EU*, Wilfried Martens Centre for European Studies (2016). https://www.martenscentre.eu/wp-content/uploads/2020/06/russia-gongos_0.pdf. Accessed July 19, 2023.

285 Keith Johnson, "Russia's Quiet War Against European Fracking," *Foreign Policy* (June 20, 2014). https://foreignpolicy.com/2014/06/20/russias-quiet-war-against-european-fracking/. Accessed July 19, 2023.

286 Héctor Herrera, "The legal status of fracking worldwide: An environmental law and human rights perspective," GNHRE (January 6, 2020), https://gnhre.org/human-rights/the-legal-status-of-fracking-worldwide-an-environmental-law-and-human-rights-perspective/ (accessed July 19, 2023); and Isabelle Gerretsen, "Spain to end fossil fuel production by 2042 under new climate law," Climate Home News (May 14, 2021), https://www.climatechangenews.com/2021/05/14/spain-end-fossil-fuel-production-2042-new-climate-law/ (accessed July 19, 2023).

produced by fracking, including from the United States.[287] It's unclear to what extent the anti-fracking sentiment in Europe and subsequent bans on fracking can be attributed to Russian covert activities, but it likely had an influence.

Russian energy-related disinformation targeting the United States has mainly focused on amplifying concerns about fracking, domestic oil and gas production, and new pipelines, reflecting Russia's attempt to paint America's natural gas as less environmentally friendly than Russia and to negatively impact America's energy security by targeting new pipelines. A 2017 declassified version of a U.S. intelligence community report released by the U.S. Office of the Director of National Intelligence noted that RT, the Russian state-controlled international news outlet,

> …runs anti-fracking programming, highlighting environmental issues and the impacts on public health. This is likely reflective of the Russian Government's concern about the impact of fracking and U.S. natural gas production on the global energy market and the potential challenges to Gazprom's profitability.[288]

According to a 2018 report from United States House of Representatives Committee on Science, Space, and Technology titled *Russian Attempts to Influence U.S. Domestic Energy Markets by Exploiting Social Media,*

> Twitter, Facebook, and Instagram were able to identify Russian accounts linked to the Internet Research Agency (IRA), a Russian company based in Saint Petersburg established by the Russian government for the purpose of deceptively using various social and traditional media platforms to advance Russian propaganda. The information received from Twitter,

287 Reuters Staff, "France studying possible ban on import of U.S. Shale gas – minister," Reuters (May 10, 2016), https://www.reuters.com/article/france-usa-shalegas/france-studying-possible-ban-on-import-of-u-s-shale-gas-minister-idUSL5N1875VT (accessed July 19, 2023); and Priyanka Shrestha, "Ireland plans to ban fracked gas imports and stop LNG terminal developments," Energy Live News (May 24, 2021), https://www.energylivenews.com/2021/05/24/ireland-plans-to-ban-fracked-gas-imports-and-stop-lng-terminal-developments/ (accessed July 19, 2023).

288 U.S. Office of the Director of National Intelligence, "Background to Assessing Russian Activities and Intentions in Recent US Elections: The Analytic Process and Cyber Incident Attribution" (January 6, 2017). https://www.dni.gov/files/documents/ICA_2017_01.pdf. Accessed July 25, 2023.

> Facebook, and Instagram shows that Russian agents indeed sought to disrupt U.S. energy markets and influence domestic energy policy by exploiting American social media platforms. [289]

About 4% of IRA tweets during the period of the data, 2015-2017, were on energy or environmental issues, compared with 8% of IRA tweets on U.S. elections, indicating that energy and environmental issues is an important area for Russia's disinformation.[290] Furthermore, according to a 2017 letter from the U.S. Congressional Committee on Science, Space, and Technology to the then Treasury Secretary Steven Mnuchin, publicly available records supported their allegations that Russian entities funneled tens of millions of dollars through a shell company registered in Bermuda to environmental groups in the United States to influence their agendas.[291]

Risks and Potential Implications

Heightened competition during the energy transition will likely amplify energy-related disinformation campaigns, running the risk of exacerbating domestic political division in the United States and allied countries on the right energy transition pathway, particularly the growth in mining activities. The environmental issues associated with mining pose a real vulnerability for the U.S. and allied countries' goals to increase domestic mining and support the energy transition. Adversaries will likely perceive this as an opportunity to target the U.S. and allied publics with disinformation and amplify or exaggerate environmental and health concerns, while helping them to maintain a leadership position.

Considering that there are documented environmental and health problems associated with mining, the United States and allies need to get ahead of this and actively communicate these concerns and what will be done to mitigate and reduce these risks. These risks include mining and

289 U.S. Congress House Committee on Science, Space, and Technology, "Russian Attempts to Influence U.S. Domestic Energy Markets by Exploiting Social Media," Homeland Security Digital Library (March 1, 2018). https://www.hsdl.org/?abstract&did=808676. Accessed July 19, 2023.

290 Ibid. and U.S. Congress House Committee on Energy and Commerce, Letter from U.S. Representative Bill Johnson (March 7, 2022), https://billjohnson.house.gov/uploadedfiles/3.7.22_russia_energy_letter_final.pdf (accessed July 19, 2023); and Keith Johnson, "Russia's Quiet War Against European Fracking."

291 U.S. Congress House Committee on Science, Space, and Technology, "Smith, Weber Letter To Mnuchin Re Russia and Green Groups," uploaded to Scribd (June 29, 2017). https://www.scribd.com/document/353439133/Smith-Weber-Letter-to-Mnuchin-re-Russia-and-Green-Groups. Accessed July 19, 2023.

processing waste that can contaminate nearby water resources without proper waste storage, environmental damage to surrounding areas (soil, water, and air quality), and health problems in the community.[292] To this end, in 2019 the World Bank launched the Climate-Smart Mining Initiative to mitigate the environmental, climate, and social impact of mining in developing countries.[293] The World Bank forecast that production of energy transition minerals, like cobalt, graphite, and lithium, would need to increase by 500% by 2050 to fulfill the requirements of the energy transition. The United States should consider launching a similar initiative domestically to acknowledge potential environmental risks and communicate plans to mitigate those risks.

Both China and Russia have geopolitical and commercial incentives to pursue disinformation campaigns in this area. Its dominance of critical minerals and technologies for the energy transition has transformed China into a leader in clean energy supplies, which is different from its traditional role as a large energy consumer dependent on imports. The prospects of Western countries and partners increasing mining and processing, thereby reducing China's control of supply chains, might explain the motivations behind the DRAGONBRIDGE campaign targeting new REE processing projects.

Russia holds 16% of the world's REE reserves, and before Russia's invasion of Ukraine, Russia was offering financial incentives to companies with a goal of increasing Russia's share of global REE production from 0.01% to 10% by 2030.[294] Russia accounted for 17% of global mining of battery-grade, class 1 nickel, as of 2020, and prior to its invasion

292 Iris Crawford and Scott Odell, "Will mining the resources needed for clean energy cause problems for the environment?" MIT Climate Portal (July 21, 2022), https://climate.mit.edu/ask-mit/will-mining-resources-needed-clean-energy-cause-problems-environment (accessed July 19, 2023); and American Geosciences Institute, "Can we mitigate environmental impacts from mining?" https://www.americangeosciences.org/critical-issues/faq/can-we-mitigate-environmental-impacts-mining (accessed April 2023).

293 Climate-Smart Mining team, "Climate-Smart Mining: Minerals for Climate Action," World Bank Brief (May 26, 2019). https://www.worldbank.org/en/topic/extractiveindustries/brief/climate-smart-mining-minerals-for-climate-action. Accessed July 19, 2023.

294 Anastasia Lyrchikovaa and Gleb Stolyarov, "Russia has $1.5 billion plan to dent China's rare earth dominance," Reuters (August 12, 2020), https://www.reuters.com/article/russia-rareearths/russia-has-1-5-billion-plan-to-dent-chinas-rare-earth-dominance-idUSL8N2F73F4 (accessed July 19, 2023); and U.S. Geological Survey, *Mineral commodity summaries 2023.*

of Ukraine, planned to boost production up to 30% by 2030.[295] While the 2018 report *Russian Attempts to Influence U.S. Domestic Energy Markets by Exploiting Social Media* did highlight one instance of a Russian disinformation social media post targeting U.S. lithium mining, there is insufficient evidence to conclude that Russia is or will launch a campaign targeting critical minerals mining in Western countries, as seen with China's DRAGONBRIDGE. However, given Russia's history with disinformation in the energy sector with the purpose of exacerbating divisions, it should not be ruled out. In addition, Russia might amplify its efforts to paint U.S. natural gas production and new pipelines negatively to the U.S. public via social media outlets, particularly as the debate heats up about the role of natural gas in the energy transition.

295 International Energy Agency, "Share of global production and rank for selected minerals and metals in Russia, 2020" (May 13, 2022), https://www.iea.org/data-and-statistics/charts/share-of-global-production-and-rank-for-selected-minerals-and-metals-in-russia-2020 (accessed July 19, 2023); and *Mining Journal*, "Norilsk Nickel to boost production up to 30% by 2030," (November 18, 2019), https://www.mining-journal.com/base-metals/news/1375986/norilsk-nickel-to-boost-production-up-to-30-by-2030 (accessed July 19, 2023).

Energy Insecurity and Uncertainty

The United States' access to adequate energy supplies at affordable prices to fuel a healthy economy becomes even more important in the era of great power competition, especially economic competition with China. An energy crisis—characterized by supply shortfalls and exorbitant prices—can wreak havoc on an economy. While the transition to low-carbon fuels has promised to unlock an era of energy abundance, the beginning years of the transition have revealed that the pathway to decarbonization is not as easy as proponents have stated. There are multiple clear signs that decarbonization will take longer than a mere couple decades to the mid-century.

There are real risks associated with assuming the energy transition can be quickly achieved. Risks include: (1) an underinvestment in future energy supplies and high prices, (2) inadequate energy storage levels in disruptions and/or wartime scenarios, (3) concentration of oil and gas production in OPEC countries, and (4) public distrust of the reliability of low-carbon fuels. Before elaborating on these risks, the following sections will explain the several signposts showing the transition will likely take longer than expected and that the exact timing is largely uncertain. Several factors make the pace of transition uncertain, including timing of technological breakthroughs and deployment, financing the high cost of transition, buildout of electricity grids, and long-term affordability of clean energy compared with fossil fuel supplies, especially in developing countries.

Technological Breakthroughs and Deployment

Projections showing how the world can get to net zero by 2050 are 50% reliant on energy technologies that do not currently exist at scale and are not commercially viable. According to a June 2022 IEA report, "In the NZE [Net Zero Emissions by 2050 scenario], half of the emissions reductions by 2050 come from technologies, including small modular reactors, that are not yet commercially viable."[296] Other clean energy technologies that do not yet exist at scale or are not yet commercially or economically

296 International Energy Agency, *Nuclear Power and Secure Energy Transitions* (June 2022), p10. https://www.iea.org/reports/nuclear-power-and-secure-energy-transitions. Accessed July 19, 2023.

viable include carbon dioxide removal (CDR) technologies like direct air capture, long-duration energy storage to support renewable energy, and low-carbon hydrogen and ammonia. SMRs are being developed by over a dozen countries, but their commercial viability and economic costs are still somewhat unknown. According to the U.S.-based Institute for Energy Economics and Financial Analysis, the estimated cost for a SMR designed by NuScale, a U.S.-based company, has increased from $58 per megawatt hour (MWh) to $89 per MWh, and the total cost of NuScale's project in Utah rose from $5.3 billion to $9.3 billion.[297] Some U.S. utilities have been hesitant to partner with NuScale due to the rising costs and uncertainty.[298]

An unprecedented, massive rapid deployment of proven renewable energy, like solar and wind, is also needed to meet decarbonization goals. A 2022 study by the U.S. National Renewable Energy Laboratory modeled how the United States could achieve the Biden administration's goal of decarbonizing the U.S. electrical grid by 2035.[299] It found that annual deployment levels of solar and wind energy would have to increase for each by more than four times to achieve the least-cost electricity mix where solar and wind provide 60-80% of generation. According to NREL, this "requires a massive acceleration in deployment rates," nearly tripling the U.S. transmission capacity on the grid by 2035. It also requires technological breakthroughs with new forms of energy storage to support intermittent renewable energy. All these factors add to the uncertainty of the timing of the energy transition—not only in the United States, but worldwide.

297 David Schlissel, "Small modular reactor project likely to end badly for utilities and worse for taxpayers," Institute for Energy Economics and Financial Analysis (January 24, 2023), https://ieefa.org/resources/small-modular-reactor-project-likely-end-badly-utilities-and-worse-taxpayers (accessed July 19, 2023); and
Robert Walton, "Rising steel prices, interest rates could push NuScale Utah project cost to $100/MWh, but support remains," Utility Dive (November 16, 2022), https://www.utilitydive.com/news/nuscale-nuclear-reactor-smr-uamps-rising-steel-prices-interest-rates/636619/ (accessed July 19, 2023).

298 Adrian Cho, "Several U.S. utilities back out of deal to build novel nuclear power plant," *Science* (November 4, 2020). https://www.science.org/content/article/several-us-utilities-back-out-deal-build-novel-nuclear-power-plant. Accessed July 19, 2023.

299 U.S. Department of Energy, "NREL Study Identifies the Opportunities and Challenges of Achieving the U.S. Transformational Goal of 100% Clean Electricity by 2035," EERE (August 30, 2022), https://www.energy.gov/eere/articles/nrel-study-identifies-opportunities-and-challenges-achieving-us-transformational-goal (accessed July 19, 2023); and Paul Denholm, Patrick Brown, Wesley Cole, Trieu Mai, and Brian Sergi, "Examining Supply-Side Options to Achieve 100% Clean Electricity by 2035," NREL (August 2022), https://www.energy.gov/eere/articles/nrel-study-identifies-opportunities-and-challenges-achieving-us-transformational-goal (accessed July 19, 2023).

Hard-to-decarbonize areas—such as cement, asphalt, steelmaking, chemicals, long-distance trucking, shipping, and aviation—will be impossible to decarbonize with the current suite of commercial clean energy technologies. Thus, technological breakthroughs are needed for new forms of technology, like clean hydrogen.[300] However, it's still unknown and too preliminary to conclude that new forms of clean energy technologies will be able to displace fossil fuels in those hard-to-decarbonize areas in the foreseeable future.

Financing the High Cost of Transition

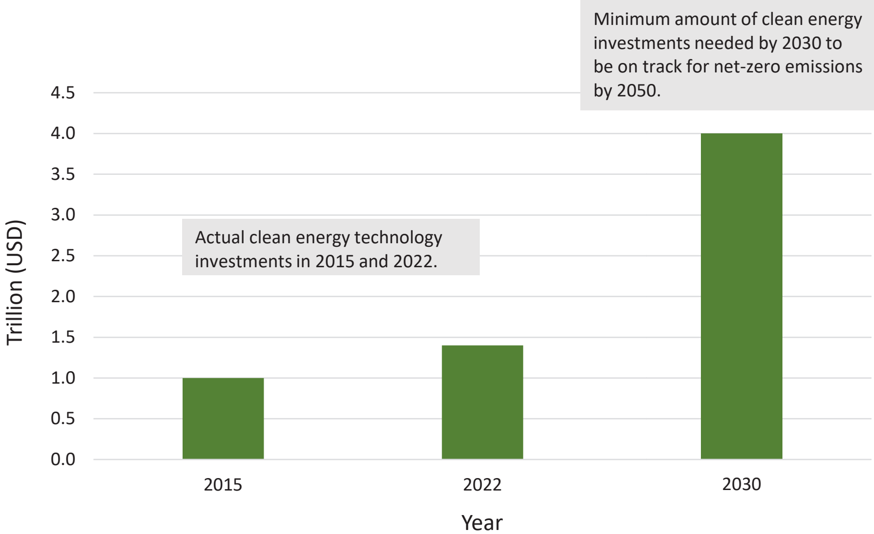
Global clean energy investments would have to increase substantially over the next seven years to be on track to meet net-zero emissions by 2050 and the global Paris Agreement goal. According to the IEA, clean energy investments hit $1.4 trillion in 2022, but would have to exceed $4 trillion per year by 2030 to align with the Paris Agreement (Figure 12).[301] Similarly, in early 2023 S&P Global estimated an almost $25 trillion cumulative funding gap between forecast spending and the investment level required to meet Paris Agreement goals.[302] Given the high funding requirements, clean energy investments will ultimately have to be largely privately, rather than publicly, financed and built. The ability of developed nations to incentivize such a level of financing and for developing nations to attract financing, while not falling into unsustainable debt, is a major issue underpinning the uncertainty of the energy transition and its timing.

300 Kellie Nault, "Clean Hydrogen: A long-awaited solution for hard-to-abate sectors," Harvard News (October 3, 2022). https://seas.harvard.edu/news/2022/10/clean-hydrogen-long-awaited-solution-hard-abate-sectors. Accessed July 19, 2023.

301 International Energy Agency, *World Energy Outlook 2022* (November 2022), p23. https://www.iea.org/reports/world-energy-outlook-2022. Accessed July 19, 2023.

302 Ashutosh Singh, Roman Kramarchuk, and Karl Nietvelt, "Energy Transition: Gaps in the Pathways," S&P Global (January 13, 2023). https://www.spglobal.com/en/research-insights/featured/special-editorial/look-forward/energy-transition-gaps-in-the-pathways. Accessed July 19, 2023.

