SECTION 3: CHINA'S ENERGY PLANS AND PRACTICES

Abstract

Despite Chinese leaders' stated commitments to decarbonize the economy, China remains heavily reliant upon energy-intensive and carbon-intensive industries and is the world's largest emitter of greenhouse gases. Its growing energy demand and significant import reliance on fossil fuels drive the government's focus on securing sufficient energy supplies to meet its needs. China thus employs a comprehensive energy strategy that seeks to ensure adequate energy supply and to reduce its vulnerabilities to maritime energy import chokepoints. By cultivating leadership in clean energy technologies, Beijing is seeking to profit from a global clean energy transition while further deepening its geoeconomic leverage. Ultimately, Beijing's energy strategy will intensify U.S.-China technology competition.

Key Findings

- China's demand for imported energy has significantly expanded in tandem with its growing economy, leading it to become a net crude oil importer in 1993. China depends on imports for 72 percent of its oil consumption, and the overwhelming majority of China's oil imports must pass through maritime chokepoints over which the United States has significant influence. To mitigate its vulnerabilities, China's government has invested billions of dollars in overland pipelines, launched a national tanker fleet it can direct to sail through conflict zones and potentially run blockades, and begun building out its capabilities for long-range power projection.
- Through its powerful economic planning agency, the National Development and Reform Commission (NDRC), the Chinese central government imposes strict energy price controls as levers that can be adjusted to remedy imbalances and allocate resources within China's energy system. These controls contribute to pervasive energy market distortions. Inconsistent and conflicting central government guidance contributes further to local energy system mismanagement. The resulting system is too brittle to correct for sudden energy supply disruptions and price shocks, and it contributed to a domestic energy crisis in 2021 that caused ripple effects throughout the global economy.
- Despite climate pledges by Chinese leaders, China remains the world's largest carbon dioxide emitter, and it continues to build out its coal-fired power plants with unprecedented speed. More-

over, decarbonization of China's energy-intensive economy sufficient to meet its stated goals would require large-scale economic restructuring, and policymakers have yet to make significant progress toward this goal. China's international and domestic climate targets intentionally delay the politically difficult policies required to meaningfully reduce emissions.

- Chinese national oil companies (NOCs) have also cultivated close relations with suppliers in the developing world, using local corruption in supplier countries as a competitive advantage and targeting oil-rich countries with low transparency to secure access to resources. Chinese NOCs exert growing control over global oil supplies by coopting foreign oil production through oil-backed loans or by pursuing ownership stakes in foreign oil-producing assets to secure "equity oil."
- Beijing is cultivating leadership in clean energy technologies in order to secure future markets and supply chains. A secondary goal is for domestically produced clean energy technologies to support China's decarbonization efforts. China's status as a global clean energy technology manufacturing hub and the fastest-growing renewable energy market affords it unique advantages in commercializing the next generation of clean energy technologies.

Recommendations

The Commission recommends:

- Congress direct the U.S. Department of Defense to produce a classified report on the feasibility of and the military requirements for an effective blockade of energy shipments bound for China in the event of military conflict involving China. The report should place particular attention on the Strait of Malacca and the feasibility of operationalizing a blockade of shipping bound for China intending to transit that waterway. The report should also consider the extent to which China may be able to satisfy its energy needs during a crisis or conflict through stockpiles, by rationing supplies, and by relying on overland shipments through current and planned cross-border oil and gas pipelines.
- Congress direct the U.S. Department of Energy to produce an annual report detailing the extent to which U.S. supply chains for key energy technologies, components, and materials are subject to Chinese control or manipulation.

Introduction

China's economic model is energy- and carbon-inefficient. This system is a product of sustained Chinese government policy decisions to prioritize economic growth over energy efficiency or climate considerations. This model has delivered decades of breakneck economic growth while supporting the political and economic interests of powerful state-owned enterprises (SOEs) and local governments. The Chinese economy is powered by a coal-dependent energy system and energy-intensive infrastructure. Prescriptive planning targets and a system of price controls managed by China's NDRC overlay this infrastructure and generate significant market distortions. Meanwhile, a deeply fragmented energy policymaking system remains unable to implement system-wide rectifications. In part because of these systemic inefficiencies, Chinese leaders harbor a sense of energy insecurity, or a concern that sufficient energy supply might not be readily available to meet domestic demand, like during the energy crisis of 2021. Dependence on oil imports by sea is central to this sense of energy insecurity because it creates a significant vulnerability to foreign interdiction in the event of conflict.

The Chinese Communist Party's (CCP) need for economic growth and energy security drives Chinese policies that challenge U.S. naval dominance along key sea lanes. China's government actively seeks to circumvent or break what it perceives to be U.S.-controlled chokepoints in sea lanes vital to China's commercial access to oil. It does so largely by attempting to advance the People's Liberation Army (PLA) naval power projection farther from China's shores. At the same time, Chinese firms are racing to outpace the United States in innovating and commercializing the next generation of new energy technologies, with the potential to further embed them within clean energy supply chains.