Figure 12. Worldwide Annual Clean Energy Investments, 2015 to 2030



Source: International Energy Agency, World Energy Outlook 2022 and Energy Technology Perspectives 2023

Electricity Grids

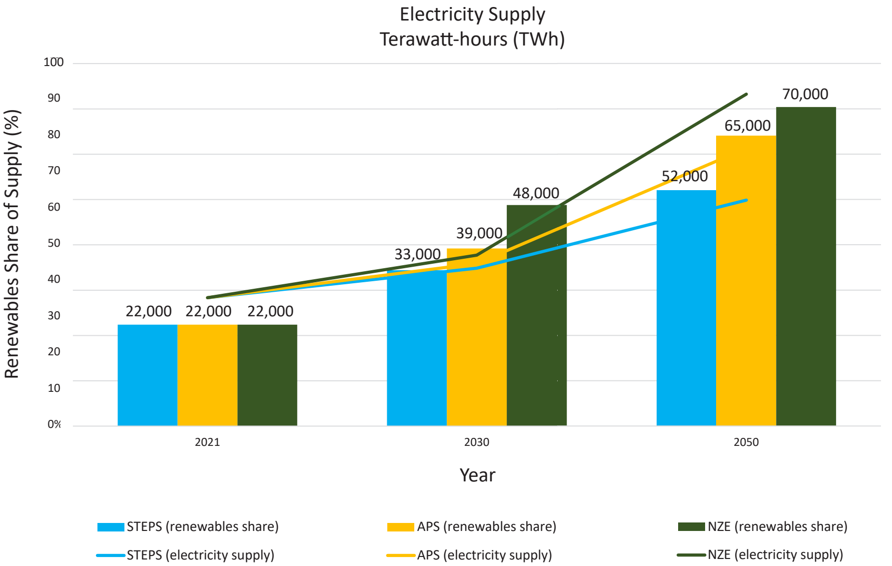
The electricity grid, just like energy storage, is an enabling technology of the energy transition. Without an expansion of grid capacity and upgrades to increase automation and efficiency, in both developed and developing countries, the energy transition will not come to fruition. The transition requires an expansion of grid capacity worldwide to support new demand coming from the transportation sector, heat-intensive industries, and hard-to-abate sectors.[303] This expansion will also need to support growing electricity demand in developing countries due to population growth and more demand for cooling.[304] For example, electricity supply worldwide would have to increase nearly 160% by 2050, compared with 2021, to reach the Paris Agreement goal in IEA's NZE scenario where renewable energy makes up 88% of global electricity supply, compared with 28% in 2021 (Figure

303 Frank A. Felder, "Policy Responses Needed for Grid Reliability Crisis," Energy Intelligence (September 1, 2022). https://www.energyintel.com/00000182-f871-d92d-a5b7-f8fdcc270000. Accessed July 19, 2023.

304 International Energy Agency, *World Energy Outlook 2022*, p277.

13).[305] In a scenario in which the Paris Agreement goal is not fully reached, but renewable energy increases to 65% of global electricity supply by 2050, electricity supply would have to grow cumulatively by 76%.[306] According to the IEA's 2021 report on a roadmap to net zero by 2050, annual investments in electrical grids would have to increase from $260 billion to $820 billion by 2030.[307]

Figure 13. IEA's Electricity Supply Projections to 2050



Source: International Energy Agency, World Energy Outlook 2022
Notes: STEPS is Stated Policy Scenario (trajectory implied by current policies), APS is Announced Pledges Scenario (assumes all aspirational targets announced by governments are met on time and in full) and NZE is Net Zero Emissions by 2050.

For instance, Europe has plans to install a massive amount—more than 66 GW per year on average—of solar and on-and-offshore wind capacity between now and 2030. However, according to a December 2022 report from energy consultancy Rystad Energy, insufficient grid capacity in Europe

305 Ibid., p281.

306 Ibid.

307 International Energy Agency, *Net Zero by 2050* (May 2021). https://www.iea.org/reports/net-zero-by-2050. Accessed July 19, 2023.

will impede it from fully integrating the new renewable capacity onto the grid and will lead to curtailment of solar and wind.[308] According to Rystad,

> With the pace of renewable energy development substantially exceeding the speed of grid upgrades and expansion projects in parts of Europe, policymakers and the power sector will need to carefully examine if a country's development plans for new generation capacity match its development plans for both internal and cross-border transmission capacity. The timelines for new projects are very long and some countries in Europe are already curtailing renewable power that could be used elsewhere.[309]

The situation in the United States is similar to Europe. U.S. grid capacity would have to nearly triple in capacity to meet the Biden administration's goal of decarbonizing the grid by 2035.[310] Electricity infrastructure in the United States has aged and needs major upgrades and modernization, potentially costing upwards of $2 trillion.[311]

The poor condition of electricity infrastructure in many countries and the high cost to upgrade and expand capacity has the potential to delay the energy transition, especially as the highest renewable energy potential tends to be in remote areas, adding to the need for long transmission lines to carry the power to demand centers. China is making the most progress on building out massive transmission lines to harness generation from renewable energy, as explained in earlier sections of this paper. Nearly all other countries are behind on building out this infrastructure, including the United States and Europe.

308 Fabian Ronningen, "Gridlock: Europe's power network needs fast-track investment for decarbonization targets to be met," Rystad Energy (December 13, 2022). https://www.rystadenergy.com/news/gridlock-europe-s-power-network-needs-fast-track-investment-for-decarbonization-t. Accessed July 19, 2023.

309 Ibid.

310 U.S. Department of Energy, "NREL Study Identifies the Opportunities and Challenges of Achieving the U.S. Transformational Goal of 100% Clean Electricity by 2035," EERE (August 30, 2022). https://www.energy.gov/eere/articles/nrel-study-identifies-opportunities-and-challenges-achieving-us-transformational-goal. Accessed July 19, 2023.

311 Tim McLaughlin, "Creaky U.S. power grid threatens progress on renewables, EV," A Reuters Special Report (May 12, 2022). https://www.reuters.com/investigates/special-report/usa-renewables-electric-grid/. Accessed July 19, 2023.

Developing countries are also grappling with this problem. In July 2022, an ASEAN publication featured a survey given to 48 energy and climate experts in Southeast Asia. They were asked what energy infrastructure was most critical for the energy transition. The top response out of 92 choices, receiving 50% of votes, was “transmission and distribution grid extension and upgrade.”[312] When asked what technical challenges make it harder to achieve NDC targets, of 71 choices, 25% of the respondents answered, “limitations of grid connections due to inadequate capacity of transmission lines.”

Long-term affordability

Clean energy technologies have more complicated, lengthier supply chains than traditional energy supply chains, such as for oil, gas, and coal. According to the IEA’s Energy Technology Perspectives 2023 report,

> In the case of clean energy technologies, the main steps include the extraction of minerals; the processing of those minerals into usable materials; the manufacturing of components; their assembly into finished equipment; the installation of that equipment; its operation; and its decommissioning and reuse or recycling of certain components.[313]

The COVID-19 pandemic and Russia’s invasion of Ukraine in 2022 triggered supply chain disruptions, and led to an increase in the cost of minerals and metals essential to clean energy technologies. According to the IEA,

> The average price of lithium was nearly four times higher in 2022 than in 2019, and twice for cobalt and nickel. Battery metal price hikes in early 2022 led to increasing battery

312 Emi Minghui Gui, Beni Suryadi, Zulfikar Yurnaidi, and Monika Merdekawati, *Strengthening International Collaboration and Regional Cooperation to Support Energy Transition and Net Zero Goals in ASEAN*, ASEAN Centre for Energy (July 26, 2022). https://aseanenergy.org/strengthening-international-collaboration-and-regional-cooperation-to-support-energy-transition-and-net-zero-goals-in-asean/. Accessed July 19, 2023.

313 International Energy Agency, *Energy Technology Perspectives 2023* (January 2023), pp28-29. https://www.iea.org/reports/energy-technology-perspectives-2023. Accessed July 19, 2023.

> prices—up nearly 10% globally relative to 2021—after years of continuous decline. The price of solar PV-grade polysilicon, copper and steel all roughly doubled between the first half of 2020 and that of 2022. These increases contributed to pushing up the price of PV modules rising by 25% and that of wind turbines outside China rising by up to 20%.[314]

Unplanned supply disruptions have been a feature of oil and gas markets, particularly the former, causing price swings and periods of high prices. Given that critical minerals and metals are even more geographically concentrated than oil and gas production[315] and mining operations typically require an even longer investment lead time,[316] price swings will likely also occur in the future for minerals and metals, leading to periods of high pricing for clean energy technologies absent a diversification of mineral types or additional technological breakthroughs. Periods of higher prices for clean energy technologies may delay energy transition efforts, particularly in developing countries that have access to relatively cheaper coal, oil, and natural gas.

In the same ASEAN publication referenced in the previous section, 48 energy and climate experts in the region were asked what economic and governance challenges made it harder for their country to achieve their NDC goal. [317] The top response out of 141 choices, receiving 58% of votes, was "higher costs of renewable energy."[318] The ASEAN report concluded that this "is often the result of lack of economies of scale, lack of local supply chains and reliance on imported equipment and products, restricting the availability and accessibility of renewable energy technologies." [319] Another factor adding to the cost in developing countries is the cost of capital.

314 Ibid., pp29, 82.

315 Ibid., p83.

316 International Energy Agency, "Global average lead times from discovery to production, 2010-2019" (October 26, 2022). https://www.iea.org/data-and-statistics/charts/global-average-lead-times-from-discovery-to-production-2010-2019. Accessed July 19, 2023.

317 Emi Minghui Gui, Beni Suryadi, Zulfikar Yurnaidi, and Monika Merdekawati, *Strengthening International Collaboration and Regional Cooperation to Support Energy Transition and Net Zero Goals in ASEAN*.

318 Ibid.

319 Ibid.

According to the IEA's 2022 World Energy Outlook (WEO), "The cost of capital for a solar PV plant in 2021 in key emerging economies was between two and three-times higher than in advanced economies and China."[320] Additional costs include the expansion of enabling infrastructure, such as the electrical grid.

Risks and Potential Implications

As explained earlier in this section, there are four main risks associated with overestimating the speed and magnitude of the transition to low-carbon fuels. Policymakers in several countries, including the United States, are making decisions on energy policy right now based on an anticipated rapid transition and complete transformation of energy systems. This could lead to (1) an underinvestment in future energy supplies, (2) inadequate energy storage levels in a disruption and/or wartime scenario, (3) concentration of oil and gas production in OPEC countries, and (4) public distrust of the reliability of low-carbon fuels.

Underinvestment

There is growing consensus among energy watchers that there is likely underinvestment in the oil and gas sectors, which could lead to higher oil and gas prices and potential supply shortages during the energy transition. In the past, international oil companies (IOCs) typically increased investments in new assets during periods of high prices, which also contributed to the boom-bust-cycle of the global oil market. Although not perfect, the traditional model of investing, mainly reliant on market signals and the fundamentals underlying prices—supply, demand, and inventories—helped to inform investment decisions.

With the energy transition, understanding and forecasting future market fundamentals is more complicated. For example, before the energy transition gained steam, forecasts of long-term demand trends were mostly dependent on economic and population growth. Now with major consumers' announcements to reach net-zero emissions by the mid-century, forecasting demand for fossil fuels—especially oil in the transportation sector and natural gas and coal in the electricity sector—is much more complicated as future demand is dependent on a host of variables and

320 International Energy Agency, *World Energy Outlook 2022*, p23.

unknowns in addition to economic and population growth. The investment and deployment of clean energy technologies, technological breakthroughs for clean forms of energy storage, and the massive buildout of associated infrastructure all add to the uncertainty of projecting future oil and gas consumption. Hence, this increases the risk of underinvestment as private actors fear stranded fossil fuel assets and economic losses.

From October to November 2022, the Atlantic Council surveyed energy stakeholders from more than 50 countries. The results were featured in their 2023 Global Energy Agenda published January 2023.[321] In a survey question asking respondents the most important cause of oil and gas market price volatility over the next 10 years, the most respondents (nearly 40%) believed it would be due to underinvestment because of environmental, social, and governance (ESG) and climate pressure and nearly 35% believed the most important cause would be "unpredictable market fundamentals."[322]

We are already starting to see signs of potential underinvestment in the oil and gas sectors. According to Rystad Energy, global spending on oil and gas exploration was at a 20-year low in 2022, based on data on annual oil and gas lease rounds and awarded acreage.[323] Russia, Australia, and the United States had the largest drop in completed lease rounds. From January to August 2022, foreign direct investment (FDI) in new oil and gas production projects substantially increased amounting to $42 billion;[324] however, this follows years of underinvestment and around 70% of that amount is the $28.75 billion North Field East project in Qatar.[325]

321 H.E. Mohamed Al Hammadi, et al., *The 2023 Global Energy Agenda*, Atlantic Council Global Energy Center (January 2023). https://www.atlanticcouncil.org/wp-content/uploads/2023/01/The-2023-Global-Energy-Agenda.pdf. Accessed July 19, 2023.

322 Ibid.

323 Aatisha Mahajan, "Global oil and gas exploration shrinks as companies shift focus to lower-risk core assets and regions," Rystad Energy (September 6, 2022). https://www.rystadenergy.com/news/global-oil-and-gas-exploration-shrinks-as-companies-shift-focus-to-lower-risk-cor. Accessed July 19, 2023.

324 Alex Irwin-Hunt, "Energy crisis triggers new wave of oil and gas investment," fDi intelligence (October 11, 2022). https://www.fdiintelligence.com/content/data-trends/energy-crisis-triggers-new-wave-of-oil-and-gas-investment-81552. Accessed July 19, 2023.

325 Jiyeong Go, "Ukraine war boosts global FDI into natural gas," fDi intelligence (September 13, 2022). https://www.fdiintelligence.com/content/data-trends/ukraine-war-boosts-global-fdi-into-natural-gas-81415. Accessed July 19, 2023.

Recent comments by leading energy watchers also heed this warning:

From the IEA's 2022 World Energy Outlook:

> ….recent investment levels in clean energy technologies have been far below what is needed to bring about a peak and decline in fossil fuel demand, yet investment in fossil fuel supply has been geared towards a world of stagnant or even declining demand for these fuels. This underlying mismatch has made the energy system more vulnerable to the sorts of shocks that came in 2022 with Russia's invasion of Ukraine.[326]

From Daniel Yergin, a preeminent energy security expert, who wrote in December 2022:

> What has become clear is that "preemptive underinvestment" has constrained the development of adequate new oil and gas resources. There are a number of reasons for this underinvestment—government policies and regulations; environmental, social, and governance (ESG) considerations by investors; poor returns caused by two price collapses in seven years; and uncertainty about future demand. The shortfall in investment was "preemptive" because of what was mistakenly assumed—that sufficient alternatives to oil and gas would already be in place at scale by now. Some have described what is currently unfolding as the "first energy crisis of the energy transition"—a mismatch between supply and demand. If it does prove to be only the first, future such crises will create uncertainty, cause major economic problems, and undermine public support for the energy transition.[327]

326 International Energy Agency, *World Energy Outlook 2022*, pp186-187.

327 Daniel Yergin, "Bumps in the Energy Transition," IMF (December 2022). https://www.imf.org/en/Publications/fandd/issues/2022/12/bumps-in-the-energy-transition-yergin. Accessed July 19, 2023.

From a Rystad Energy article published in September 2022:

> Global exploration activity has been on a downward trend in recent years, even before the Covid-19 pandemic and oil market crash, and that looks set to continue this year and beyond. It is clear that oil and gas companies are unwilling to take on the increased risk associated with new exploration or exploration in environmentally or politically sensitive areas.[328]

According to an International Energy Forum report published in February 2023, "Annual upstream oil and gas investment needs to rise by 28 percent to reach $640 billion by 2030 to ensure adequate global supplies."[329] Joseph McMonigle, Secretary General of the IEF wrote, "While we ramp up investment in renewables and pursue the energy transition, we also need to lift investment in oil and gas to support the global economy, and protect the quality of life for everyone."[330]

It is becoming increasingly apparent that investments in both clean energy and fossil fuels need to increase to meet growing energy demand globally in the future. Currently, the share of fossil fuel energy in the total primary energy supply worldwide is around 80%.[331] Meeting future energy demand growth, plus transitioning to a global energy portfolio dominant in clean energy will take time—likely longer than a quarter of a century.

Challenges to Managing Supply Disruptions

The ability to manage and offset energy supply disruptions in a world increasingly reliant on low-carbon technologies will be challenging absent substantial advancements in low-carbon forms of energy storage. Unplanned, prolonged supply disruptions are a regular feature of modern-day

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328 Aatisha Mahajan, "Global oil and gas exploration shrinks as companies shift focus to lower-risk core assets and regions."

329 International Energy Forum, "Annual Upstream Oil And Gas Investment Needs to Rise 28 Pct by 2030 - New Report by IEF and S&P Global Commodity Insights" (February 16, 2023). https://www.ief.org/news/annual-upstream-oil-and-gas-investment-needs-to-rise-28-pct-by-2030-new-report-by-ief-and-sp-global-commodity-insights. Accessed July 19, 2023.

330 Ibid.

331 International Energy Agency, *Energy Technology Perspectives 2023* (January 2023), p38. https://www.iea.org/reports/energy-technology-perspectives-2023. Accessed July 19, 2023.

energy markets, particularly in oil markets. Unplanned oil supply disruptions are typically driven by geopolitics—conflict and protests causing ongoing production shut-ins (e.g., Libya and Iraq) or western sanctions targeting new investment in and/or energy exports of rogue states (e.g., Iran, Venezuela, and Russia). Global oil and gas inventories and crude oil spare production capacity among OPEC countries have been the main two mechanisms used to at least partially offset supply shortages, though often not enough to avoid spikes in global oil prices.

Replacing a large share of fossil fuels in the global energy mix with low-carbon energy does not necessarily mean that unplanned supply disruptions will go away. Unplanned supply disruptions are also common in renewable energy markets, particularly as wind and solar are intermittent forms of energy, and wind speeds can be difficult to predict. For example, in 2021 there was a "wind drought" in much of Europe, with wind speeds dropping by 15% or more below the annual average in some areas, reducing the amount of expected wind power.[332]

Solar and wind are non-dispatchable sources of energy, meaning power output cannot be adjusted to meet peak demand or respond to abrupt changes to demand loads. Currently, renewable energy is typically paired with more stable, dispatchable, and/or baseload fuels such as natural gas, which can respond promptly to changing electricity demand loads and be dispatched to make up for fluctuations in solar and wind power. In an ideal net-zero scenario, energy storage harnessed from low-carbon energy would be used to promptly respond to changes in solar and wind generation.

Forms of clean energy storage include grid-scale, long-duration batteries, and pumped hydro storage. Grid-scale battery storage could be advantageous because the batteries can be charged when there is abundant solar and wind and discharged during peak hours. However, grid-scale batteries are currently much more expensive than traditional forms of fossil fuel storage. According to Bloomberg New Energy Finance (BNEF), the volume-weighted average price for lithium-ion battery packs across all sectors was $151 per kilowatt hours (kWh) in 2022, is expected to stay nearly flat at $152/kWh in 2023, and is projected to fall below $100/kWh after 2026 when more lithium mining projects are slated to come online.

332 Jim Robbins, "Global Wind Speeds: are they falling due to climate change?" Energy Post (October 14, 2022). https://energypost.eu/global-wind-speeds-are-they-falling-due-to-climate-change/. Accessed July 19, 2023.