This section identifies the drivers of China's energy and climate policy and assesses energy initiatives to address its energy insecurity and climate-related vulnerabilities. First, the section overviews China's energy mix and consumption patterns to contextualize its energy supply vulnerabilities. The section then analyzes these vulnerabilities, including sensitivity to global energy price shocks and policy-induced crises as well as susceptibility to maritime chokepoints. Next, it discusses climate-related vulnerabilities for which China sees technology as an immediate solution despite the necessity of long-term economic restructuring. Finally, the section considers the implications for the United States of China's energy and climate policies and efforts to mitigate related vulnerabilities. This section is based on the Commission's March 2022 hearing on "China's Energy Plans and Practices," consultations with academics and industry experts, and open source research and analysis.

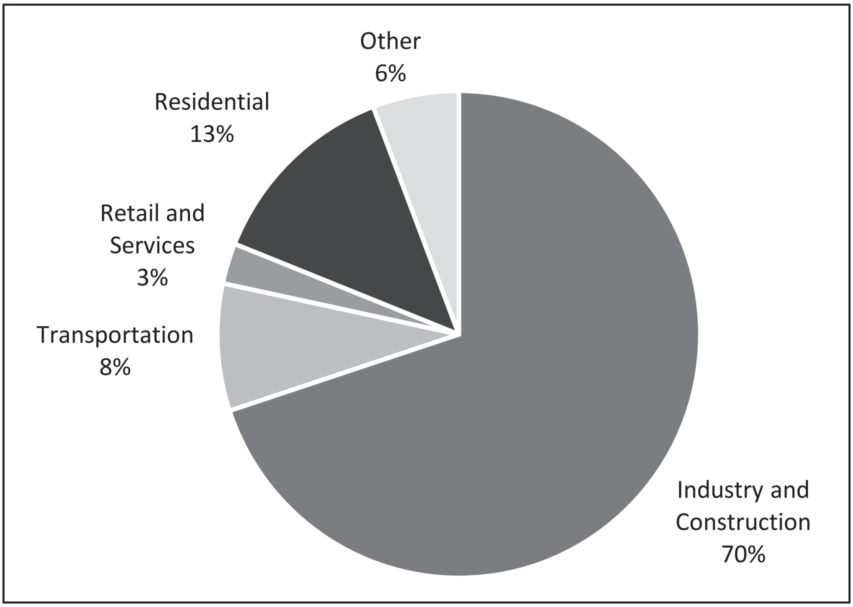
China's Economy Is Energy and Carbon Intensive

Energy intensity* is a central feature of China's economic model, causing an enduring link between economic growth and voracious energy consumption. For example, the Chinese economy requires more than twice as much energy to produce the same amount of economic growth as more energy-efficient countries, like the United Kingdom (UK), that have transitioned away from heavy industries.[1] Along with this energy intensity, the sheer size of China's economy makes it the world's largest consumer of energy, accounting for

*Energy intensity refers to the amount of energy required to produce one unit of output. As of 2021, China's economy required 0.144 kilograms of oil equivalent (a proxy measure for energy intensity) to produce $15 worth of GDP (adjusted for purchasing power parity), while the U.S., Indian, and Russian economies respectively required 0.104, 0.100, and 0.212 kilograms to produce the same amount. Notably, purchasing power parity adjustments artificially increase the value of GDP in countries like China with a low cost of living, causing energy intensity indicators to appear lower than they are. Enerdata, "Energy Intensity," 2021.

approximately 25 percent of global energy consumption in 2021.[2] China's heavy industries, including steel, aluminum, and concrete, combined with the construction industry, together account for the vast majority of energy demand and drive China's carbon footprint, with these sectors accounting for approximately 70 percent of total energy consumption by 2019 (see Figure 1).* These sectors also contributed to at least 38.6 percent of China's gross domestic product (GDP) for all years between 1970 and 2019, making them essential drivers of Chinese economic growth.[3]

Figure 1: China's Energy Consumption by Sector, 2019



Source: China's National Bureau of Statistics via CEIC database.

China's economy runs primarily on fossil fuels, making it the world's largest emitter of carbon dioxide. Between 2000 and 2021, China's total energy consumption posted a 256.5 percent expansion, with coal dominating China's energy mix due to extensive domestic reserves.† [4] Coal reserves and imports of foreign oil and natural gas have long served as the backbone of China's energy system, supplying much of the energy used for industrial factories, transportation, and residential heating. While China is the world's largest

*Because heavy industries require high levels of heat to produce materials like steel and aluminum, they contribute to an enormous demand for energy that is usually generated from coal. As such, the power, steel, cement, and coal-chemicals industries were responsible for approximately 72 percent of China's carbon emissions and 86 percent of coal consumption in 2019. Jake Schmidt, "China's Top Industries Can Peak Collective Emissions in 2025," *National Resource Defense Council*, January 18, 2022; China's National Bureau of Statistics via CEIC database.

†China is home to the world's fourth-largest proven coal reserves as of 2018, yet it also imports coal from countries like Indonesia to reduce the cost of transporting it to industrial centers on the east coast. China's industrial clusters in the northeast are primary supplied by nearby coal mines, while China's eastern and coastal industrial hubs rely upon imported coal from nearby suppliers like Indonesia. Mining Technology, "Countries with the Biggest Coal Reserves," January 6, 2020; *Reuters*, "China Coal Futures Surge on Supply Worries amid Indonesia Export Ban," January 4, 2022.

coal consumer, producer, and importer, it is simultaneously home to the world's largest renewable energy capacity buildout, accounting for 33 percent of the world's total installed renewable energy capacity.[5] (For more on the market structure, key policy goals, and challenges related to individual energy sources in China's energy mix, see Appendix.) Despite Beijing's desire for renewable energy to account for a larger percentage of China's energy mix, institutional and technical barriers prevent renewable energy from being a significant contender with coal for space on China's energy grid, detailed further below. As a result, renewable energy sources only contributed to about 14 percent of China's total energy mix in 2020 (see Table 1).[6]

Outsized Importance of Oil

Though it represents only one-fifth of China's energy mix, oil is and will remain a largely irreplaceable energy resource in China until the development and widespread use of new energy technologies. Chinese leaders appear to separate oil disruptions from the broader array of potential energy supply problems, considering them national security issues while regarding electricity supply disruptions as issues of social or economic management.[7] Oil is vital not only to PLA operations but also to China's civilian transportation sector, where few substitutes for road fuels exist at scale. In addition to oil's role as China's premier road fuel, it remains the principal energy source for several sectors that are difficult to electrify, including heavy transport, aviation, and shipping.[8] Even as China aims to develop its electric vehicle (EV) industry, these new energy vehicles only represent 2.06 percent of the total 292 million vehicles in China, with the rest relying on some form of petroleum-consuming internal combustion engine.[9]

Table 1: Share of China's Total Energy Consumption by Source, 2000–2020

Year	Coal	Oil	Natural Gas	Renewables	Nuclear
2000	69.6%	22.2%	2.1%	5.7%	0.4%
2005	73.3%	18.3%	2.2%	5.5%	0.7%
2010	70.0%	18.0%	3.8%	7.5%	0.7%
2015	63.7%	18.7%	5.5%	10.7%	1.2%
2020	55.9%	19.5%	8.2%	14.2%	2.2%

Note: Renewables include solar, wind, hydro, biofuels, geothermal, and biomass.
Source: BP Statistical Review of World Energy Database; BP, "Energy Outlook 2020—China," 2020.

Challenges to Renewable Energy Integration in China

China's installed capacity in renewable energy sources far outstrips its actual use of these sources because of geographic constraints, technological limitations, and local protectionism.

- *Geographic constraints:* Renewable energy sources are cultivated according to the presence of geographic features like rivers, steady and unimpeded sunlight, and predictable wind patterns, and they have therefore developed within clusters, some in China's hinterlands.[10] Geographic clustering has led to high rates of wasted renewable energy,* as local electricity grids do not always have the capacity to accept all of the renewable energy generated by nearby plants. China continues to invest in nationwide high voltage transmission lines to connect renewable energy from where it is generated to consumers across the country.
- *Technology limitations:* China's electricity grid cannot yet reliably incorporate renewable energy without technical upgrades. Renewable energy sources like solar and wind are intermittent energy sources because they cannot always produce steady flows of energy due to fluctuations in sunlight and wind. As a result, energy grids must be able to adjust for fluctuations in the amount of renewable energy provided to the grid at different periods in time, often relying on fossil fuels to compensate for dips in renewable energy supply.[11]
- *Local protectionism:* Local grids in coal-prevalent regions have historically attempted to avoid buying renewable energy generated from other regions in order to support energy generated locally by coal-fired power plants. China's central government passed the Renewable Energy Law of 2005 to address this, mandating that all grid operators purchase all renewable energy connected to their grid; however, implementation and enforcement of the law has been inconsistent.[12]

Supply Vulnerabilities Drive China's Energy Policy

Chinese policymakers are acutely concerned about the nation's energy security due to the Chinese economy's significant energy intensity and reliance on imported fossil fuels. Chinese leaders define energy security as the ensured uninterrupted availability of energy resources sufficient to meet China's needs at an affordable price. On June 13, 2014, General Secretary of the CCP Xi Jinping announced

*In power generation, "wasted renewable energy" refers to the phenomenon of curtailment, or the deliberate reduction of a source's output below what it could produce. China has particularly high curtailment in renewables, as its electricity grid often cannot accept all of the energy generated by solar and wind farms. Oversupply of renewables may occur due to a number of factors, including weather patterns such as peaking sunlight during midday or strong winds during a storm. Curtailment also results from local grid companies simply choosing not to purchase renewable energy from local generators due to a preference for energy generated from other sources. California Independent System Operator, "Impacts of Renewable Energy on Grid Operations," May 2017.