BNEF noted the prices are higher than previously projected, which could "hurt the economics of energy storage projects."[333] According to a study published in 2019, in a scenario where solar and wind power met 100% of electricity demand, energy storage capacity costs would have to be between $10/kWh to $20/kWh to be cost-competitive with a nuclear power plant and be $5/kWh to compete with a peaker natural gas plant—which is significantly higher than the $151/kWh price of lithium-ion battery packs.[334]

Concentration of Oil and Gas Suppliers

Over time, the energy transition will likely lead to greater concentration of global oil and gas production in OPEC members in the Middle East as they have the lowest production costs, can better withstand periods of price uncertainty, and the industry is made up of national oil companies (NOCs) backed by their respective governments. Long-term forecasts are showing a growing share of global oil supply coming from OPEC nations, particularly as IOCs are scaling back investment plans and reserve replacement goals. According to the 2022 IEA WEO, "some Middle East producers are the only part of the upstream industry investing more today than prior to the Covid-19 pandemic."[335]

According to the IEA's NZE scenario, featured in the 2022 WEO, the share of global oil production from OPEC will greatly increase as investments and production falls in Western and non-OPEC countries. The IEA wrote, "The share of oil supply coming from OPEC members rises from 35% in 2021 to 52% in 2050. Even though the oil market is much smaller in 2050 than today [in the NZE scenario], the share of OPEC by then would be higher than at any point in the history of oil markets."[336] As mentioned earlier—from January to August 2022, foreign direct investment in oil and gas production projects amounted to $42 billion, and nearly 70% of that

333 Veronika Henze, "Lithium-ion Battery Pack Prices Rise for First Time to an Average of $151/kWh," Bloomberg New Energy Finance (December 6, 2022). https://about.bnef.com/blog/lithium-ion-battery-pack-prices-rise-for-first-time-to-an-average-of-151-kwh/. Accessed July 19, 2023.

334 Micah S. Ziegler, Joshua M. Mueller, Gonçalo D. Pereira, Marco Ferrara, Yet-Ming Chiang, and Jessika E. Trancik, "Storage Requirements and Costs of Shaping Renewable Energy Toward Grid Decarbonization," *Joule* 3, no 9 (September 18, 2019), pp2134-2153. https://doi.org/10.1016/j.joule.2019.06.012. Accessed July 19, 2023.

335 International Energy Agency, *World Energy Outlook 2022*, p24.

336 Ibid., p134.

went to the North Field East gas project in Qatar.[337]

The policy-driven, government-involved nature of the energy transition is an environment that is easier for NOCs, like those of OPEC countries, to maneuver compared with privately-owned companies that do not have government funds to help hedge risk during the transition. The IEA has rightfully advised that "reductions in fossil fuel investment need to be sequenced so they do not run ahead of the huge scaling up in clean energy technologies that is required to get to net zero emissions."[338] However, this is difficult to do in the United States, for example, where the energy industry is privatized.

The United States and its allies are at risk of a scenario where one or two decades from now the transition to low-carbon fuels takes longer than expected, but oil and gas production from non-OPEC countries, like the United States, has slowed, leading to a larger share of global oil and gas supply coming from the Middle East. Even if the size of global oil and gas markets reduce over the next one or two decades, they will likely still play important roles in economies, particularly in hard-to-decarbonize sectors. Thus, increased dependence on Middle East producers to meet oil and gas demand, even if that demand is relatively smaller, is not ideal for energy security.

The forecast increase in OPEC's global share of oil and gas production, to possibly up to 50% by 2050, would increase U.S. and allied energy supply vulnerabilities. The United States and its allies have long known the risks of becoming overly reliant on OPEC for energy supplies. In the 1973-74 OPEC Oil Embargo and subsequent global energy crisis, Arab oil producers halted oil exports to the United States and other nations in retaliation for their support to Israel during the Yom Kippur War, nearly quadrupling the price of oil. Even recently, OPEC Plus—made up of OPEC members and additional producers, including Russia—have made announcements to cut production even while global oil supply was tight. In October 2022 and April 2023, OPEC Plus announced coordinated cuts to their oil production. While OPEC has justified cuts by citing concerns about future global oil demand, it's also likely the group is aiming to keep crude oil prices elevated to serve

337 Alex Irwin-Hunt, "Energy crisis triggers new wave of oil and gas investment," fDi intelligence (October 11, 2022). https://www.fdiintelligence.com/content/data-trends/energy-crisis-triggers-new-wave-of-oil-and-gas-investment-81552. Accessed July 19, 2023.

338 International Energy Agency, *World Energy Outlook 2022*, p188.

their economies. OPEC Plus' actions are also beneficial to Russia, as the global price increase will likely support Russian oil revenue. Multiple times in recent years, the Biden administration has requested that OPEC raise oil production to reduce global oil prices,[339] but OPEC's recent announcements demonstrate, at the very least, its indifference to U.S. requests.

Public Distrust

Another risk of overestimating the speed of the energy transition and scaling back oil and gas investments too much too soon is causing public wariness of low-carbon energy sources. A mismatch between supply and demand in the future—potentially brought on by insufficient investment in both low-carbon and fossil fuel energy and a lag in key technological breakthroughs to scale up intermittent renewable energy to the desired amount—could cause energy supply shortages, price spikes, and subsequent economic disruptions. Warnings of such potential macroeconomic disruptions have been made by notable experts including Daniel Yergin, long-time energy expert and vice chairman of S&P Global,[340] and Jean Pisani-Ferry, a nonresident senior fellow at the Peterson Institute for International Economics.[341]

High-level international figures and activists have called for the end to the world's use of fossil fuels because of concern over the climate, environmental, and health impacts stemming from GHG emissions and pollution.[342] However, the call to abandon fossil fuels entirely is likely not aligned with mainstream public opinion. For example, a survey of 10,237

339 Trevor Hunnicutt and Jeff Mason, "U.S. calls on OPEC and its allies to pump more oil," Reuters (August 11, 2021), https://www.reuters.com/world/middle-east/us-call-opec-its-allies-increase-oil-production-cnbc-2021-08-11/ (accessed July 19, 2023); and Alex Marquardt, Natasha Bertrand and Phil Mattingly, "Inside the White House's failed effort to dissuade OPEC from cutting oil production to avoid a 'total disaster,'" CNN (October 5, 2022), https://www.cnn.com/2022/10/04/politics/white-house-lobby-opec-oil-production-cuts-gasoline-prices-midterms/index.html (accessed July 19, 2023).

340 Daniel Yergin, "Bumps in the Energy Transition," IMF (December 2022). https://www.imf.org/en/Publications/fandd/issues/2022/12/bumps-in-the-energy-transition-yergin. Accessed July 19, 2023.

341 Jean Pisani-Ferry, "Climate policy is macroeconomic policy, and the implications will be significant," Peterson Institute for International Economics, Policy Briefs 21-20 (August 2021). https://www.piie.com/publications/policy-briefs/climate-policy-macroeconomic-policy-and-implications-will-be-significant. Accessed July 19, 2023.

342 UN News, "Climate and Environment," United Nations (November 11, 2022). https://news.un.org/en/story/2022/11/1130462 (accessed July 19, 2023); and Sam Meredith, "'Turn the valve off': Climate activists push for an abrupt end to the fossil fuel era," CNBC (December 29, 2021), https://www.cnbc.com/2021/12/29/climate-activists-push-for-an-abrupt-end-to-global-fossil-fuel-use.html (accessed July 19, 2023).

adults in America given by the Pew Research Center from January 24-30, 2022 found that nearly 70% of respondents prioritized developing alternative energy like solar and wind over expanding oil, gas, and coal production; however, two-thirds of those respondents disagreed with a complete phaseout of fossil fuels, opting instead for a mix of fossil fuels and renewable energy.[343] In addition, several developing countries still intend to develop their fossil fuel energy resources to aid their economic development goals. Thus, if governments push for policies resulting in a steep decline in fossil fuels investments amid slow development and deployment of low-carbon technologies, the general public and many developing countries—which are already wary of a world without fossil fuels—could become apprehensive about the energy transition.

343 Alec Tyson, Cary Funk, and Brian Kennedy, "Americans Largely Favor U.S. Taking Steps To Become Carbon Neutral by 2050," Pew Research Center (March 1, 2022). https://www.pewresearch.org/science/2022/03/01/americans-largely-favor-u-s-taking-steps-to-become-carbon-neutral-by-2050/. Accessed July 19, 2023.

Competitive Flashpoints: Wrap Up

While the United States embarks on plans to transform its energy systems, there must be heightened awareness of how the energy transition can impact great power competition. As mentioned earlier in the paper, the energy transition has the potential to reshuffle dominant energy suppliers and import dependencies, and countries leading the race to supply the transition will reap the economic and political benefits. This paper outlines competitive flashpoints associated with the energy transition, the risks, and potential implications so policymakers can undertake actions to avoid these pitfalls during the transition. These potential pitfalls include increasing U.S. energy reliance on adversaries, weakening U.S. energy security, increasing tensions and differences with developing countries, bolstering Chinese foreign policy goals, and ceding leadership in the energy domain to both China and Russia, among other drawbacks mentioned in the section above. The United States' energy planning must be crafted in a way that does not disadvantage the United States politically, economically, and geopolitically vis-à-vis its rivals. Avoiding these pitfalls will require rethinking and reconsideration of the United States' current energy transition strategy. The following sections offer policy recommendations on how the United States can increase its low-carbon energy without adversely affecting its competitive standing among its rivals.

Policy Recommendations: Rethinking the Current Strategy

Accelerating the energy transition has been at top of the Biden administration's agenda since taking office in 2021. The administration has made noteworthy progress with the passage of new legislation with billions of dollars earmarked toward clean energy technologies. As mentioned earlier in the paper, U.S. lawmakers have introduced or passed legislation targeting a boost in domestic production of critical minerals and low-carbon technologies to both support the energy transition and reduce future U.S. reliance on adversaries. For example, the Bipartisan Infrastructure Law signed November 2021 included more than $100 billion over five years (FY2022-FY2026) for clean energy, climate, and minerals-related activities. The CHIPS and Science Act, signed August 2022, included millions of dollars per year toward basic energy research, critical minerals, and clean energy technology programs.[344] The 2022 Inflation Reduction Act included nearly $370 billion toward energy and climate activities.[345] The U.S. Department of Energy (DOE) has announced numerous initiatives to boost clean energy technology research and development, the U.S. Department of Defense has awarded funds to companies to boost mining and processing operations in the United States, and the U.S. Department of State is pursuing energy diplomacy initiatives to form international partnerships.

While all of that has been essential to taking the first steps toward the energy transition, the policy recommendations of this paper take a broader perspective and seek to address general energy policy planning, strategy, and goals that should shape the pace and general course of the energy transition. The main goal of energy policy planning should be energy security—defined earlier as "…having access to affordable energy without having to contort one's political, security, diplomatic, or military

344 Mariana Ambrose, John Jacobs, and Natalie Tham, "CHIPS and Science Act Summary: Energy, Climate, and Science Provisions," (November 14, 2022). https://bipartisanpolicy.org/blog/chips-science-act-summary/. Accessed July 19, 2023.

345 International Energy Agency, *Energy Technology Perspectives 2023*, p40.

arrangements unduly"[346]—and the avoidance of bolstering the political standing of our adversaries. In other words, the United States should only adopt policies to reduce GHG emissions in the energy sector that do not weaken energy security and that do not give our adversaries enduring advantages.

For this reason, the policy recommendations of this paper challenge policymakers to take a step back and reexamine the potential trajectory of the energy transition to try and avoid unintended outcomes with secondary and tertiary effects on U.S. energy security, economic competitiveness, and international relations. For example, the Biden administration set a target for offshore wind to generate 30 GW of electricity by 2030 and 15 GW of floating offshore wind by 2035.[347] The United States is not a top manufacturer of wind turbines—Chinese and European companies are the leading turbine makers—and thus, unless there is a quick boost in the U.S. domestic wind manufacturing base, the United States will have to import wind components to make its 2030 and 2035 goals. The United States should only seek to accomplish its wind goals if it can do so without becoming dependent on Chinese wind manufactures, which are growing faster in capacity and with lower costs compared with European manufacturers. If it realizes over time that reaching these goals requires dependence on Chinese wind manufacturers, then U.S. policymakers should adjust the goals, and focus on increasing the United States and allied wind manufacturing base.

The policy recommendations below seek to answer the question: How do we embark on the energy transition while not disadvantaging the United States geopolitically and weakening our energy security, especially in the context of great power competition? All seven competitive flashpoints outlined in this paper can cause some form of disruption to U.S. energy security and disadvantage the United States vis-à-vis great power rivals. To avoid energy planning that leads the nation down this path, U.S.

346 Meghan L. O'Sullivan, "The Entanglement of Energy, Grand Strategy, and International Security," Harvard's Belfer Center for Science and International Affairs (May 2013). https://www.belfercenter.org/publication/entanglement-energy-grand-strategy-and-international-security. Accessed July 19, 2023.

347 White House, "FACT SHEET: Biden-Harris Administration Announces Actions to Expand Offshore Wind Nationally and Harness More Reliable, Affordable Clean Energy" (February 22, 2023). https://www.whitehouse.gov/briefing-room/statements-releases/2023/02/22/fact-sheet-biden-harris-administration-announces-actions-to-expand-offshore-wind-nationally-and-harness-more-reliable-affordable-clean-energy/. Accessed July 19, 2023.

policymakers should consider the policy recommendations below. The recommendations are intended to influence a rethinking of our current energy transition strategy in light of great power competition, rather than provide comprehensive and detailed policy recommendations for each problem identified in this paper. The recommendations include:

- **Rethinking the Energy Transition Strategy:** More attention to intermediary goal planning is needed—rather than setting long-term, end-consumption goals—to better understand if timelines are realistic and avoid reliance on adversaries.
- **Building Resilient Clean Energy Supply Chains:** Allow time to build out clean energy technology supply chains, located in the United States and/or in allied countries, to avoid a future where the U.S. energy supply is dependent on technologies and equipment from Chinese companies operating either within or outside of China.
- **Rethinking the Transition's Energy Mix:** All forms of energy have limitations, constraints, and tradeoffs, including renewable energy. Thus, maximizing energy security requires energy diversity, allowing operators to immediately respond to changes in demand and offset outages.
- **Devising a New Disruptions Analysis Framework:** How will supply disruptions be promptly addressed or offset if the U.S. energy system shifts to being predominantly fueled by renewable energy in the future? Countries have used natural gas and coal—which can be stored for long durations—to partially offset and cope with unplanned disruptions of Russian gas supplies during the 2022-2023 energy crisis. A new disruptions analysis framework is needed to understand how to deal with disruptions in the future.
- **Maintaining U.S. Role as a Dominant Energy Exporter and Seek New Opportunities:** The United States should take a more deliberative approach to developing a long-term strategy to lead global exports of certain energy sources that the United States has a comparative advantage in—and are in demand. The United States should develop a strategy to cement its position as a leading liquefied natural gas (LNG) exporter into the longer term to reduce global demand for Russian gas, especially Russia's growing LNG exports, among allies

and friends.

- **Reducing U.S. and Allied Reliance on Russia's Nuclear Industry:** While it will be difficult for the United States to economically compete and rival Russian nuclear exports on the global market, the United States and its allies need to at least reduce their own reliance on Russia. The United States should also work with its allies to bolster capabilities to provide alternatives to Russian nuclear fuel and reactors on the global market.

Rethinking the Energy Transition Strategy

The current strategy for the energy transition, predominately employed by the U.S. government and the EU, consists of policymakers setting "end-consumption goals" to compel the reduction of fossil fuels and the increase of low-carbon fuels. Examples of end-consumption goals include mid-century, energy mix targets of 80-90% low-carbon energy, or sector-specific goals such as banning the sale of internal combustion cars by 2035. The rationale for setting these long-term goals makes sense, as they increase the likelihood progress will be made by compelling government planning and coordination across key agencies, influencing private investment decisions, and influencing consumer behavior and socializing new technologies, among other reasons. Thus, setting mid-and-long-term end consumption goals supports the energy transition.

However, the end-consumption goals dominating headlines carry much risk and conceal the several intermediary steps that must take place to achieve the goal. Instead of solely setting end-consumption goals, decisionmakers should focus on setting goals for intermediary requirements and inputs. For example, if a country wishes to have an energy consumption mix of 80% renewable energy and battery storage—how much critical minerals (lithium, nickel, rare earth, etc.) will need to be mined? What portion will that country need to mine domestically? What portion will need to be imported, and will that be available given global demand and/or reliable import sources? These types of questions should be analyzed to feed into realistic outlooks for long-term, end-consumption goals. In addition, U.S. policymakers should set domestic production goals. Key questions for U.S. policymakers on domestic goals are:

- What is the U.S. domestic goal for mining and processing of critical minerals? What are the barriers to increasing domestic mining, and what goals should the U.S. government pursue to reduce barriers?
- What is the U.S. domestic goal for manufacturing solar panels and wind turbines?
- If the domestic manufacturing of solar panels and wind turbines, along with the mining of critical minerals, falls short of the U.S. demand projections, what will be the U.S. import source?

Secondly, long-term end-consumption goals are often based on technologies that do not exist, which can introduce market distortions. End-consumption goals should be based on technologies that exist today rather than hinging on the scaling up of novel energy technology concepts like renewable-based hydrogen. Banking on non-existing technologies could lead to tight energy supplies and high prices in the future because of insufficient investment in the present. Governments should devote public funding to achieving technological breakthroughs with clean energy technologies. As breakthroughs are achieved and new technologies are cleared for commercialization, then end-consumption goals can be modified over time, even annually. Below are a few examples demonstrating the risks and tradeoffs of setting long-term, end-consumption goals ahead of intermediary planning.

In March 2023, the EU officially approved a law banning the sale of new petrol and diesel cars by 2035.[348] The policy is meant to support the EU's overall goal of achieving climate neutrality by 2050. Similarly, in 2022, California also announced that the sale of new gasoline-powered cars will be banned in the state starting in 2035.[349] The goals are dependent on an unprecedented expansion of infrastructure consisting of solar and wind farms, transmission lines, and distribution lines as current electrical grids in the EU or United States could not handle a majority EV fleet on the road that is fueled by renewable electricity. If these policies are enacted and fossil fuel energy is still the predominate source for electricity, then that would contradict its purpose.

Moreover, these premature policies could send mixed, confusing signals to the market that could lead to a future price spike and supply shortfall of internal combustion vehicles and crude oil if the plan to ban these types of vehicles proves impossible by these dates. Mandating an increase in EVs while reducing fossil fuel use in the electricity sector means that the electricity sector must experience a massive growth in renewable energy, like solar and wind. Nuclear energy could also be used, but multiple

348 Euan Sadden, "EU approves law banning sales of new petrol, diesel cars from 2035," S&P Global (March 29, 2023). https://www.spglobal.com/commodityinsights/en/market-insights/latest-news/metals/032923-eu-approves-law-banning-sales-of-new-petrol-diesel-cars-from-2035. Accessed July 19, 2023.