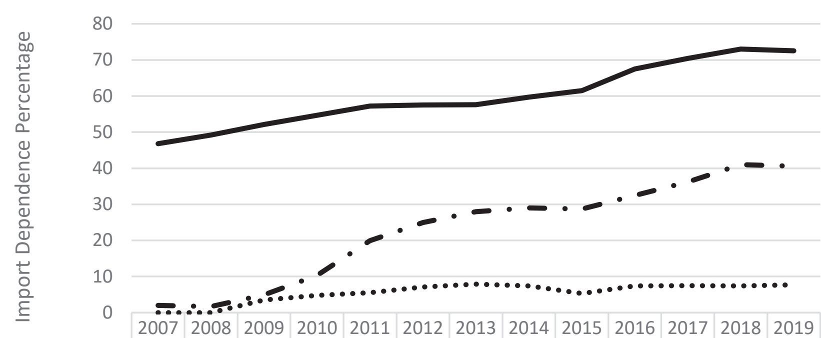
five energy security strategic objectives called the "Four Transformations and One Cooperation" to guide China's energy policies. The "Four Transformations" are (1) curb unnecessary energy consumption, (2) build a diversified domestic energy supply structure not reliant on any one energy source, (3) invest in new energy technologies to upgrade China's domestic industries, and (4) use energy system regulations to promote the growth of China's energy sector.[13] The "One Cooperation" refers to enhancing international cooperation in every aspect but doing so with the premise that domestic needs and solutions must have priority.[14] China's international initiatives prioritize domestic energy needs using coercive measures such as securing highly volatile oil-backed loans and corrosive measures such as engaging with highly corrupt countries to more quickly secure access to their resources.

China's reliance on imported fossil fuels increases its economy's sensitivity to global energy price shocks, with Chinese government attempts to control domestic energy prices causing pervasive market distortions. Exemplified by an energy crisis in the fall of 2021, strict NDRC price controls and unclear CCP guidance to local governments on emissions reductions has resulted in pervasive mismanagement of the Chinese energy system. Distortions caused by central- and local-level market interventions generate ripple effects throughout the global economy, contributing to supply chain disruptions and global inflationary pressures while exacerbating China's feeling of energy insecurity. China is also the world's top importer of crude oil and coal, contributing to its perceived vulnerability to foreign-imposed disruptions.[15] The Chinese government is absorbing enormous costs to mitigate potential disruptions to its energy imports, revealing leaders' concerns that a U.S.-China military conflict could cut off its access to oil.

China's Economy Is Vulnerable to Energy Crises

China's energy intensity increases its import reliance for coal, natural gas, and oil. This represents a key vulnerability for China's leaders, who have repeatedly stated that the Chinese people "must hold [their] energy supplies firmly in [their] own hands."[16] In 2018, China was 73 percent and 41 percent import dependent on oil and natural gas, respectively (see Figure 2).[17] According to Michal Meidan, director of the Gas and China Programs at the Oxford Institute for Energy Studies, Chinese policymakers are concerned that China's import dependency leaves it vulnerable to the actions of a hostile foreign power.[18] To mitigate these risks, China has attempted to increase domestic production and diversify its energy mix. China is unlikely to achieve either objective fast enough, as its demand for natural gas and oil are predicted to peak in 2040 and 2030, respectively.[19] Despite efforts to expand domestic natural gas exploration and production, China's production cannot keep pace with its demand, thereby intensifying its future import dependency.[20] Similarly, while Chinese oil companies are heavily investing in domestic oilfield development and exploration, production of crude oil decreased by 2 percent over the last ten years.[21]

Figure 2: China's Oil, Gas, and Coal Import Dependency, 2007–2019



	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Oil	46.8	49.2	52.1	54.7	57.2	57.5	57.6	59.7	61.5	67.5	70.4	73	72.5
Gas	2	1.7	4.9	10.3	19.9	25	28	29	28.7	32.5	36.2	41	40.6
Coal	0	0	3.5	4.8	5.5	7.1	7.9	7.4	5.3	7.4	7.5	7.4	7.7

Note: Figure illustrates the percentage of China's total oil, gas, and coal consumption from imported sources.
Source: International Energy Agency, "Oil, Gas and Coal Import Dependency in China, 2007–2019."

China's energy-intensive model increases its economic vulnerability to energy crises, with the Chinese government's energy price control system attempting to buffer against exogenous price shocks. China's NDRC uses price controls as levers that can be adjusted to remedy imbalances and allocate resources within China's energy system according to policy goals. For example, the NDRC currently sets a fluctuating 20 percent price band with a maximum price that utilities can pay power generators for electricity. Furthermore, this price varies according to region, energy source, and type of electricity consumer (e.g., household or industrial).[22] Such price controls distort national energy markets, as the NDRC manages the price of electricity according to policy goals such as the promotion or restriction of certain technologies or energy sources.[23] Electricity prices in China thus do not fully reflect the economic costs of electricity production, thereby forcing power generators to rely on government subsidies or suffer reduced profit margins when costs outstrip the price cap.* When this mechanism fails to effectively coordinate state behavior, it can exacerbate the impact of energy price shocks and cause disruptions throughout China's economy.