349 Nadia Lopez, "California phases out new gas cars — so what's next for electric cars?" CalMatters (August 25, 2022). https://calmatters.org/environment/2022/08/electric-cars-california-to-phase-out-gas-cars/. Accessed July 19, 2023.

European countries and also California have taken steps to reduce nuclear energy due to concerns over safety and nuclear waste. In addition, the nuclear energy industry has been suffering from project delays and cost overruns. Thus, solar and wind have been the dominant clean energy sources cited in climate neutrality plans adopted by these governments.

Second, from a geopolitical standpoint, these policies will likely help China increase its EV exports to Europe and boost its global EV market share. China can manufacture EVs relatively cheaper, largely because it uses inexpensive coal-fired electricity generation and labor, and it has the world's largest lithium-ion manufacturing operations. If the United States and Europe push policies that force their societies to expand EV purchases before more U.S. and European companies are able to start or expand their EV production, including finding ways to reduce costs and become more competitive, then this will benefit Chinese companies—potentially locking in the United States' and Europe's future dependence on China. Shortly after the EU approved the law to ban petrol and diesel cars by 2035, the secretary general of the China Passenger Car Association told Chinese press that the move by the EU created opportunity to boost Chinese EV exports to Europe, which are already exported to France, the UK, the Netherlands, and Norway.[350] He believed EV cars manufactured in China could meet EU regulations and standards and noted that EV production in China has increased, now making up 70% of the global market. Europe's imports of EVs manufactured in China are increasing, and a 2022 U.S.-based consultancy study found that Europe could import up to 800,000 Chinese-built cars, most of which are EVs, by 2025, potentially shifting Europe to a net-importer of cars.[351]

The EVs originating from China are from Chinese car brand makers along with Western companies, like Tesla and BMW, which have been moving some of their EV production operations to China. The expansion of Western EV operations in China makes economic sense in terms of keeping manufacturing costs competitive and positioning operations in a growing domestic market. European carmakers like BMW and Volkswagen have opened EV operations in China due to limited production capacity at

350 GT Staff Reporters, "EU's ban on fossil fuel cars set to boost China's EV exports," *Global Times* (February 15, 2023). https://www.globaltimes.cn/page/202302/1285508.shtml. Accessed July 19, 2023.

351 Peter Sigal, "Europe forecast to import 800,000 Chinese-built cars by 2025," Automotive News Europe (November 7, 2022). https://europe.autonews.com/automakers/chinese-electric-car-exports-europe-soar. Accessed July 19, 2023.

home.[352] However, given increasing political tensions between the United States and China, Western policymakers should caution EV makers from being overly concentrated in China in case of an escalatory scenario in the future.

Market watchers believe Chinese-brand EVs will gain popularity internationally. Market consultancy Fitch Solutions forecast Chinese EVs will rise from a market share of 5% in 2022 to up to 15% in 2025 in the European market, which was the world's second largest EV market as of 2022.[353] Chinese EV brands make up much of the EVs sold within China, and Chinese brands are now planning to accelerate sales globally. According to Fitch Solutions, many European EV brands are targeting high-end EVs, potentially leaving a gap for lower cost Chinese EV brands.[354] Demand for lower cost EVs will likely also open opportunities for Chinese brands in emerging markets. While Chinese carmakers struggled in the past to successfully sell their internal combustion vehicles internationally, due in part to quality issues and a late entrance into the market, on the contrary, Chinese EV makers started operations before several of their Western counterparts, supported by heavy subsidies from the Chinese central and regional governments for Chinese EV makers and battery makers. In turn, Chinese EV companies have built the core competencies required to be competitive.[355]

Energy security is the backbone of a functioning economy and modern-day living, and therefore, future energy planning needs to be realistic, methodical, and rooted in what is technologically known and possible at the time of planning. Hence, setting intermediary goals on inputs and the requirements—rather than solely setting end-consumption goals—can help to gauge if the end-consumption goal is realistic within the given timeframe,

352 Myungshin Cho, "China's Electric Car Exports Surge to Record on European Demand," Bloomberg (December 27, 2022). https://www.bloomberg.com/news/articles/2022-12-28/china-s-electric-car-exports-surge-to-record-on-european-demand. Accessed July 19, 2023.

353 Neil Winton, "China's Electric Car Assault On Europe Will Accelerate In 2023, Then Hit Top Gear-Report," *Forbes* (December 8, 2022). https://www.forbes.com/sites/neilwinton/2022/12/08/chinas-electric-car-assault-on-europe-will-accelerate-in-2023-then-hit-top-gear. Accessed July 19, 2023.

354 Ibid.

355 Jeanne Whalen, "Would you buy a made-in-China electric car? They're coming," *The Washington Post* (November 26, 2022). https://www.washingtonpost.com/technology/2022/11/26/polestar-china-ev/. Accessed July 19, 2023.

to map out uncertainties, and mitigate future risks, like America's reliance on adversaries.

Building Resilient Clean Energy Technology Supply Chains

The United States is facing multiple barriers to establishing resilient clean energy supply chains domestically, such as cost competitiveness. However, there are three areas the United States can immediately address to help reduce some barriers. This includes increasing data transparency, re-evaluating domestic regulations, and identifying comparative advantages among allies and partners to share the responsibility of building resilient supply chains. With fossil fuel production, data on supply, demand, and trade is much less complicated. Therefore, the U.S. government needs to develop new thinking and strategies on how to collect data and increase transparency into clean energy supply chains. Greater data transparency will also help with setting intermediary goals.

The United States has been exploring ways to engage in “onshoring” and “friend-shoring” of supply chains. For instance, the Inflation Reduction Act (IRA) of 2022 allocated $60 billion to bolster domestic clean energy manufacturing and permitted tax credits for the usage of materials for clean energy projects manufactured in North America or countries that have a free trade agreement with the United States.[356] Much of these initiatives will take time before they can lead to supply chains that are reliable, robust, and resistant to geopolitical entanglement. U.S. policymakers should hastily work to speed the process but allow time for secure supply chains to sprout before locking in dependency on China. That dependency on China will be more difficult to disentangle the more our energy system is reliant on Chinese clean energy supplies.

Data Transparency

Why aren’t policymakers more focused on setting intermediary targets? One key reason might be a lack of transparency in data on intermediary inputs, making it challenging for policymakers to shift their efforts to intermediary goal setting in parallel with end-consumption goal setting. As

356 William Tobin, Daniel Helmeci, and Selin Kumbaraci, “Does the Inflation Reduction Act take the right approach to shoring up clean energy supply chains?” Atlantic Council Global Energy Center (August 10, 2022). https://www.atlanticcouncil.org/blogs/energysource/does-the-inflation-reduction-act-take-the-right-approach-to-shoring-up-clean-energy-supply-chains/. Accessed July 19, 2023.

noted in earlier sections of this paper, renewable energy technologies have larger supply chains and more inputs compared with fossil fuels. To make renewable energy targets equivalent in nature to fossil fuel production targets and projections—which are used to understand the balance between supply and demand—renewable energy targets should include layers below solar and wind generation. What are the main inputs to solar generation? With solar panels, inputs span from (but are not limited to) critical minerals, polysilicon, ingots, wafers, and cells. Furthermore, solar power systems require additional fundamental inputs including batteries, solar regulators, and inverters.[357] Any shortages along this supply chain can impact the price of solar energy additions. For example, in 2022, utility-scale solar installations in the United States unexpectedly fell 31% over the previous year due to supply chain disruptions and trade barriers, including a U.S. law banning some solar panel materials originating in China's Xinjiang region due to force labor allegations.[358]

U.S policymakers should consider expanding the mandate and duties of the U.S. Energy Information Administration (EIA)—the objective analytical and statistical arm of DOE— to increase data transparency of the production, demand, and outlook for clean energy supply chains. EIA provides data transparency into various energy markets and provides insight into U.S. domestic energy production and demand. Congress has authorized energy companies operating in the United States report data to EIA via standardized surveys approved by the Office of Management and Budget (OMB) every three years. With OMB approval, EIA can add new, modify, or discontinue surveys.

According to a 2020 Congressional Research Service report, "A main driver for the creation of EIA was the energy crisis of the 1970s. At the time, many lawmakers felt a lack of federal energy data had contributed to the crisis and limited policymaking in response."[359] Similarly, the lack of federal

357 International Energy Agency, "Special Report on Solar PV Global Supply Chains" (July 2022), https://www.iea.org/reports/solar-pv-global-supply-chains/executive-summary (accessed July 19, 2023); and Solar Online Australia, "Solar System Basics – How Solar Power Works," https://www.solaronline.com.au/solar_system_basics.html (accessed April 2023).

358 Solar Energy Industries Association, "U.S. Solar Market Insight" (March 9, 2023). https://www.seia.org/us-solar-market-insight. Accessed July 19, 2023.

359 Ashley J. Lawson, Mark Holt, and Michael Ratner, "The U.S. Energy Information Administration," Congressional Research Service (September 9, 2020). https://crsreports.congress.gov/product/pdf/R/R46524/6. Accessed July 19, 2023.

data on clean energy supply chains will limit policymakers' ability to gauge (1) if the United States can achieve its end-consumption energy targets and (2) if the United States can achieve those targets, will it leave it reliant on adversaries like China? Without more granular data on supply chains, the U.S. government will be limited in its ability to set intermediary goals, undertake adequate planning and coordination across agencies, and offer enough support and incentives to private sector actors.

The U.S. Infrastructure and Jobs Act, signed into law in November 2021, directs EIA to develop plans to model and forecast demand of critical minerals used in the energy sector, including for production, transmission, and storage.[360] While this a noteworthy initial step, the breadth of data collection and forecasting required to better understand clean energy markets should go beyond critical minerals and encompass the full supply chain. Setting up such an operation will take a lot of resources, such as time, money, and a larger labor force. However, not investing in data transparency on clean energy markets, as was done with oil markets long before, will leave a blind spot for U.S. policymakers. Private energy consulting companies and the IEA are collecting this data globally, which could help reduce the burdens of a U.S. agency wishing to do the same. However, EIA typically has superior data on energy activities in the United States because of its survey data, and therefore, at minimum, EIA should expand surveys to capture the full breadth of activities—across the supply chains of production, transmission, and storage—in clean energy markets within the United States.

Streamlining Regulations

A major impediment to increasing mining of critical minerals in the United States is the lengthy and costly permitting process for mining projects. The permitting process in the United States takes about seven to 10 years to complete, compared with two to three years in Canada and Australia, which have similar environmental requirements.[361] The U.S. process is lengthier

360 Brent D. Yacobucci, "Energy and Minerals Provisions in the Infrastructure Investment and Jobs Act (P.L. 117-58)," Congressional Research Service (March 31, 2023). https://crsreports.congress.gov/product/pdf/R/R47034. Accessed July 19, 2023.

361 Senate Committee on Energy & Natural Resources, "Full Committee Hearing On The Scope And Scale Of Critical Mineral Demand And Recycling," Archived Webcast (April 7, 2022). https://www.energy.senate.gov/hearings/2022/4/full-committee-hearing-on-the-scope-and-scale-of-critical-mineral-demand-and-recycling. Accessed July 19, 2023.

because it is impacted by local, state, federal, and tribal regulations, along with an opaque review process and a litigious U.S. culture.[362] U.S. companies have called for a more efficient permitting process, along with an increase in federal funding of geological mapping of critical mineral deposits on federal lands.[363] U.S. policymakers have proposed various policies to streamline and reduce the timeline for permitting, including setting time limits on reviews and environmental assessments. U.S. allies like Canada and various countries in Europe are also looking to streamline permitting and reduce the time and costs to invest in mining projects.

While reducing the burden of the permitting process is an essential component to curtailing reliance on China for minerals, officials in the United States and allied countries must be cautious about reforms weakening environmental assessments as mining is an extractive industry like fossil fuels. Decisionmakers must carefully focus reforms on reducing red tape, streamlining regulations and the review process, creating a more transparent application and review process, and reducing associated fees, rather than undercutting environmental impact studies. An article published by The Breakthrough Institute in June 2023 called "Getting Critical Minerals Right" provides an in-depth look into the U.S. mining regulatory process and provides specific recommendations to make the process more efficient without undermining environmental considerations.[364]

Allied Comparative Advantages

China is dominating the global supply of critical minerals and clean energy manufacturing largely because it can sell these goods relatively cheaper due to lax environmental laws, cheaper electricity derived mostly from coal, lower labor costs, and government subsidies. It will be an uphill battle for the United States and its allies to separately launch domestic

362 U.S. Department of Commerce, *A Federal Strategy to Ensure Secure and Reliable Supplies of Critical Minerals* (January 2020). https://www.commerce.gov/sites/default/files/2020-01/Critical_Minerals_Strategy_Final.pdf. Accessed July 19, 2023.

363 Ernest Scheyder and Valerie Volcovici, "Push to shorten U.S. mine permit review process gains steam," Reuters (September 1, 2022). https://www.reuters.com/business/autos-transportation/push-shorten-us-mine-permit-review-process-gains-steam-2022-09-01/. Accessed July 19, 2023.

364 Peter Cook and Seaver Wang, "Getting Critical Minerals Right," The Breakthrough Institute (June 29, 2023). https://thebreakthrough.org/issues/energy/getting-critical-minerals-right. Accessed July 19, 2023.

industries that rival the cost competitiveness of China. In addition, the extensive mineral requirements of the energy transition, coupled with demand in non-energy sectors like defense and consumer electronics, will make it difficult for large consumers to solely rely on domestic industries for both upstream (mining) and downstream (processing/refining) activities.

Thus, the United States, its allies, and/or friendly nations must work together to systematically map out and develop a cooperative arrangement exploiting the comparative economic and resource advantages of each country involved. U.S. policymakers should consider creating some type of cooperative trade agreement or economic partnership arrangement with relevant countries focusing on a bucket of goods pertinent to clean energy supply chains, such as critical minerals and/or solar and wind energy components. There are several U.S. allied and friendly nations that contain large mineral resources. Figure 14 displays data from the U.S. Geological Survey (USGS) showing large reserve holders and producers of minerals used in clean energy technologies.[365]

365 U.S. Geological Survey, *Mineral commodity summaries 2023.*

Figure 14. Potential U.S. Partners on Critical Minerals

Mineral	Potential U.S. Partners
Cobalt	**Australia** holds 18% of world reserves, second to the Democratic Republic of the Congo.
Copper	**Chile** holds the largest reserves of copper. **Australia and Peru** are second and third, respectively.
Gallium	**Japan, South Korea, and Ukraine** produce small quantities of gallium, though reserves are unknown.
Graphite	**Madagascar, Mozambique, Namibia, and Tanzania** are mining large graphite deposits. **Turkey and Brazil** hold the first and second largest reserves of graphite, respectively.
Lithium	**Chile and Argentina** hold 36% and 10% of world reserves, while **Australia** holds 24%.
Manganese	**South Africa** mines 36% of the world's manganese and holds 38% of world reserves.
Nickel	**Australia, Indonesia, and Brazil** hold more than half of the world's reserves.
Platinum-group metals	**South Africa** holds 90% of world reserves and is the largest producer of platinum.
Rare earth elements	**Vietnam and Brazil** hold about 16% each of world reserves and are among the global top four holders, behind China and Russia.
Zinc	**Australia** holds 30% of world reserves.
Zirconium	**Australia** holds 70% of world reserves and is the largest producer.

Source: U.S. Geological Survey (USGS) Mineral Commodity Summaries 2023; Note: Data is as of 2022.

In 2022, the U.S. Department of State launched the Minerals Security Partnership (MSP)—including Australia, Canada, Finland, France, Germany, Japan, South Korea, Sweden, the UK, the United States, and the European Commission. In early 2023, MSP partners held a meeting with some mineral-bearing Africa countries to discuss ESG standards. While initiating dialogue is important, U.S. officials must bear in mind that China is moving at a much faster pace to establish strategic investment partnerships and increase its access to mining in Africa and Latin America.

Competition between Western countries and China is heating up to secure critical mineral partnerships in developing countries. In April 2023, the United States announced a preliminary $500 million trade deal with Tanzania to in part support the development of a new cobalt and nickel processing plant.[366] The United States recently has also signed similar

366 Jevans Nyabiage, "China-US battle for African influence shifts to green critical minerals," *South China Morning Post* (April 9, 2023). https://www.scmp.com/news/china/diplomacy/article/3216457/china-us-battle-african-influence-shifts-green-critical-minerals. Accessed July 19, 2023.

preliminary agreements with the DRC and Zambia.[367] Australian and Canadian firms are also engaged in producing critical minerals in African countries.[368] Nonetheless, China has gotten a head start in securing investments in prolific mines globally and continues to make strides. As mentioned earlier in the paper, China has partial ownership of some of the largest lithium mines in Australia, Chile, and Argentina, cobalt mines in the DRC, and nickel mines in Indonesia. Three Chinese companies also recently signed a deal with Bolivia's state-owned company YLB to explore lithium deposits. Bolivia, Chile, and Argentina make up South America's Lithium Triangle and together account for about 60% of the world's lithium resources. Chinese companies are also dominating partnerships in Southeast Asia, opening manufacturing facilities to produce supply chain components for wind and solar, which some market analysts attribute to Chinese companies attempting to reduce exposure to Western sanctions targeting Chinese solar manufacturing.[369] Southeast Asian countries can manufacture various solar supply chain components—like polysilicon, ingots, wafers, and cells—almost as cheaply as China, based on cost estimates from the National Renewable Energy Laboratory (NREL).[370]

Therefore, to compete with China on clean energy supply chains, the United States and its partners must step up their game. A U.S.-led economic cooperation arrangement or trade agreement among a group of countries spanning several countries based on comparative economic advantages can potentially build supply chains that are cost competitive and carry lower geopolitical risk. Which countries among U.S. partners and friends are relatively better at mining and/or processing various minerals, in terms of costs and

367 U.S. Department of State, "The United States Releases Signed Memorandum of Understanding with the Democratic Republic of Congo and Zambia to Strengthen Electric Vehicle Battery Value Chain," Media Note (January 18, 2023). https://www.state.gov/the-united-states-releases-signed-memorandum-of-understanding-with-the-democratic-republic-of-congo-and-zambia-to-strengthen-electric-vehicle-battery-value-chain/. Accessed July 19, 2023.