An energy crisis in the fall of 2021 exemplified China's vulnerability to its own policy-induced energy shortages. The crisis was chiefly due to the inability of China's price control mechanisms to adjust to sudden fluctuations in global energy commodity prices, causing

---

*National, provincial, and local governments subsidize power generators by supplying fossil fuels at reduced costs, as well as soft loans and land-use rights. Some state-owned generators also cross-subsidize operations by using profits from a parent or subsidiary business to cover losses. The Chinese government also directly subsidizes renewable energy power generators through feed-in tariffs that guarantee that the price paid for electricity covers the firm's costs. Bertrand Rioux et al., "How Do Price Caps in China's Electricity Sector Impact the Economics of Coal, Power and Wind? Potential Gains from Reforms," *Energy Journal* 28 (2017): 68.

power generators to face significant financial losses.[24] At the time, a 10 percent fluctuating benchmark ensured that electricity prices could not increase above a set price, though the NDRC later widened the benchmark to allow a 20 percent fluctuation.[25] These price controls prevented power generators from passing on globally rising coal prices to consumers, instead forcing them to either shutter their operations or produce electricity at a financial loss.[26] Power generators across the country closed their operations "for repairs," causing rolling blackouts in 20 provinces as well as factory closures and residential power rationing.[27] Due to the pervasive economic disruptions caused by energy shortages, industrial value added, which measures the contribution of industry to China's economy, slowed dramatically. During the height of the energy crisis in September 2021, industrial value added increased by only 3.1 percent year-on-year, marking its lowest level since 2002, aside from pandemic-related interruptions in 2020 and 2022.[28] China's energy crisis exacerbated existing global inflationary pressures for commodities, causing the global trading price of steel to increase by almost 20 percent between August and October 2021.[29] One year later, in August 2022, Chinese officials made a similar decision to ration industrial power during an energy shortage in southwest China, once again forcing factory closures that disrupted supply chains and curtailed industrial output (see textbox "Drought and Heatwave Cause Second Summer Energy Crunch in a Row").[30]

Drought and Heatwave Cause Second Summer Energy Crunch in a Row

A drought and a coinciding heatwave in China's southwestern provinces have caused energy shortages throughout China in August into September 2022, forcing major manufacturers to halt production.[31] The southwestern province of Sichuan experienced an energy crisis due to severe droughts that curtailed hydroelectric power, which provides over 80 percent of Sichuan's energy.[32] Excess hydroelectric power from Sichuan also provided approximately 30 percent of China's hydroelectric power, equivalent to approximately 2.3 percent of China's overall energy mix in 2021 (for more on China's hydropower sector, see "Appendix, Renewable Energy: Hydropower, Wind, Solar, Geothermal, and Biofuels").[33] The droughts caused the Yangtze River to fall to its lowest level on record, contributing to a nearly 14 percent year-on-year drop in Sichuan's hydropower output.[34]

Additionally, a record heat wave drove temperatures up to 113 degrees in neighboring Chongqing during August 2022, 22 degrees above the average monthly high temperature during the month.[35] Residential demand for air conditioning has skyrocketed throughout the region, further exacerbating the gap between energy supply and demand. To preserve power for residential use amid the heat wave, local officials in at least 19 provinces instituted a system of power rationing that cut power to factories, local small businesses, shopping malls, and city light displays.[36]

China's state-directed style of energy management introduces systemic inefficiencies that can augment the country's sense of energy insecurity through sudden energy disruptions. In her testimony to the Commission, Dr. Meidan explained that since 2003 each of China's power outages and supply interruptions have been caused by domestic policies rather than external forces.[37] For example, in 2005 a misalignment between China's domestic pricing mechanisms and global prices caused a gasoline shortage, as Chinese oil companies preferred to export their supplies to offset losses caused by the domestic pricing mechanism.[38] Mismatched policy priorities and conflicting government directives can also contribute to policy-induced disruptions, as local cadres attempt to promote both economic growth and emissions reductions. On numerous occasions, centrally mandated energy intensity reduction targets have incentivized local governments to suddenly shut off residential heating in their jurisdictions or dramatically reduce industrial output to meet the targets.[39] Power rationing generated popular discontent in affected regions, as citizens complained that critical aspects of everyday life, including the ability to take online classes, work from home, and even cook meals, were suddenly disrupted for days on end.[40]

While state dominance of the energy sector creates both market inefficiencies and vested fossil fuel interests, it also supports responsiveness in times of crisis when interests are aligned. In the fall of 2021, coal prices skyrocketed due to a global supply shortage and sudden rebound in demand driven by China's economic recovery.[41] To rectify the shortage, Chinese regulators, including the NDRC and the National Energy Administration (NEA), directed the most efficient domestic mines in Inner Mongolia, Shanxi, and Shaanxi to boost production, while provincial governments and state-owned power generators increased their coal imports from Russia, Indonesia, and Mongolia.[42] Combined with the NDRC's decision to relax its price controls, the government's coordinated actions to increase domestic coal production helped to alleviate the crisis.

China's Oil Insecurity and the Shadow of Conflict

Chinese leaders have adopted policies to mitigate perceived vulnerabilities in China's access to oil while undermining U.S. naval power. Central to China's vulnerabilities are maritime chokepoints, through which the overwhelming majority of China's oil imports must transit and over which the U.S. government has significant influence. The Chinese government's fears of U.S. naval interdiction of its sea lanes have led the PLA and Chinese SOEs to develop capabilities that could challenge U.S. naval supremacy in the Indian Ocean. Additionally, China's government is attempting to create alternative patterns of seaborne transit through Southeast Asia to avoid the chokepoint at the Strait of Malacca. The efforts are costly and would marginally reduce but not solve China's dependency on seaborne oil imports, but their success would work toward addressing China's self-assessed vulnerability to a naval blockade in the event of a major conflict.

Maritime Chokepoints: Beyond the "Malacca Dilemma"

One key vulnerability in China's seaborne oil imports is the series of maritime chokepoints inherent in Asia's geography. The Strait of Malacca is China's most critical maritime chokepoint, and approximately 80 percent of China's oil imports transit the strait.[43] Chinese leaders and strategists are keenly aware of this vulnerability. As early as 2003, Chinese state media commented on concerns raised by then General Secretary Hu Jintao warning of overreliance on the sea route passing through the Strait of Malacca, labeling China's dependence the "Malacca Dilemma."[44] In addition to Malacca, sea routes from China's coast to the Middle East and Europe must pass through a series of maritime chokepoints, including the Strait of Hormuz, Bab El Mandab, and the Suez Canal.[45] Researchers with the Naval Research Academy, the PLA Navy's only designated scientific research institution, described this route through the Strait of Malacca to the Middle East and North Africa as China's "distant-ocean lifeline."[46] Similarly, the 2020 edition of the *Science of Military Strategy*, one of the PLA's leading textbooks on China's military strategy, notes that China's principal maritime transport route runs from the South China Sea, through the Strait of Malacca, through the Suez Canal, and into the Mediterranean Sea.[47]

A second challenge geography poses to maritime oil imports is the sheer distance tankers must transit to reach oil suppliers, leading to longer transit times. Gabriel Collins, Baker Botts Fellow in Energy and Environmental Regulatory Affairs at Rice University's Baker Institute, identified a clear trend in Chinese tankers "having to go further from home to buy barrels" of oil, as China's share of oil imports from Asia-Pacific countries fell from 21 percent in 2005 to only 3.5 percent in 2020.[48] Emily Meierding, assistant professor at the Naval Postgraduate School, notes that a one-way Very Large Crude Carrier (VLCC)* transit from the Persian Gulf to a VLCC-capable port on China's coast would likely take approximately 21 days, with each round-trip voyage taking at least 40 days.[49] This is a median transit time. Smaller tankers and VLCCs directly transiting oil from Russia's east coast to China typically complete a round-trip voyage in less than two weeks, while a round-trip VLCC voyage from Russia's western ports to a compatible port in China would take up to four months.[50] The growing transit distance involved in China's oil imports is in part the result of Chinese leaders' concerted effort to hedge against overdependence on a small number of suppliers by diversifying China's import partners and delivery methods (see Table 2). For example, since 2015 Saudi Arabia and Russia have remained in close competition to be China's top source of crude oil, and as of 2021 China's top five oil providers are Saudi Arabia, Russia, Iraq, Oman, and Angola.[51] Sourcing oil across regions diversifies China's oil suppliers as well as its oil import routes, reducing the risk along any one energy supply route.[52]

---

*One VLCC can carry between 1.9 and 2.2 million barrels of oil, or between 160,000 and 320,000 metric tons. U.S. Energy Information Administration, *Oil Tanker Sizes Range from General Purpose to Ultra-Large Crude Carriers on AFRA Scale*, September 16, 2014.

Table 2: China's Top Ten Crude Oil Suppliers in 2021

Supplier	Volume (MMbpd)	Import Share
Saudi Arabia	1.8	17.1%
Russia	1.6	15.5%
Iraq	1.1	10.5%
Oman	0.9	8.7%
Angola	0.8	7.6%
United Arab Emirates	0.6	6.2%
Brazil	0.6	5.9%
Kuwait	0.6	5.9%
Malaysia	0.4	3.7%
Norway	0.3	2.6%

Note: "MMbpd" refers to millions of barrels per day.
Source: General Administration of Customs via CEIC.