368 Gracelin Baskaran, "Could Africa replace China as the world's source of rare earth elements?" Brookings (December 29, 2022). https://www.brookings.edu/blog/africa-in-focus/2022/12/29/could-africa-replace-china-as-the-worlds-source-of-rare-earth-elements/. Accessed July 19, 2023.

369 Luna Sun, "Chinese solar firms ramping up investment in Southeast Asia to evade US, European trade tensions," *South China Morning Post* (July 29, 2022). https://www.scmp.com/economy/china-economy/article/3186923/chinese-solar-firms-ramping-investment-southeast-asia-evade. Accessed July 19, 2023.

370 Michael Woodhouse, David Feldman, Brittany Smith, Jarett Zuboy, Jay Huggins, Vignesh Ramasamy, and Robert Margolis, "The Global Solar Photovoltaic Supply Chain and Bottom-UP Cost Model Results," NREL (September 26, 2022). https://www.nrel.gov/docs/fy23osti/84036.pdf. Accessed July 19, 2023.

fewer environmental impacts? Which countries among U.S. partners and friends are relatively better at manufacturing the various components making up solar and wind technologies? U.S. officials should focus on mapping out such comparative advantages to identify partners to form a cooperative arrangement and then determine preferential trade terms and investment assistance, among other measures, that can help the United States and allies reduce dependence on Chinese supply chains without incurring substantially higher costs that cause higher energy prices.

Rethinking the Transition's Energy Mix

The top forms of energy the world currently consumes are oil, coal, natural gas, hydroelectricity, and nuclear energy.[371] Over the next three decades, several Western countries are aiming to transform their energy systems from fossil-fuel dominated systems to those dominated by renewable energy, mainly solar and wind. Therefore, most Western countries are looking to substantially cut or eliminate oil, coal, and natural gas, and some European countries are aiming to cut nuclear energy over safety concerns—putting nearly all their eggs into one renewable energy basket.

All types of energy have limitations, constraints, and tradeoffs. Renewable energy is dependent on variable, hard-to-predict weather; natural gas, oil, and coal are finite resources; coal resources can be affected by wet or frozen coal; hydroelectricity can be limited by the amount of water stored; and nuclear power can be constrained by the availability of water and nuclear fuel and lengthy refueling and maintenance periods.[372] Thus, maximizing energy security requires energy diversity, allowing operators to respond to changes in demand and offset outages.

The U.S. government and its allies should take into account risks and tradeoffs across fuels and aim to have a diverse energy portfolio to reduce the probability of energy disruptions and high prices, and hence, strengthen energy security. This energy portfolio should seek to (1) eliminate the dirtiest energy source—coal use without emissions removal technologies, (2) reduce demand growth for oil, (3) expand renewable energy like solar and wind, and (4) expand the use of natural gas and nuclear energy as baseload and peak sources of energy to support renewable energy growth.

Recent Debates on Natural Gas and Nuclear Power

Not too long ago, natural gas was perceived as a cleaner form of energy contributing to emissions reductions. The Obama administration supported the expansion of natural gas to reduce GHG emissions and to reduce

371 U.S. Energy Information Administration, "International Data," https://www.eia.gov/international/overview/world. Accessed April 2023.

372 NERC, "Ensuring Energy Adequacy with Energy Constrained Resources," White Paper (December 2020). https://www.nerc.com/comm/RSTC/ERATF/ERATF%20Energy%20Adequacy%20White%20Paper.pdf. Accessed July 19, 2023.

U.S. reliance on foreign energy,[373] and it included natural gas as a clean energy solution in its Power Africa Initiative to double access to electricity in sub-Saharan Africa.[374] Coal-to-natural gas switching at power plants was perceived as a shorter path to significantly cut emissions especially from countries in Asia with high coal consumption. According to the EIA, "natural gas is a relatively clean burning fossil fuel" compared with coal and oil, emitting nearly half of the amount of CO2 than coal.[375] According to a 2019 IEA report, even when accounting for both CO2 and methane emissions, "on average, coal-to-gas switching reduces emissions by 50% when producing electricity and by 33% when providing heat."[376]

However, in the past couple of years, some Western governments have nixed natural gas consumption as a long-term solution to lower emissions and have lumped it together with coal and oil. The Biden administration set a target to eliminate direct use of all fossil fuels in power generation by 2035,[377] marking an abrupt change from Obama's policy. In early 2023, the EU agreed to promote the global phaseout of fossil fuels,[378] though several countries in the EU do support gas as a transitional fuel until they scale-up various renewable forms of energy.[379] Those opposing the expansion of natural gas consumption are concerned both with its higher level of CO2 and methane emissions relative to renewables.

373 Megan Slack, "Everything You Need to Know: President Obama's Blueprint for American-Made Energy," Obama White House Archives (January 26, 2012). https://obamawhitehouse.archives.gov/blog/2012/01/26/everything-you-need-know-president-obamas-blueprint-american-made-energy. Accessed July 19, 2023.

374 White House, "Factsheet: Power Africa," Obama White House Archives (July 25, 2015). https://obamawhitehouse.archives.gov/the-press-office/2015/07/25/fact-sheet-power-africa. Accessed July 19, 2023.

375 U.S. Energy Information Administration, "Natural gas explained." https://www.eia.gov/energyexplained/natural-gas/natural-gas-and-the-environment.php. Accessed April 2023.

376 International Energy Agency, *The Role of Gas in Today's Energy Transitions*, World Energy Outlook Special Report (July 2019). https://www.iea.org/reports/the-role-of-gas-in-todays-energy-transitions. Accessed July 19, 2023.

377 H.J. Mai, "Energy experts share how the U.S. can reach Biden's renewable energy goals," NPR (February 2, 2023). https://www.npr.org/2023/02/02/1148370220/biden-renewable-energy-goals. Accessed July 19, 2023.

378 Kate Abnett, "EU agrees to push for fossil fuel phaseout ahead of COP28," Reuters (March 9, 2023). https://www.reuters.com/business/environment/eu-agrees-push-fossil-fuel-phaseout-ahead-cop28-2023-03-09/. Accessed July 19, 2023.

379 Camilla Naschert, "'It's about trust': EU green taxonomy scrutinized over inclusion of nuclear, gas," S&P Global (January 5, 2022). https://www.spglobal.com/marketintelligence/en/news-insights/latest-news-headlines/it-s-about-trust-eu-green-taxonomy-scrutinized-over-inclusion-of-nuclear-gas-68279835. Accessed July 19, 2023.

Nuclear power—a clean, but not renewable form of energy—is also under scrutiny in parts of the Western world. European governments in Germany, Portugal, Austria, and Luxembourg are against expanding nuclear power.[380] The U.S. government has been supportive of nuclear energy across different political administrations—both Trump and Biden administrations supported nuclear power—however, public polling has shown a divide among the American public on nuclear power. Polling data from the Pew Research Center from early 2022 showed 35% of U.S. adults support the production of nuclear power, 26% believe the government should discourage it, and the remainder of respondents did not indicate an answer.[381] Those opposing nuclear power expansion are concerned about safety and nuclear waste. As mentioned earlier in the paper, public sentiment toward nuclear power has wavered over time, especially following major nuclear accidents at Three Mile Island in the United States in 1979, Chernobyl in Soviet-era Ukraine in 1986, and the Fukushima-Daiichi nuclear plant in Japan in 2011 following an earthquake and tsunami.

Tradeoffs of Renewable Energy

While concerns about natural gas and nuclear power are valid, they are not the only forms of energy that carry risks. Like all forms of energy, renewable energy also has drawbacks and tradeoffs. Drawbacks include 1) environmental impacts from supply chain inputs such as mining, 2) land use requirements, and 3) capacity adequacy issues. These drawbacks can be somewhat mitigated to enable the continued scale-up of renewable energy, but governments will experience difficulties with fully decarbonizing grids with mostly solar and wind energy. Thus, rushing to eliminate and/or reduce investments in natural gas and nuclear power is likely too premature.

Environmental Risks: The mining requirements of clean energy technologies are substantial as they require more mineral inputs than

380 Lindsay Maizland, "Could Nuclear Power Cut Europe's Dependence on Russian Energy?" Council on Foreign Relations (March 15, 2022). https://www.cfr.org/in-brief/could-nuclear-power-cut-europes-dependence-russian-energy. Accessed July 19, 2023.

381 Rebecca Leppert, "Americans continue to express mixed views about nuclear power," Pew Research Center (March 23, 2022). https://www.pewresearch.org/fact-tank/2022/03/23/americans-continue-to-express-mixed-views-about-nuclear-power/. Accessed July 19, 2023.

fossil fuels.[382] An onshore wind plant requires six times more minerals than a similarly sized gas-fired power plant, and an electric vehicle requires six times that of a conventional car, according to the IEA.[383] As stated earlier in the paper, minerals and metals used in electricity networks, such as copper and aluminum, will also see a substantial boost in demand growth as increasing electrification is key to decarbonizing the electricity and transportation sectors. Several environmental organizations fear the environmental impacts of the expansion of mining globally to support the energy transition. Mining produces GHG emissions, toxic waste, requires freshwater, and risks contaminating local water resources if not managed properly. According to an article from the Massachusetts Institute of Technology (MIT), U.S. copper mining produces the largest percentage of mining and processing waste, with some waste storage piles spanning up to 1,000 acres, and some of the toxins have entered nearby local water systems.[384] REE mining produces both toxic and radioactive waste.[385]

Nonetheless, environmental regulations, waste management, and the shutdown of illegal mines can mitigate environmental impacts of mining. Scientists are also studying cleaner mining methods like phytomining—also known as hyperaccumulator metal extraction—which has the potential to unlock sustainable mining production if it can overcome economic and regulatory barriers. More research is also needed to determine its impact on the surrounding ecosystem.[386] In addition, mineral recycling can potentially play an important role in the future, but it will take some time to have enough minerals in the system to recycle and meet growing demand.

382 International Energy Agency, *The Role of Critical Minerals in Clean Energy Transitions* (May 2021), p5. https://www.iea.org/reports/the-role-of-critical-minerals-in-clean-energy-transitions. Accessed July 19, 2023.

383 International Energy Agency, "Clean energy demand for critical minerals set to sour as the world pursues net zero goals" (May 5, 2021). https://www.iea.org/news/clean-energy-demand-for-critical-minerals-set-to-soar-as-the-world-pursues-net-zero-goals. Accessed July 19, 2023.

384 Iris Crawford and Scott Odell, "Will mining the resources needed for clean energy cause problems for the environment?" MIT Climate Portal (July 21, 2022). https://climate.mit.edu/ask-mit/will-mining-resources-needed-clean-energy-cause-problems-environment. Accessed July 19, 2023.

385 Jaya Nayar, "Not So Green Technology: The Complicated Legacy of Rare Earth Mining," Harvard International Review (August 12, 2021). https://hir.harvard.edu/not-so-green-technology-the-complicated-legacy-of-rare-earth-mining/. Accessed July 19, 2023.

386 Maria J. Krol-Sinclair and Thomas Hale, "The United States Needs to Innovate New Mineral Production Technologies. Here's One." Center for Strategic and International Studies (March 24, 2023). https://www.csis.org/analysis/united-states-needs-innovate-new-mineral-production-technologies-heres-one. Accessed July 19, 2023.

The IEA estimates that recycling of copper, lithium, nickel, and cobalt from spent batteries will only meet about 10% of primary supply requirements for minerals by 2040.[387]

Land Use Requirements: The expansion of mining, solar farms, onshore wind farms, and electricity infrastructure—all needed to support clean energy technologies—poses questions about land availability. According to the IEA, there are locations in the world where land availability and other factors will constrain the scale-up of solar and wind energy.[388] A 100-MW solar plant—enough to power up to 17,000 homes (but this could vary depending on the capacity factor)[389]—requires nearly 250 acres of land.[390] According to a study by NREL, the direct land use of 80% of the wind projects examined was 1 acre per MW or below, but some ranged upward of 4 acres per MW.[391] In comparison, the land footprint per megawatt of fossil fuels and nuclear power plants are a small fraction of wind and solar.[392] By 2035, the United States is forecast to develop about 50 million acres of new land for energy production—most of which will be used for renewable energy.[393] Scholars worry that the vast land requirements for renewable energy will increase competition for land with other industries like agriculture and impact wildlife. The land requirement has raised questions

387 International Energy Agency, *The Role of Critical Minerals in Clean Energy Transitions.*

388 International Energy Agency, *Exploring Clean Energy Pathways: The role of CO2 storage* (July 2019), p3. https://www.iea.org/reports/the-role-of-co2-storage. Accessed July 19, 2023.

389 U.S. Nuclear Regulatory Commission, "What is a Megawatt?" (February 24, 2012). https://www.nrc.gov/docs/ML1209/ML120960701.pdf. Accessed July 19, 2023.

390 International Energy Agency, *Exring Clean Energy Pathways: The role of CO2 storage.*

391 Paul Denholm, Maureen Hand, Maddalena Jackson, and Sean Ong, *Land-Use Requirements of Modern Wind Power Plants in the United States*, NREL (August 2009). https://www.nrel.gov/docs/fy09osti/45834.pdf. Accessed July 19, 2023.

392 Dave Merrill, "The U.S. Will Need a Lot of Land for a Zero-Carbon Economy," Bloomberg (June 3, 2021), https://www.bloomberg.com/graphics/2021-energy-land-use-economy/#xj4y7vzkg (accessed July 19, 2023); and John van Zalk and Paul Behrens, "The spatial extent of renewable and non-renewable power generation: A review and meta-analysis of power densities and their application in the U.S.," *Energy Policy* 123 (December 2018), pp83-91, https://doi.org/10.1016/j.enpol.2018.08.023 (accessed July 19, 2023).

393 Andrew Moore, "Renewable Energy Poses Challenge For Wildlife Conservation," NC State University College of Natural Resources News (November 13, 2019). https://cnr.ncsu.edu/news/2019/11/renewable-energy-poses-challenge-for-wildlife-conservation/. Accessed July 19, 2023.

of whether land constraints will present a limit to how extensively renewable energy can be scaled up.[394]

Energy Adequacy: Government plans to decarbonize grids pose significant challenges for grid operators and energy adequacy—the ability of a grid operator to use its generation asset mix to meet power demand at all times—because it reduces dispatchable resources on the grid. According to a 2022 report on future grid reliability from the Independent System Operator New England (ISONE), which oversees the U.S. region's power grid, current simulation software used to model variable resources and storage needs to be overhauled because the software is outdated—developed when wind, solar, and storage were a small part of the resource mix—and is not rooted in reality and lacks granularity.[395]

The ISONE report highlighted grid reliability issues with wind and solar:

> In the current electrical grid, resources such as wind and solar are capable of high output at some moments, but not others. Wind farms generate large amounts of power when the wind is blowing, but zero power when the air is still; solar farms generate large amounts of power when the sun is shining, but generate less power when the sky is cloudy, and zero power when the sky is dark, or panels are covered in snow. As a result, they cannot easily function as dispatchable resources—meaning, they cannot be quickly deployed at moments of high demand (a hot summer evening, for example, or an overcast, still day). These constraints result in highly variable power output from wind and solar resources. Since the variable demand for electrical power does not mirror the variation in output of these resources, a grid-wide shift towards these kinds

394 Xudong Wu, Ling Shao, Guoqian Chen, Mengyao Han, Yuanying Chi, Qing Yang, Mohammed Alhodaly, and Muhammad Wakeel, "Unveiling land footprint of solar power: A pilot solar tower project in China," *Journal of Environmental Management* 280 (February 15, 2021), https://doi.org/10.1016/j.jenvman.2020.111741 (accessed July 19, 2023); and K. Calvert and W. Mabee, "More solar farms or more bioenergy crops? Mapping and assessing potential land-use conflicts among renewable energy technologies in eastern Ontario, Canada," *Applied Geography* 56 (January 2015), pp209-221, https://doi.org/10.1016/j.apgeog.2014.11.028 (accessed July 19, 2023).

395 ISO New England, *2021 Economic Study: Future Grid Reliability Study Phase 1* (July 29, 2022). https://www.iso-ne.com/static-assets/documents/2022/07/2021_economic_study_future_grid_reliability_study_phase_1_report.pdf. Accessed July 19, 2023.

> of resources, as reflected in the FGRS scenarios, can pose significant challenges to maintaining electrical grid reliability.[396]

Similarly, according to a 2020 report from the North American Electric Reliability Corporation, an organization that sets grid reliability standards in the United States:

> Operational uncertainty is increasing due to the types of, and conditions under which, energy, and by implication, fuel, is available or acquired; examples of these uncertainties are resources solely dependent on the availability of wind and solar, which are similar to run-of-river hydro plants in that they have no energy storage capabilities and are completely dependent on real-time weather conditions.[397]

Benefits of Pairing Natural Gas, Nuclear Energy, and Renewable Energy

An energy strategy that focuses on expanding natural gas, nuclear, and renewable energy in the generation mix can reduce CO2 emissions in the short term without compromising energy security. Natural gas and nuclear power provide the dispatchable energy needed to safely enable higher levels of renewable energy integration onto the grid. ISONE's 2022 study on a deep decarbonization scenario found that adding a relatively small amount of dispatchable units to a renewable-heavy grid—3,000 MW of dispatchable resources—could replace 17,000 MW of wind, solar, and storage capacity.[398] Hence, this diverse fuel mix could facilitate faster growth in electricity generation to support more power demand for EVs, which could reduce demand for oil in the transportation sector.

In a 2022 IEA report titled *Secure Energy Transitions in the Power Sector*, natural gas is highlighted as a critical part of energy security as renewable energy ramps up. According to the report,

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396 Ibid.

397 NERC, "Ensuring Energy Adequacy with Energy Constrained Resources," white paper (December 2020). https://www.nerc.com/comm/RSTC/ERATF/ERATF%20Energy%20Adequacy%20White%20Paper.pdf. Accessed July 19, 2023.

398 ISO New England, *2021 Economic Study: Future Grid Reliability Study Phase 1.*

> Gas security will become increasingly relevant to electricity security. Gas-fired plants will play an expanded role in the provision of adequacy, energy, and flexibility in their power systems and thus it will be crucial to ensure that gas will be deliverable when needed in instances of high electricity and gas demand combined with low availability of variable renewables.[399]

The report continues,

> Increased reliance on renewables will augment the need for technologies that provide flexibility and adequacy to the system. This will include storage, interconnections, natural gas-fired plants in many regions, and demand-side response enabled by digitalization.[400]

Hence, natural gas can play a crucial role in the transition to low-carbon fuels. Further development of carbon capture utilization and storage (CCUS) technologies to reduce costs and improve scalability of CCUS would reduce CO2 emissions at natural gas power plant sites. In addition, governments could provide financial incentives to companies responsible for gas upstream, midstream, and downstream infrastructure to reduce methane leaks, provide a grace period to adjust, followed by regulations that promote methane reductions.