China's Tanker Fleet and Navy Deployments Move to Secure Critical Sea Lanes

China's government has attempted to mitigate its perceived risk caused by maritime chokepoints by increasing its PLA Navy deployments in the Indian Ocean and constructing a national tanker fleet. These efforts appear to respond to Chinese strategists' concerns that the U.S. Navy might interdict ships transiting oil to China along extended Indian Ocean sea lanes or at a maritime chokepoint.[53] In a 2021 speech to a think tank affiliated with China's State Oceanic Administration, Hu Bo, director of the Center for Maritime Strategy Studies at Peking University, noted that the prevailing assessment within China's strategy community is that the United States demonstrated the will to interdict China's seaborne energy imports during the 1993 "*Yinhe* Incident"* and has the opportunity to do so in the future.[54]

Driven largely by anxieties regarding a U.S. naval blockade, in the early 2000s Chinese leaders directed the construction of a large† domestic tanker fleet.[55] China's two leading energy shipping companies, China Ocean Shipping Company, Limited

* In 1993, U.S. Navy vessels surveilled and shadowed the Chinese container ship *Yinhe* (*Milky Way*)—which U.S. intelligence reports indicated may have been carrying a large quantity of materials useful for developing chemical weapons—as it was en route to Iran. U.S. diplomats persuaded countries in the Persian Gulf to deny *Yinhe* docking permissions until the crew submitted to cargo inspection, which occurred after a delay of approximately one month. U.S. and Saudi officials did not find materials for chemical weapons on board. In testimony before the Commission, Christopher Colley, assistant professor of security studies at the National Defense College of the United Arab Emirates, explained that Chinese maritime security experts commonly consider this event a "national humiliation" that "must never be allowed to happen again." Although the 1993 *Yinhe* incident took place almost three decades ago, it continues to shape perceptions in China of risks to Chinese maritime security. Christopher Colley, written testimony for the U.S.-China Economic and Security Review Commission, *Hearing on China's Activities and Influence in South and Central Asia*, May 12, 2022, 1–2; Kai He, *China's Crisis Behavior: Political Survival and Foreign Policy after the Cold War*, Cambridge University Press, April 2016, 49–50; Patrick E. Tyler, "No Chemical Arms aboard China Ship," *New York Times*, September 6, 1993.

† In 2020, China's fleet was the third-largest domestic oil tanker fleet in the world. Greece had the world's largest oil tanker fleet valued at $38 billion, followed by Singapore's valued at $14 billion and then China's valued at $13 billion. UN Trade and Development, "Maritime Transport Services and Infrastructure Supply," 2020, 42.

(COSCO) Shipping Energy Transportation and China Merchants Energy Shipping, likely do not have sufficient combined tanker capacity to fulfill all of China's oil import demand.[56] China would need approximately 4.5 fully laden VLCC deliveries per day to maintain current seaborne import levels, and the two companies combined would need a VLCC fleet nearly twice as large to sustain this rate of delivery.[57]

An important driver of China's national tanker fleet is preparation for future conflict. China's national tanker fleet exists to ensure a continued flow of seaborne oil and gas imports through conflict zones and potentially U.S. Navy blockades. Non-Chinese commercial tankers are unlikely to be willing to operate in areas that pose heightened risk to the vessel, its crew, and its cargo, whereas China's government can provide significant financial incentives for its national tanker fleet to do so.* Similarly, China's government can compel the SOE owners of the Chinese tanker fleet to run a potential U.S. Navy blockade, forcing U.S. sailors to forcibly board or fire† on the tanker to enforce the blockade.[58]

China's leaders are also moving to secure its "distant-ocean lifeline" with larger PLA Navy deployments in the Indian Ocean. PLA documents clearly state that the PLA Navy is attempting to develop into a force capable of rapidly deploying and defeating U.S. naval interdiction along key sea lanes west of the Strait of Malacca. According to the 2020 *Science of Military Strategy*, the current PLA Navy deployment conducting antipiracy operations in the Indian Ocean "may expand" the scope of its missions if "hegemonic countries" (referring to the United States) "exercise control over important transit routes that are vital to China."[59] The PLA Navy is also already exercising the capabilities it would need in such a conflict. Between December 2008 and January 2022, the PLA Navy conducted 40 antipiracy deployments in the Gulf of Aden, including many from its base in Djibouti since it began operations in 2017, exercising capabilities almost certainly designed to develop PLA Navy sailors' ability to project power along sea lanes in the Indian Ocean.[60] These efforts may include building PLA bases or facilities in the Indian Ocean. The U.S. Department of Defense's 2021 report on China's military power notes China's government has likely considered several countries near the Persian Gulf, including Pakistan and the United Arab Emirates, as locations for future PLA bases.[61] Also in 2021, the *Wall Street Journal* reported that China's government was

---

* State-owned and -flagged ships that self-insure are financially incentivized to accept higher risks of operating near or through a conflict zone. In contrast, independent insurance firms are likely to increase insurance rates from as low as 2.5 percent of ship value on an annual basis to as much as 10 percent of ship value on a daily basis if the ship operates in what the firms designate a War Risk Exclusion Zone. Andrew Erickson and Gabe Collins, "Beijing's Energy Security Strategy: The Significance of a Chinese State-Owned Tanker Fleet," *Orbis*, 2007, 681.