As with renewable energy, nuclear power is among the most reliable and cleanest forms of energy. Nuclear power plants have the highest capacity factor at nearly 93%—compared with geothermal at 71%, natural gas at 54%, coal at 49%, hydropower at 37%, wind at nearly 35%, and solar at nearly 25%, according to DOE.[401] A capacity factor measures the reliability of a power plant; a factor of 100% means that the power plant generates electricity all the time. The lifecycle emissions of nuclear power are among

399 International Energy Agency, "Secure Energy Transitions in the Power Sector" (April 2021). https://www.iea.org/reports/secure-energy-transitions-in-the-power-sector. Accessed July 25, 2023.

400 Ibid.

401 U.S. Department of Energy, "What is Generation Capacity?" Office of Nuclear Energy (May 1, 2020). https://www.energy.gov/ne/articles/what-generation-capacity. Accessed July 19, 2023.

the lowest in comparison to other forms of energy. Based on a number of studies estimating lifecycle emissions, the average emissions for nuclear were 29 tonnes of CO_2 per gigawatt hour (GWh) compared with 26 tonnes per GWh for both hydroelectric and wind, 45 tonnes per GWh for biomass, 85 tonnes per GWh for solar, 499 tonnes per GWh for natural gas, 733 tonnes per GWh for oil, and 888 tonnes per GWh for coal.[402] The main drawbacks of nuclear energy are the initial high capital costs to build the plant, the use of uranium and plutonium for nuclear fuel, the radioactive waste produced throughout the process, and the risk of a nuclear incident, though some experts believe past nuclear incidents like Fukushima might have been prevented if plant operators had adhered to best practices and international standards.[403]

Refocusing on Coal-to-Gas Switching

Plans to eliminate natural gas risk reducing potential progress on emissions reductions goals. Because solar and wind energy require baseload power, several countries are likely to turn to coal as a baseload source if natural gas markets experience supply shortages or high prices. For instance, global coal consumption reached an all-time global high in 2022, as Russia's curtailment of gas exports led Europe scrambling to purchase gas volumes from LNG spot markets, triggering a gas supply shortfall and high prices worldwide.[404] As a result, several European and Asian countries increased their consumption of coal. In addition, emerging and developing countries in Asia plan to increase their use of coal, even while increasing renewable energy, because coal is more cost competitive than natural gas.[405] Instead of Western governments pushing for an end to natural gas use, they should focus on promoting coal-to-gas switching, as this would have a larger impact on emissions reductions.

402 World Nuclear Association, *Comparison of Lifecycle Greenhouse Gas Emissions of Various Electricity Generation Sources*, WNA Report (July 2011). https://www.world-nuclear.org/uploadedFiles/org/WNA/Publications/Working_Group_Reports/comparison_of_lifecycle.pdf. Accessed July 19, 2023.

403 James M. Acton, Mark Hibbs, and George Perkovich, "Was the Fukushima Accident Preventable?" Carnegie Endowment for International Peace (March 2012). https://carnegieendowment.org/2012/03/06/was-fukushima-accident-preventable-pub-47411#:~:text=Even%20if%20they%20had%20failed,Island%20accidents%E2%80%94was%20therefore%20preventable. Accessed July 19, 2023.

404 International Energy Agency, "The world's coal consumption is set to reach a new high in 2022 as the energy crisis shakes markets" (December 16, 2022). https://www.iea.org/news/the-world-s-coal-consumption-is-set-to-reach-a-new-high-in-2022-as-the-energy-crisis-shakes-markets. Accessed July 19, 2023.

405 Ibid.

Coal still accounts for a substantive portion of global energy consumption. According to the Energy Institute's data for 2022, coal met 27% of global energy consumption, only second to oil at 32%.[406] As mentioned earlier in the paper, coal production emits more CO2 than its fossil counterparts. According to EIA, more than 200 pounds of CO2 are produced per million British thermal units (MMBtu) of coal, compared with more than 160 pounds of CO2 per MMBtu of distillate fuel oil and 117 pounds of CO2 per million British thermal units (MMBtu) equivalent of natural gas.[407] Figure 15 shows that regions with the highest share of global coal consumption also have the highest share of global CO2 emissions from energy, indicating that coal plays a dominant contributing role in global emissions, though other factors also contribute to CO2 emissions. Coal is the dominant energy source in the Asia Pacific—accounting for almost 50% of the region's energy consumption and 80% of the world's coal consumption, which is the main reason the region accounted for more than half of global CO2 emissions from energy, as of 2022.[408]

Figure 15. Global Coal and CO2 Emissions from Energy, by Region, as of 2022

Region[1]	Share of Global Coal Consumption	Share of Global CO2 Emissions
Asia Pacific	80.8%	52.2%
North America	6.5%	17.0%
Europe	6.2%	11.0%
Commonwealth of Independent States (CIS)	3.0%	5.9%
Africa	2.5%	3.8%
South & Central America	0.7%	3.7%
Middle East	0.2%	6.4%

Source: Energy Institute's Statistical Review of World Energy
[1]Note: For a list of countries within each region, please visit: https://www.energyinst.org/statistical-review

406 Energy Institute, "Statistical Review of World Energy" (June 26, 2023). https://www.energyinst.org/statistical-review. Accessed July 19, 2023.

407 U.S. Energy Information Administration, "Natural gas explained." https://www.eia.gov/energyexplained/natural-gas/natural-gas-and-the-environment.php. Accessed April 2023.

408 Energy Institute, "Statistical Review of World Energy" (June 26, 2023). https://www.energyinst.org/statistical-review. Accessed July 19, 2023.

The benefits of coal-to-gas switching for emissions and the environment have long been touted. It is a demonstrated, sustained way to reduce CO2 emissions. The United States provides a good example. According to a 2021 EIA report, lower CO2 emissions from the U.S. electric power sector—which dropped by 32% from 2,544 million metric tons (MMmt) of CO2 in 2005 to 1,724 MMmt in 2019—were largely the result of coal-to-natural gas switching in electricity generation. During that period, coal as a share of U.S. electricity generation fell from 50% in 2005 to 23% in 2019, while natural gas increased from 19% in 2005 to 38% in 2019.[409] The increase in renewable energy generation—from 9% in 2005 to 18% in 2019—also contributed to lower CO2 emissions, but the shift from coal to natural gas had a larger effect on lowering emissions, according to EIA. The relatively fast-paced displacement of coal by natural gas in the United States was enabled by the fact that coal power plants can be replaced or converted to natural gas plants.[410] If similar rates of coal-to-gas switching occurred in Asian countries, the fall in global CO2 emissions would be unprecedented.

409 Glenn McGrath, "Electric power sector CO2 emissions drop as generation mix shifts from coal to natural gas," U.S. Energy Information Administration (June 9, 2021). https://www.eia.gov/todayinenergy/detail.php?id=48296. Accessed July 19, 2023.

410 Lindsay Aramayo, "More than 100 coal-fired plants have been replaced or converted to natural gas since 2011," U.S. Energy Information Administration (August 5, 2020). https://www.eia.gov/todayinenergy/detail.php?id=44636#. Accessed July 19, 2023.

Devising a New Disruptions Analysis Framework

Unplanned supply disruptions are major threats to energy security because they can lead to supply shortages and high prices, depending on the duration and magnitude of the outage. The 2022-2023 energy crisis—largely caused by an unplanned disruption of Russian gas supplies to Europe—led to soaring energy prices worldwide. Europe and Asia, the regions most affected by the crisis, both increased coal consumption, and Europe increased LNG imports to cope with disruptions. Europe also filled its natural gas storage to help with colder winter months.

As a refresher of the situation, after the EU supported sanctions against Russia following its February 2022 invasion of Ukraine, Russia's state-owned natural gas company Gazprom drastically cut pipeline gas exports to the region, leaving European buyers scrambling to purchase LNG from global markets and pushing up global LNG prices. Russia cut gas pipeline supplies to Europe by about 80 billion cubic meters (bcm) in 2022 compared with the previous year, and Europe increased its global LNG imports by about 50 bcm in 2022—two-thirds of which was from the United States.[411] Because Russian gas pipelines to Europe largely lack alternative outlets and could not be re-directed to other markets like with its oil exports, Russia's reductions to Europe created a tight global gas market affecting countries around the world. Europe began competing for global LNG spot cargoes (LNG not tied to long-term contracts) and outbid buyers in South and Southeast Asia, like Bangladesh, India, and Pakistan. Gas supply shortages in Pakistan and Bangladesh caused power outages, and countries in South and Southeast Asia have had to increase coal and fuel oil consumption to cope with the gas shortfall. The competition for global LNG cargoes could have been worse if it wasn't for a mild 2022-2023 winter and a year-over-year 20% drop in Chinese LNG imports in 2022 due COVID-related lockdowns.

Solar and wind energy are non-dispatchable, variable fuels that lack storage options and cannot be readily available to offset a disruption. In contrast, oil, gas, and coal inventories or spare capacity are used to fully or partially offset energy disruptions. U.S. policymakers need to develop a new

411 International Energy Agency, *How to Avoid Gas Shortages in the European Union in 2023* (December 2022). https://www.iea.org/reports/how-to-avoid-gas-shortages-in-the-european-union-in-2023. Accessed July 19, 2023.

disruptions analysis framework to examine potential disruptions that could occur if the U.S. energy system shifts to being predominantly fueled by renewable energy in the future, and how those disruptions can be promptly addressed or offset. Understanding our risk exposure to disruptions in a low-carbon energy world is an important aspect of energy security planning. Disruptions analysis has long been used in fossil fuel markets. Traditional disruption analysis frameworks should be adapted and tailored to the threats and risks inherent to low-carbon fuel markets and supply chains. This new disruption analysis framework can also help us to understand the threshold in which replacing fossil fuels with renewable energy will weaken our ability to mitigate supply disruptions, and if a larger reliance on renewable energy will require larger investment in fossil fuel inventories.

In the context of oil markets, recent examples of unplanned disruptions include shut-in production in Libya due to conflict, oil sanctions against Iran, and weather-related disruptions in the U.S. Gulf offshore. Oil disruption analysis focuses on examining the potential duration and magnitude of shut-in production or exports, and how that disruption will impact prices, which depends on the availability of substitutable fuels, fuel-switching, inventories, or spare production capacity. The globalized nature of oil markets, where supplies can be redistributed to various buyers, bolsters the ability of market actors to mitigate supply disruptions. With the emergence of seaborne, globally-traded LNG, similar disruption analysis can also be applied to natural gas, though gas markets are more regional than oil.

Disruption analysis during an energy transition and in a low-carbon energy world would need to be much more complex than traditional oil market disruption analysis, given longer supply chains and energy storage limitations. Disruptions analysis in the energy transition should plan for three types of disruptions: immediate, gradual, and over-the-horizon. Immediate disruptions are an abrupt halt to supply, like dim sunlight and low wind speeds. Gradual disruptions are disruptions to the supply of key inputs, components, and manufactured products that would require alternative supplies or substitutes to avoid energy supply shortfalls that may follow. For example, if China were to significantly reduce exports of processed lithium, that would impact battery pack manufacturers globally, including the United States, given that China accounts for 50-70% of processed lithium globally. Depending on the duration and magnitude of the disruption, this could impact EV manufacturers and EV drivers that are due for a new battery. This disruption would unfold more gradually than an immediate halt to energy flows, but nonetheless would have an impact on prices and potentially physical supply over time if the disruption was prolonged.

An over-the-horizon disruption is an anticipated shortfall of energy supplies five or more years out caused by insufficient investments. The transition to a world dominated by low-carbon energy fuels is not purely market driven—it is largely government driven where policymakers establish targets for low-carbon energy usage, which in turn reduces the market incentive for investments in new fossil fuel production. Therefore, potential supply shortfalls in the future of low-carbon energy and/or fossil fuel energy must be actively tracked by an entity within the U.S. government. Long-term mismatches in supply and demand are not typically under the umbrella of disruptions analysis. However, given aggressive net-zero planning, and the bifurcated nature of various actors in privatized U.S. energy markets (e.g., a national oil company or national renewables company do not exist), long-term mismatches in investment need to be closely watched to avoid an overall dearth in energy investments, which we are already seeing signs of, as explained earlier in the paper. In the United States, energy markets are privatized and coordination across renewables, nuclear, and fossil fuel industries does not formerly exist. Therefore, how does the United States ensure that it will have adequate and affordable energy supplies as fossil fuel investments fall? Are investments in clean energy technologies and technological breakthroughs occurring at a sufficient pace to allow clean energy to offset the losses to fossil fuel supplies in the future?

In addition, a new disruptions analysis framework tailored to the energy transition is needed to redefine terms traditionally used in disruptions analysis of fossil fuels. These terms include offsets, substitutes, and alternative suppliers, which are all essential to disruptions analysis because they are used to mitigate the impact of a disruption. For example, the term "offsets" in the context of oil market disruptions refers to strategic and/or commercial inventories or OPEC spare crude oil capacity that can be brought online to reduce the physical and price impact of the disruption. How should we look at disruption "offsets" in the context of variable sources like solar or wind? Will we continue to invest in fossil fuel inventories to offset disruptions in renewable energy, even if the share of fossil fuels in our energy mix is falling? What are the available substitutes for critical minerals or alternative suppliers if there are disruptions to traditional suppliers? U.S. policymakers, particularly at DOE, should consider establishing a team to create a new disruptions analysis framework for the energy transition.

Maintaining U.S. Role as a Dominant Energy Exporter and Seeking New Opportunities

U.S. policymakers should seek to build an energy security strategy that is resilient in an environment of heightened great power competition. U.S. adversaries Russia and China are leading exporters of various fuels, key inputs, and/or manufactured components, as detailed in this paper. In the era of great power competition, the United States should seek to counterbalance the energy dominance of its adversaries, position the United States to be capable of counteracting supply disruptions caused by adversaries in certain energy areas, and create mutual vulnerabilities in global energy markets. For example, in terms of mutual vulnerability, China will likely be more reluctant to disrupt the supplies of critical minerals (like REEs) to the United States in an escalatory or war-time scenario, if the United States is a dominant LNG exporter—as China is a major LNG importer and dependent on global markets. The United States should take a more deliberative approach to develop a long-term strategy to lead global exports of certain energy sources that the United States has a comparative advantage in—and that are in demand. As explained earlier in the paper, energy security is a pillar of national security, and the goals of a U.S. export strategy should aim to strengthen national security for the United States and its allies.

Climate ambitions to eliminate all fossil fuels benefit China—as China is the leading exporter of renewable energy technologies—but this disadvantages the United States, as it is one of the world's leading exporters of fossil fuels. As stated in this paper, natural gas should be incorporated into energy transition goals in the United States and elsewhere, as it can support greater integration of renewable energy and reductions in carbon-intensive coal. If the United States pursues a pathway of greatly reducing its oil and gas production in the future, it will be more difficult to counterbalance the rising power of China as an energy supplier, and the United States will concede oil and natural gas export market share to Russia and OPEC countries. This will make it easier for Russia and China, in addition to OPEC, to use its energy exports as leverage in the future. The U.S. government should be cautious about U.S. oil production falling too prematurely and leaving U.S. consumers even more dependent on OPEC, as shown by the IEA long-term forecasts.[412]

Strategic energy planning in the United States is difficult to do, but it is precisely what U.S. adversaries have been doing for decades and it has given them advantages on the global stage. China, Russia, and several other nations develop energy production and export strategies that align with their national security priorities. These countries have state-owned companies leading the development and export of their resources, making government decisionmaking and planning of national resources possible. On the contrary, the United States has a market economy with private companies making investment, production, and export decisions, though there are government regulations they must abide by. However, this paper does not recommend the United States nationalize energy assets, as a market economy promotes innovation, efficiencies, and is complementary to the values of a democracy. Instead, the U.S. government should work together with the private sector to ensure that a strategic U.S. national security asset—its energy assets—are being planned in a manner that aligns with the country's national security goals and supports the goals of our allies. The U.S. government should also increase energy diplomacy efforts abroad by promoting the signing of long-term supply contracts among allies and friendly countries. Working with private sector companies at home while coincidingly increasing energy diplomacy abroad could enable the U.S. government to better align its energy and national security goals, particularly in the current environment of great power competition and heightened geopolitical risks.

U.S. Leading Global LNG Exports

The United States should develop a long-term strategy to cement its position as a leading LNG exporter into the longer term to reduce global demand of Russian gas, especially Russia's growing LNG exports, among allies and friends. The United States is expected to become the world's leading LNG exporter in 2023, a trend that's expected to hold at least through this decade. In 2022, the United States was the third-largest LNG exporter, closely behind Qatar and Australia. Tight global LNG market conditions and high prices from 2021 to date opened a window of opportunity for LNG

412 International Energy Agency, *World Energy Outlook 2022*, p134.

exporters to sign new long-term contracts to obtain financing, make final investment decisions (FIDs), and start construction of new LNG facilities. Since Russia's invasion of Ukraine, U.S. LNG projects have locked in a high number of supply contracts with buyers hoping to obtain a lower sale price under a contract rather than paying higher, volatile spot prices.

The increase in U.S. natural gas production and LNG exports in recent years, though driven by market forces and unplanned by the government, enabled the United States to provide its European allies with much needed gas after Russia cut off most of its pipeline exports to the region. The White House formed a U.S.-EU Task Force on Energy Security where U.S. government officials met with European government officials, industry, NGOs, and private sector companies to coordinate additional volumes to Europe.[413] European LNG buyers have also been willing to pay a premium for spot LNG cargoes, outbidding other buyers and prompting gas shortages in South Asian countries.

U.S. LNG proved to garner foreign policy wins in two areas. First, it helped to partially shield Europe from Russia's attempt to use energy as a weapon of war. Second, in the longer term, growing U.S. LNG supplies will likely contribute to reducing Russia's future role in the global LNG market, at least through this decade. The recent and projected growth of U.S. LNG and the proliferation of new long-term contracts signed with U.S. LNG companies will likely reduce the need for Russian LNG that was assumed prior to Russia's invasion. In addition, Western sanctions on the export liquefaction technology and equipment to Russia will make it challenging for Russia to achieve its goal of suppyling 20% of global LNG by 2035.

The U.S. government needs to help keep the momentum going as Europe will need even more U.S. LNG in the coming years to meet demand, fill up storage, reduce or eliminate their LNG imports from Russia, and curb its coal consumption.[414] Market watchers warn it will be challenging for U.S. LNG to totally displace Russian gas to Europe over the next three years because of rising global competition for LNG cargoes and because the bulk of planned U.S. LNG projects will start exporting after three years. New, land-based U.S. LNG facilities that have reached FID, as of mid-2023, are mostly slated

413 White House, "Joint Readout of U.S.-EU Task Force Meeting on Energy Security" (November 7, 2022). https://www.whitehouse.gov/briefing-room/statements-releases/2022/11/07/joint-readout-of-u-s-eu-task-force-meeting-on-energy-security/. Accessed July 19, 2023.

414 International Energy Agency, *How to Avoid Gas Shortages in the European Union in 2023.*

to start commercial exports between late 2023 and 2028, and additional facilities that have not yet reached FID are predicted to start exporting sometime during the second half of the decade, though their forecasts are more uncertain. The U.S. government should explore how it can assist to ensure construction times are on time, or if possible, completed earlier to provide more gas to replace Russian gas to Europe and also capture growing gas markets in Asian countries seeking to reduce their consumption of coal and fuel oil. Construction times for LNG facilities in some cases can be shortened with financial incentives, like schedule performance bonuses, or by resolving issues with labor availability or productivity.[415] U.S. government officials should meet with industry representatives, as what's done with the U.S.-EU Task Force on Energy Security, to identify construction bottlenecks, and see if there is a role for government to assist.

Promoting U.S. LNG supply contracts should be a central focus of the U.S. government's energy diplomacy with Europe. As explained earlier in the paper, insufficient grid capacity in Europe will impede it from fully integrating its expansion of renewable capacity onto the grid and will lead to curtailment of solar and wind, according to a well-known energy consultancy.[416] Thus, despite the EU's desire to phase out all fossil fuel energy, including natural gas, that is unlikely to happen in the foreseeable future. U.S. government officials should make this clear to European counterparts and stress the need to sign additional U.S. LNG supply contracts so European countries can avoid having to revert to Russia in the future for gas supplies.

While the outlook for U.S. LNG looks promising, there are some uncertainties. First there are demand uncertainties. Global demand for LNG will be affected by renewable energy growth, the level of coal-to-gas switching, and the economic environment. In most scenarios, market watchers expect global LNG demand to grow from now to 2050, but the amount varies depending on those factors. U.S. LNG companies have around a dozen LNG projects in the planning pipeline that have not reached FID but have entered the approval process under the Federal Energy Regulatory Commission and DOE. Their future success largely depends on future global LNG demand and

415 Tom Zeal, "Are LNG Liquefaction Projects Taking Longer to Construct?" Merlin Advisors (April 2019). https://www.gti.energy/wp-content/uploads/2019/10/40-LNG19-04April2019-Zeal-Tom-paper.pdf. Accessed July 19, 2023.

416 Fabian Ronningen, "Gridlock: Europe's power network needs fast-track investment for decarbonization targets to be met," Rystad Energy (December 13, 2022). https://www.rystadenergy.com/news/gridlock-europe-s-power-network-needs-fast-track-investment-for-decarbonization-t. Accessed July 19, 2023.

their ability to secure long-term supply contracts with buyers. This provides an opportunity for U.S. government officials to engage in energy diplomacy on natural gas with countries beyond Europe, such as in South and Southeast Asia, which are seeking to increase their natural gas consumption to offset coal and fuel oil use to reduce emissions.

Gas production in South and Southeast Asia has been declining, prompting the region to turn to imports to satisfy growing natural gas demand. The region's potential for LNG import growth is substantial—in IEA's 2022 baseline forecast scenario, based on the current trajectory, LNG imports in the region rise from 13 bcm in 2020 to 128 bcm by 2050.[417] In both IEA's baseline scenario and Paris Agreement scenario (in which global temperature rise is limited to well below 2°C), the region's natural gas demand grows by 40% from 2020 to 2030, which would need to be met by imports. Forecast gas demand continues to grow through 2050 in both scenarios; in the Paris Agreement scenario it grows less but plays an important role to push out coal and provide flexibility to manage the grid and support greater renewable energy integration. The main uncertainties underlying these forecasts are the region's ability to bring online more LNG import capacity and LNG-to-power projects, and the price of natural gas relative to coal, as several countries in the region have access to cheap coal. If gas demand growth falls short of the forecast, then the region will continue pairing coal with renewable energy in the power sector. Some have questioned if low emissions fuels such as hydrogen and bioenergy can displace coal and/or natural gas in the power sector beyond 2030, but the former technology is not yet commercially viable at scale and requires a substantial amount of new infrastructure, and the latter prompts questions about the environmental impact and competition with food. In addition, it is doubtful that both will be cost competitive with coal or natural gas in the foreseeable future.

Coal-to-gas switching in South and Southeast Asia, as mentioned in an earlier section, is key to reducing global emissions relatively quickly. U.S. government officials should consider ramping up energy diplomacy with countries in that region to find opportunities to collaborate on bringing new LNG import facilities online, starting LNG-to-power projects, and receiving U.S. LNG through long-term contracts. There are several U.S. LNG projects that are

417 International Energy Agency, *Southeast Asia Energy Outlook 2022* (May 2022). https://www.iea.org/reports/southeast-asia-energy-outlook-2022. Accessed July 19, 2023.

seeking final investment decision but must first secure additional long-term contracts with buyers. U.S. LNG supply contracts are more advantageous to buyers because they have flexible destination clauses, meaning buyers can re-sell U.S. LNG cargoes on the global market, and U.S. contracts have various pricing options.[418] Deeper U.S. energy cooperation with the region also supports broader U.S. foreign policy objectives as laid out in the U.S. Indo Pacific Strategy.[419]

In sum, the U.S. position as the world's leading LNG exporter has geopolitical benefits, as shown by the Russia-Europe example, and can support broader U.S. foreign policy goals in the Indo-Pacific. For these reasons, the U.S. government should engage with the U.S. private sector and also abroad in energy diplomacy to help solidify this position in the longer term. As a leading LNG exporter in the long term, the United States is better positioned to challenge Russia's desire to become a leading LNG exporter. It can also counterbalance China's rise as an energy supplier of renewable energy technologies, manufactured components, and critical minerals, as China is the world's largest LNG importer, and is a large buyer of U.S. LNG supplies, including through long-term contracts.

Exploring New Opportunities

The U.S. government should explore other energy areas that present an opportunity to boost its ability to compete with Russia and China, while also reducing U.S. and allied dependence on adversaries. U.S. policymakers should assess its potential of becoming a leading exporter in various energy markets, like nuclear, solar, and wind, and then assess which market the United States is best positioned to compete in and possibly become a leading exporter. The United States will be unable to do it all; therefore, U.S. officials should home in on one of those markets and direct much of their efforts and resources there.

Another area not elaborated on in this paper is carbon dioxide removal (CDR) technologies. The United States is well positioned to lead the development and deployment of CDR technologies given its potential for

418 Siobhan Hall and Jonathan Dart, "Flexible US LNG contracts driving global spot market growth: API," S&P Global (May 20, 2019). https://www.spglobal.com/commodityinsights/en/market-insights/latest-news/natural-gas/052019-flexible-us-lng-contracts-driving-global-spot-market-growth-api. Accessed July 19, 2023.

419 White House, "Indo-Pacific Strategy of the United States," National Security Council (February 2022). https://www.whitehouse.gov/wp-content/uploads/2022/02/U.S.-Indo-Pacific-Strategy.pdf. Accessed July 19, 2023.

large geological storage along the Gulf Coast, along with vast land and energy resources. The United States and Canada are already leading the world in carbon capture and storage deployment.[420]

420 Alex Zapantis, Noora Al Amer, and Ian Havercroft, et al., *Global Status of CCS 2022*, Global CCS Institute (2022), https://status22.globalccsinstitute.com/wp-content/uploads/2022/11/Global-Status-of-CCS-2022_Download.pdf (accessed July 19, 2023); also see International Energy Agency, *Energy Technology Perspectives 2023* (January 2023), p454, https://www.iea.org/reports/energy-technology-perspectives-2023.

Reducing U.S. and Allied Reliance on Russia's Nuclear Industry

As mentioned earlier in the paper, Russia is a dominant player in the global nuclear market, leading global exports of enriched uranium and reactors. The United States and its European allies depend on Russia to satisfy a noteworthy portion of their nuclear fuel demand. While it will be difficult for the United States to economically compete and rival Russian nuclear exports on the global market, the United States and its allies need to at least reduce their own reliance on Russia.

The United States' and Europe's vulnerable position in the nuclear market was revealed during the alliance's fight against Russian aggression. After the invasion of Ukraine, Western countries left Russia's nuclear-related exports largely unsanctioned because of the world's reliance on it, including the United States and Europe, as Russia is the world's top exporter of enriched uranium and exporter of nuclear reactors for power generation. Many non-Western countries dependent on Russian nuclear services and materials have remained at the very least neutral during its invasion, including India, China, South Africa, and Iran, though there are likely additional factors underlying their positions. Russia's nuclear-related exports have increased in value since its invasion of Ukraine—totaling over $1 billion from March to December 2022—and its business with countries outside of North America and traditional customers in Europe is growing, according to a 2023 report from the Royal United Services Institute (RUSI).[421] According to the RUSI report, as of 2021, there were 44 Russian nuclear reactors operating outside of Russia in 11 countries, and from 2019 to 2022, 21 different countries received Russian nuclear-related exports.[422] Russia's nuclear-related exports, financing of nuclear reactor builds abroad, and long-term agreements to service reactors, replace parts, replenish fuel, and train locals are vehicles for Moscow to build political relationships.

U.S. and European efforts to diversify away from Russian nuclear fuel have been underway for over a decade, but progress has been slow. From 2015 to 2017, a European-funded project called European Supply

421 Darya Dolzikova, "Atoms for Sale: Developments in Russian Nuclear Energy Exports," Royal United Services Institute (February 14, 2023). https://rusi.org/explore-our-research/publications/special-resources/atoms-sale-developments-russian-nuclear-energy-exports. Accessed July 19, 2023.

422 Ibid.

of Safe Nuclear Fuel (ESSANUF) was launched to develop a conceptual fuel design to serve as an alternative to Russian nuclear fuel for Russian-built VVER-440 reactors in Europe.[423] It was led by the U.S. company Westinghouse in partnership with Spain's Enusa and a number of European institutions. Westinghouse and Enusa continued their partnership and recently completed the development of an alternative fuel for VVER-440 reactors.[424] In March 2023, Westinghouse sealed a deal with Czechia to begin deliveries starting in 2024.[425] Westinghouse has already developed an alternative nuclear fuel for the Russian-built VVER-1000, which it's been exporting to Ukraine since 2015 and will start exporting to Bulgaria under a 10-year agreement that was signed in December 2022 starting in 2024.[426] Westinghouse also signed a similar fuel-supply deal with Finland in November 2022, though it's unclear when deliveries will begin.[427] Westinghouse claims its VVER-1000 fuel is "the only fully Western option for VVER nuclear fuel fabrication"[428] and that its VVER-440 fuel is the only Russian alternative that is both designed and manufactured outside of Russia.[429]

The U.S. government has also expressed bipartisan support for expanding U.S. uranium mining, conversion, and enrichment. In 2022, during a congressional hearing, a Biden administration's DOE nominee said the U.S. government would need to spend $1 billion or more to expand U.S. uranium mining, conversion, and enrichment at a level necessary to replace

423 World Nuclear News, "Westinghouse ready to supply VVER-440 fuel" (March 13, 2018). https://world-nuclear-news.org/Articles/Westinghouse-ready-to-supply-VVER-440-fuel. Accessed July 19, 2023.

424 World Nuclear News, "Enusa and Westinghouse VVER-440 fuel collaboration" (January 18, 2023). https://world-nuclear-news.org/Articles/ENUSA-and-Westinghouse-agree-VVER-440-fuel-deal. Accessed July 19, 2023.

425 Westinghouse Electric Company, "Westinghouse Reinforces its Commitment to Energy Security in Czech Republic," News Releases (March 29, 2023). https://info.westinghousenuclear.com/news/westinghouse-reinforces-its-commitment-to-energy-security-in-czech-republic. Accessed July 19, 2023.

426 Westinghouse Electric Company, "Westinghouse's VVER-1000 Nuclear Fuel Fabrication Agreement Helps Cement Bulgaria's Energy Security," News Releases (December 22, 2022). https://info.westinghousenuclear.com/news/westinghouse-vver-1000-nuclear-fuel-fabrication-agreement-helps-cement-bulgarias-energy. Accessed July 19, 2023.

427 Westinghouse Electric Company, "Helping Finland to Secure Its Energy Future," News Releases (November 22, 2022). https://info.westinghousenuclear.com/news/helping-finland-secure-energy-future. Accessed July 19, 2023.

428 Westinghouse Electric Company, "Westinghouse's VVER-1000 Nuclear Fuel Fabrication Agreement Helps Cement Bulgaria's Energy Security," News Releases (December 22, 2022). https://info.westinghousenuclear.com/news/westinghouse-vver-1000-nuclear-fuel-fabrication-agreement-helps-cement-bulgarias-energy. Accessed July 19, 2023.

429 Westinghouse Electric Company, "Helping Finland to Secure Its Energy Future."

Russian uranium and related nuclear fuel services.[430] In 2022, Russia provided U.S. owners and operators of nuclear power reactors with 24% enrichment services and 12% of their uranium purchased.[431]

With U.S. government support, the domestic nuclear fuel cycle industry has the potential to be revived, displacing the need for Russian nuclear supplies in the United States. Under the U.S. government's $75 million uranium reserve program run by DOE, which was initiated by the Trump administration and continued by the Biden administration, the U.S. government is purchasing uranium from U.S. uranium producers and also awarded $14 million to the United States' sole uranium converter facility, ConverDyn, which was idled in 2017 and is expected to restart operations in 2023. The government has guaranteed to purchase 1 million tons of uranium hexafluoride from ConverDyn over five years.[432] As a result of U.S. government efforts, U.S. uranium production and conversion are both expected to start incrementally increasing in 2023. The U.S. government is considering increasing the program's allocation by an additional $150 million.[433]

However, despite some incremental progress on increasing domestic capabilities to produce alternatives to Russian nuclear fuel, U.S. companies do not domestically produce or export highly enriched uranium (HEU) for nuclear energy purposes due to the proliferation risk, and for countries such as Germany, operating nuclear reactors needing HEU fuel must go to Russia. The United States also does not yet commercially produce high-assay low-enriched uranium (HALEU), which is a higher enrichment than standard reactor grade, and is being utilized for some advanced fuels and next-generation reactor designs. In late 2022, DOE awarded $150 million, under a cost-share arrangement, to the American Centrifuge Operating, a

430 William Freebairn, "Replacing Russian uranium in case of ban might cost over $1 billion: DOE," S&P Global (March 17, 2022). https://www.spglobal.com/commodityinsights/en/market-insights/latest-news/electric-power/031722-replacing-russian-uranium-in-case-of-ban-might-cost-over-1-billion-doe. Accessed July 19, 2023.

431 U.S. Energy Information Administration, "Uranium Marketing Annual Report," Tables 3 and 16. https://www.eia.gov/uranium/marketing/. Accessed June 2023.

432 Duane Hope, "All Eyes on ConverDyne," Capital 10X (March 21, 2023). https://capital10x.com/all-eyes-on-converdyne/. Accessed July 19, 2023.

433 Andrea Jennetta, "US DOE awards $14 million to US uranium converter for reserve program," S&P Global (January 5, 2023). https://www.spglobal.com/commodityinsights/en/market-insights/latest-news/electric-power/010523-us-doe-awards-14-million-to-us-uranium-converter-for-reserve-program. Accessed July 19, 2023.

subsidiary of Centrus Energy Corporation, to start producing HALEU fuel for advanced reactors at a demonstration project at its Piketon facility in Ohio.[434] In June 2023, the U.S. Nuclear Regulatory Commission cleared the facility to start enrichment[435]—which can be up to 20%, higher than the 5% enrichment level for current reactors. Currently, Russia is the sole global exporter of HALEU, and thus, the United States is attempting to increase its domestic capabilities to fuel its future advanced reactors.

These U.S. policies have the potential to greatly reduce or eventually eliminate the need for Russian uranium for U.S. reactors; however, it is unlikely to lead to the United States producing enough uranium to displace Russian uranium and enrichment services on the global market because U.S. uranium costs relatively higher due to lower-quality uranium deposits.[436]

Partnering with Allies

Along with reducing its own reliance on Russia, the United States should also aim to increase its capability of providing alternatives to Russian nuclear fuel and reactors on the global market. However, because there will likely be challenges and limits to U.S. capabilities and resources, U.S. policymakers and companies should consider partnering with allies, such as Canada, France, Japan, and South Korea, to provide alternatives to Russian products and supplies on the global market. The U.S. government has effectively utilized energy diplomacy to advocate on behalf of U.S. companies trying to sign nuclear agreements with other countries; such diplomatic initiatives and efforts are outlined in the paragraph below. However, the United States will be limited in its ability to fully provide Russian alternatives, and compete with an emerging China, absent partnering with capable allies.

During both the Trump and Biden administrations, the United States increased energy diplomacy with allied and friendly countries to advocate on behalf of U.S. companies and promote U.S. partnerships on new nuclear

434 U.S. Department of Energy, "DOE Announces Cost-Shared Award for First-Ever Domestic Production of HALEU for Advanced Nuclear Reactors" (November 10, 2022). https://www.energy.gov/articles/doe-announces-cost-shared-award-first-ever-domestic-production-haleu-advanced-nuclear. Accessed July 19, 2023.

435 U.S. Department of Energy, "HALEU Demonstration Project Preps to Start First Domestic Production in U.S." (June 21, 2023).

436 Slade Johnson, "U.S. uranium production fell to an all-time annual low in 2019," U.S. Energy Information Administration (July 17, 2020). https://www.eia.gov/todayinenergy/detail.php?id=44416. Accessed July 19, 2023.

power plants. The Biden administration started initiatives like the Nuclear Futures Package to support countries with nuclear energy goals through capacity building, technical collaboration, and more. Closely related is also the Foundational Infrastructure for the Responsible Use of Small Modular Reactor Technology (FIRST) Initiative and the U.S. SMR Public Private Program and associated Small Modular and Advanced Reactor Standards and Regulations Workshop Series. Those initiatives provide capacity building support for countries wishing to bring online SMRs. NuScale, a U.S. based company developing SMRs, has signed agreements with Poland and Romania to deploy SMRs toward the end of this decade, and are in talks with Bulgaria, Czechia, Jordan, Kazakhstan, and South Korea.[437] Last Energy, another U.S.-based company developing SMRs, has signed power purchase agreements for 24 SMR units in the UK and 10 units in Poland.[438] Westinghouse is also entering the global SMR market, and in May 2023, it announced its newest AP300 design, a smaller version of its large nuclear power plant AP1000. Westinghouse is aiming for design certification of AP300 by 2027.[439] In the meantime, Westinghouse is continuing to market its AP1000, with units already operational in China, additional units under construction in China, and planned units in Poland and Ukraine.[440]

Given existing U.S. energy diplomacy efforts, U.S. government initiatives, bipartisan support, and progress made by U.S. companies in innovation and marketing their nuclear technologies, the United States is probably positioned to boost its ability in the future to offer some alternatives to Russian products and supplies for countries wishing to partner with the United States over Russia. However, the United States' nuclear industry still has a long way to go to become a dominant nuclear reactor and fuel

437 NuScale, "Projects," https://www.nuscalepower.com/en/projects (accessed May 2023); and World Nuclear News, "Expansion of US-Korean cooperation on SMRs" (April 26, 2023), https://www.world-nuclear-news.org/Articles/Expansion-of-US-Korean-cooperation-on-SMRs. Accessed July 19, 2023.

438 Will Wade, "Last Energy Signs Deals Worth $19 Billion for Nuclear Plants," Bloomberg (March 20, 2023), https://www.bloomberg.com/news/articles/2023-03-20/last-energy-signs-deals-worth-19-billion-for-nuclear-plants (accessed July 19, 2023); also see Last Energy, Press & News, https://www.lastenergy.com/news-press (accessed June 2023).

439 Westinghouse Electric Company, "Westinghouse Unveils Game-Changing AP300™ Small Modular Reactor for Mid-Sized Nuclear Technology," News Releases (May 4, 2023). https://info.westinghousenuclear.com/news/westinghouse-launches-ap300-smr. Accessed July 19, 2023.

440 Westinghouse Electric Company, "Westinghouse Celebrates Milestone Achievement for China's Sanmen Nuclear Plant," News Releases (April 5, 2023). https://info.westinghousenuclear.com/news/westinghouse-celebrates-milestone-achievement-for-chinas-sanmen-nuclear-plant. Accessed July 19, 2023.

exporter, and should consider working with allies, such as Canada, France, Japan, and South Korea, to jointly ramp up capabilities and offer Russian alternatives.

Over the past decade, companies from Russia, China, South Korea, France, and the United States have exported nuclear power plants abroad. As of June 2023, Russia is constructing over a dozen nuclear plants abroad in China, Egypt, India, Turkey, Bangladesh, Slovakia, Belarus, and Iran;[441] China is constructing a nuclear power plant in Pakistan;[442] South Korea is nearing completion of the fourth (and last) unit at its Barakah nuclear power plant project in the United Arab Emirates;[443] France is constructing two nuclear plants in the UK; and the U.S. company Westinghouse is deploying additional AP1000 reactors to China.[444]

Like the United States, its nuclear-exporting allies also have ambitions to compete with Russia and China and win bids to build nuclear power plants abroad. For example, South Korea recently set a goal of exporting 10 nuclear power plants abroad by 2030.[445] In addition, South Korea and Japan are separately seeking to increase exports of nuclear plant parts and materials. The United States should consider ways to work with nuclear-exporting allies to lower costs, provide competitive financing packages, and improve quality and safety. A 2023 analysis report from the Center for Strategic and International Studies recommends a U.S. partnership with South Korea:

> South Korea can build nuclear power plants more cheaply, on time and on budget, while the United States can impart its advanced capabilities in safe facility operation and

441 Mycle Schneider, "The World Nuclear Industry Status Report 2022" (October 2022). https://www.worldnuclearreport.org/IMG/pdf/wnisr2022-v3-lr.pdf. Accessed July 19, 2023.

442 Ayaz Gul, "China Begins Construction of Pakistan's Largest Nuclear Power Plant," Voice of America News (July 14, 2023). https://www.voanews.com/a/china-begins-construction-of-pakistan-s-largest-nuclear-power-plant-/7181016.html. Accessed July 19, 2023.

443 World Nuclear News, "Barakah 4 in final operational readiness tests" (June 8, 2023). https://world-nuclear-news.org/Articles/Barakah-4-in-final-operational-readiness-tests. Accessed July 19, 2023.

444 Westinghouse Electric Company, "Westinghouse Celebrates Milestone Achievement for China's Sanmen Nuclear Plant," News Releases (April 5, 2023). https://info.westinghousenuclear.com/news/westinghouse-celebrates-milestone-achievement-for-chinas-sanmen-nuclear-plant. Accessed July 19, 2023.

445 World Nuclear News, "Korean nuclear suppliers team up for export drive" (January 13, 2023). https://www.world-nuclear-news.org/Articles/Korean-nuclear-suppliers-team-up-for-export-drive. Accessed July 19, 2023.

> management. The two countries could pursue joint export projects that leverage each other's strengths, for instance with the United States providing reactor designs and maintenance and operation support, and South Korea providing equipment and construction work.[446]

However, Westinghouse's current lawsuit against Korean Nuclear and Hydro Power over intellectual property will likely impede cooperation, barring a resolution, and stall some of South Korea's nuclear power plant exports.[447]

The United States should also consider partnering with Canada, and possibly Australia, to boost alternatives to Russian uranium and enrichment services on the global market. The United States will be unable to do this alone because U.S. uranium costs relatively higher due to lower-quality uranium deposits. However, Canada, a principal U.S. ally, does have the resource potential to rival Russia in terms of uranium and enrichment. Canada has the world's third-largest share of uranium resources and high-quality uranium deposits, and according to the World Nuclear Association, "has a significant role in meeting future world demand."[448] In 2022, Canada was the largest supplier of uranium purchased by U.S. owners and operators of nuclear power reactors.[449] The U.S. government, along with the EU, should consider ways to collaborate with Canada, such as offering incentives to domestic companies wanting to invest in Canadian uranium mines, conversion, and enrichment facilities to increase alternatives to Russian nuclear exports on the global market. In addition to Canada, the United States might also consider ways of partnering with Australia. Australia holds the world's largest uranium resources and is the world's

446 Lami Kim, "Nuclear Belt and Road and U.S.-South Korea Nuclear Cooperation," Center for Strategic and International Studies (April 24, 2023). https://www.csis.org/analysis/nuclear-belt-and-road-and-us-south-korea-nuclear-cooperation. Accessed July 19, 2023.

447 Nuclear Engineering International, "US stalls South Korea's NPP export plans" (April 11, 2023). https://www.neimagazine.com/news/newsus-stalls-south-koreas-npp-export-plans-10747925. Accessed July 19, 2023.

448 World Nuclear Association, "Uranium in Canada," Country Profiles (January 2023). https://www.world-nuclear.org/information-library/country-profiles/countries-a-f/canada-uranium.aspx. Accessed May 2023.

449 U.S. Energy Information Administration, *Uranium Marketing Annual Report*, "Table 3," https://www.eia.gov/uranium/marketing/table3.php (accessed May 2023); also see U.S. Energy Information Administration, *Uranium Marketing Annual Report*, "Table 16."

fourth-largest uranium producer—which is all exported as the country does not generate nuclear power.[450]

In sum, the main goals for the U.S. government should be to first eliminate U.S. nuclear-related imports from Russia, and second, to partner with allies to increase alternatives to Russian and Chinese nuclear-related supplies on the global market. China is eager to start exporting nuclear technologies, though it has only built nuclear plants in Pakistan and has a proposed plan with Argentina to build Atucha III, though plans are delayed. The United States and allies should work together to gain greater market share now as it may prove difficult if China saturates the market in the future.

The Cost-Competitive Challenge

The biggest challenge the United States and allies will face is providing nuclear technologies as cheaply as Russia. Because Russia's nuclear exports are more cost competitive, the United States should market its nuclear products to countries specifically looking for Russian alternatives, and as a higher quality and safer product. Attracting customers on a purely cost basis will be difficult for the United States. Russia is known to offer generous terms, including a large loan amount, lower interest rates, and a generous repayment period—which is essential to many buyers as the cost of building nuclear power plants is in the billions of dollars, even for small reactors. Russia has offered countries loans to finance up to 80-90% of the value of the contract, according to information collected by the Columbia's Center on Global Energy Policy (CGEP) and published in an August 2022 paper.[451] Similarly, China committed to 85% of Argentina's Atucha III nuclear power plant project, which is estimated to cost $8 billion.[452] According to the 2022 CGEP paper, the United States has not offered financial

450 World Nuclear Association, "Australia's Uranium" (October 2022). https://www.world-nuclear.org/information-library/country-profiles/countries-a-f/australia.aspx. Accessed June 2023.

451 Matt Bowen and Alec Apostoaei, "Comparing Government Financing of Reactor Exports: Considerations for US Policy Makers," Columbia's Center on Global Energy Policy (August 25, 2022). https://www.energypolicy.columbia.edu/publications/comparing-government-financing-reactor-exports-considerations-us-policy-makers/. Accessed July 19, 2023.

452 Isabel Bernhard, "Why Argentina's Nuclear Power Project With China Has Stalled," *The Diplomat* (December 14, 2022). https://thediplomat.com/2022/12/why-argentinas-nuclear-power-project-with-china-has-stalled/. Accessed July 19, 2023.

assistance for its nuclear reactor exports since the 1970s.[453] From the 1950s-1970s, the United States was the leading exporter of reactors and the Export-Import Bank of the United States (EXIM) offered financial support to importing countries. The CGEP authors note EXIM and the U.S. International Development Finance Corporation (DFC) could restart U.S. financing of its nuclear reactor exports, as it already extends comparable loans for large, expensive energy projects overseas, such as $4.8 billion for LNG projects in Australia in 2012 and $4.7 billion for an LNG project in Mozambique in 2019.[454]

There are signs that the U.S. government might restart financing nuclear reactor export projects. In 2020, the DFC lifted its prohibition on financing overseas nuclear projects.[455] In December 2022, a bipartisan congressional letter was sent to DFC's Chief Executive Officer, urging the DFC to begin financing nuclear energy projects.[456] EXIM has also signed non-binding letters of intent in late 2022 and in 2023 with Romania and Poland, respectively, to provide financing for potential nuclear projects. Nonetheless, even if EXIM and DFC start financing nuclear reactor export projects, it would be difficult to provide terms as attractive as Russia and China. In addition, complicating matters further, the United States, like all members of the Organization for Economic Cooperation and Development (OECD), must adhere to OCED nuclear arrangement rules, which places limitations on loan terms for reactor exports.[457]

453 Matt Bowen and Alec Apostoaei, "Comparing Government Financing of Reactor Exports: Considerations for US Policy Makers."

454 Ibid.

455 U.S. International Development Finance Corporation, "DFC Modernizes Nuclear Energy Policy," Newsroom (July 23, 2020. https://www.dfc.gov/media/press-releases/dfc-modernizes-nuclear-energy-policy. Accessed July 19, 2023.

456 U.S. Senator Kevin Cramer, "Sen. Cramer, Colleagues Urge U.S. International Development Finance Corporation to Eliminate Prohibition on Supporting Civil Nuclear Energy" (December 8, 2022). https://www.cramer.senate.gov/news/press-releases/sen-cramer-colleagues-urge-us-international-development-finance-corporation-to-eliminate-prohibition-on-supporting-civil-nuclear-energy. Accessed July 19, 2023.

457 Matt Bowen and Alec Apostoaei, "Comparing Government Financing of Reactor Exports: Considerations for US Policy Makers."

Conclusion

The global energy transition will trigger more competition among great powers—the United States, China, and Russia. As detailed in this paper, the shift to displace fossil fuels with low-carbon technologies will introduce new complications and challenges, and policymakers need to avoid downplaying such tradeoffs and instead address them head on and modify goals where appropriate. Although the energy transition is still in its infancy, the current trajectory of U.S. energy planning will lead to greater reliance on adversaries for energy, increasing our risk exposure to energy disruptions and high prices, and giving our adversaries, namely China, an enduring advantage in global energy markets. This would be a reversal of the current environment. The United States has made tremendous progress in strengthening U.S. energy security over the past decade, which has benefited the national security of the United States and allied nations. The 2022-2023 European energy crisis would have been far worse without U.S. natural gas supplies.

Geopolitical risks have been a common feature of global energy markets, which have been dominated by fossil fuels. The plan to transition from fossil fuels to low-carbon energy will not on its own reduce these risks, but instead present new risks and challenges for the United States and allies, especially as China and Russia also seek to play prominent roles in various aspects of the transition and its politics. The paper identified seven competitive flashpoints triggered by the energy transition, with the potential to generate geopolitical, economic, and security risks for the United States. As a final recap, the competitive flashpoints identified in the paper include:

- Competition to acquire critical minerals
- Chinese dominance of low-carbon technology manufacturing
- Race to lead nuclear-related exports
- Trade and finance tensions between developed and developing nations
- Growing risk of cyber threats due to increased electrification and digitalization
- Energy-related disinformation campaigns from China and Russia
- Energy insecurity sparked by inadequate investment

U.S. policymakers should seek to build an energy security strategy that is resilient in an environment of heightened great power competition. Our adversaries, Russia and China, are dominating global energy markets. Russia is the world's leading exporter of nuclear energy technologies and fuel, a top exporter of oil despite Western sanctions, and while Russia has recently lost part of its global gas market share after cutting gas pipeline deliveries to Europe in 2022, Russia's global LNG exports rose by 10% in 2022 compared with 2021.[458] China is leading the mining, processing, and exports of critical minerals essential for the energy transition, the manufacturing of solar and wind components, the construction of high-voltage transmission lines, and is seeking to become a top exporter of nuclear technologies. Russia's invasion of Ukraine and the subsequent global energy crisis was a staunch reminder that so long as non-allied countries have global energy leverage, then global energy supplies and prices will be at the whim of foreign authoritarian governments prioritizing their own policy agenda.

Managing these competitive flashpoints will require rethinking of the energy transition and the ways goals are being set, rethinking the energy mix, building resilient supply chains, and strategizing ways in which the United States can maintain a leadership role in global energy markets, not just as a consumer, but as a supplier. In addition, the window of opportunity for the United States and allies to strategically plan clean energy supply chains not dependent on adversaries is now. The United States will be unable to compete in all areas—for example, U.S. companies will struggle to produce solar components as cheaply as China. But U.S. policymakers should focus on continuing to lead energy areas complimentary of U.S. comparative advantages, like global LNG exports, and identify new opportunities to counter Russia and/or China in energy markets in partnership with U.S. allies.

The silver lining of Russia's unprovoked invasion of Ukraine is it forced several European countries to find ways to reduce its energy dependence on Russia, which led to increased U.S.-European energy cooperation, as U.S. LNG filled most of the gap in European gas needs after Russia cut pipeline flows. Because of the growth of U.S. natural gas production and

458 Michael Ritchie, "Russia One Year On: What Changed?" Energy Intelligence (February 22, 2023). https://www.energyintel.com/00000186-747a-de95-a7ae-777e1f480000. Accessed July 19, 2023.

LNG capacity, the United States was capable of partially counteracting Russia's actions and supporting European energy security. While European energy consumers and businesses did suffer from supply shortages and exorbitant prices, the fallout would have been worse without U.S. LNG supplies. This was a win for U.S. foreign policy, though it was unplanned. The United States should formally adopt this as an energy and national security strategy—identify energy areas in which it makes the most sense to build up U.S. energy capabilities to counteract potential disruptions from adversaries in vulnerable areas.

Energy security—access to adequate energy supplies from non-adversarial countries at affordable prices—should be elevated to the forefront of energy policy planning. According to Dr. Brenda Schaffer, an energy security expert, energy policies have become a subset of climate policies,[459] and thus energy security is insufficiently accounted for in emissions reduction plans. As stated earlier, the United States should only adopt policies to reduce GHG emissions in the energy sector that do not weaken energy security and that do not give our adversaries enduring advantages. Moreover, the United States and allies should avoid rushing the energy transition, and in turn, locking in dependence on China for clean energy supply chains. In July 2023, the Central Intelligence Agency Director William Burns stated that "in today's world, no country wants to find itself at the mercy of a 'cartel of one' for critical minerals and technologies."[460] Hence, in today's global political context, U.S. energy policy planning, along with plans to reduce GHG emissions, need to better account for great power competition, energy security, and reducing reliance on adversaries, rather than quick emissions reductions at any cost.

459 Brenda Shaffer, "Lessons Learned from Europe's Energy Crisis," Center for Global Security Research, Lecture Series (February 24, 2023). https://cgsr.llnl.gov/event-calendar/2023/2023-02-24. Accessed July 19, 2023.

460 Guy Faulconbridge, "CIA's Burns: U.S. needs to de-risk and diversify away from China," Reuters (July 1, 2023). https://www.reuters.com/world/cias-burns-us-needs-de-risk-diversify-away-china-2023-07-01/. Accessed July 19, 2023.

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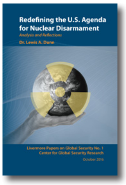

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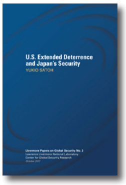

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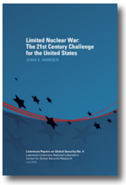

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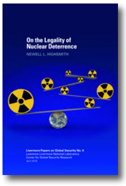

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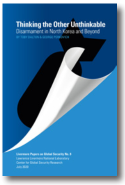

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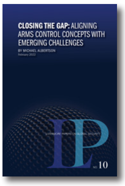

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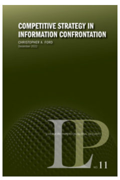

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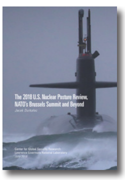

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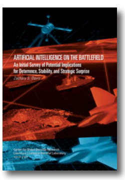

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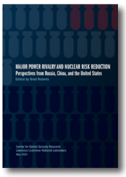

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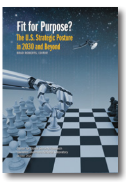

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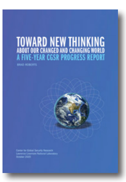

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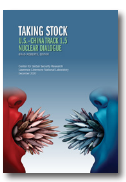

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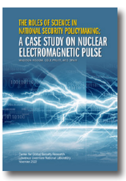

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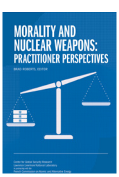

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