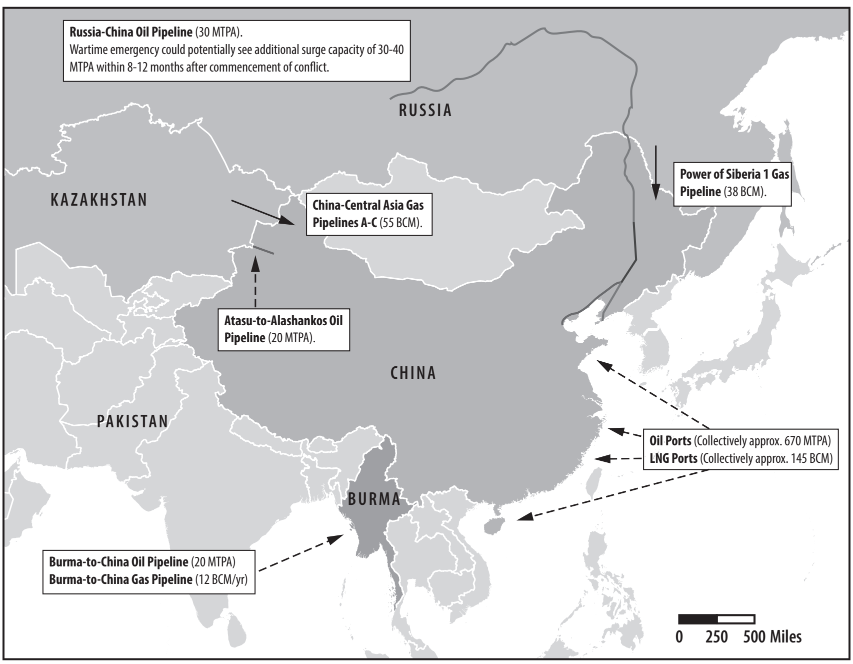
† Firing on a vessel is not necessarily an attempt to sink the vessel. The U.S. Navy is actively developing nonlethal means of stopping ships, representing a capability to kinetically enforce a naval blockade while controlling escalation by dramatically reducing the risk of death and destruction. Examples of nonlethal means to stop ships include materials designed to entangle or otherwise disable ship propellers or directed-energy weapons such as microwave systems that interfere with the vessel's electronics. Krista Romita et al., "How to Effectively Assess the Impact of Non-Lethal Weapons as Intermediate Force Capabilities," *RAND Corporation*, 2022, 1, 5; Peter von Bleichert, "Nonlethal Weapons Bridge the Gap between Shouting & Shooting," *Proceedings*, November 2017.

constructing what U.S. intelligence agencies suspected to be a military facility in the United Arab Emirates.[62]

China's Limited Overland Solutions to Reduce Dependence on Seaborne Energy Imports

China's government seeks to increase overland energy imports to reduce reliance on seaborne transit through the Strait of Malacca (see Figure 3).[63] Operating at full capacity, China's three inbound oil pipelines from Russia, Kazakhstan, and Burma (Myanmar) are able to provide a combined 70 million metric tons of oil per year, or approximately 14 percent of China's overall oil imports in 2021.[64] Natural gas pipelines are particularly significant for China's energy consumption. As of 2017, China received 46 percent of its natural gas imports through pipelines from Central Asia.[65] China continues expanding its overall pipeline import capacity, most recently through a 30-year contract to purchase ten billion cubic meters of gas each year, or approximately 3 percent of China's natural gas consumption, from Russia through a new pipeline.[66] This new pipeline is scheduled to begin delivering gas within three years and will connect to the Power of Siberia pipeline, which began delivering gas to China in 2019 after five years of construction and a decade of negotiations.[67]

Figure 3: China's Energy Import Routes



Source: Adapted from Gabriel Collins, written testimony for U.S.-China Economic and Security Review Commission, *Hearing on China's Energy Plans and Practices*, March 17, 2022, 11.

Table 3: China's Pipeline and Port Import Dependence, 2021

	Oil Pipelines	Oil Ports	LNG Pipelines	LNG Ports
Volume	70 million metric tons	670 million metric tons	105 billion cubic meters	145 billion cubic meters
Percent of Imported Demand	13.6%	130.5%	111.7%	154.3%
Percent of Total Demand	9.8%	93%	27.7%	38.3%
Percent of Energy Consumption	1.9%	18.6%	2.5%	3.4%

Note: Capacity exceeds total demand. All figures for 2021. In 2021, China consumed about 718.5 million metric tons of oil, of which 513.2 million metric tons were imported, and 378.7 billion cubic meters of natural gas, of which 94 billion cubic meters were imported.
Source: Various.[68]

China's government has also explored projects in Thailand and invested in infrastructure in Burma to bypass the Strait of Malacca. Key among these projects is a proposed canal or railway through the Isthmus of Kra in Thailand, linking the Gulf of Thailand with the Andaman Sea.[69] Although the government of Thailand has been open to these projects, diplomatic pressure from the United States and Japan have so far prevented formal approval of a canal or railway system.[70] China's government investments have targeted extensive oil and gas pipelines connecting southern China to Burma's Kyaukpyu city, where Chinese investors are also funding a deep sea port project.[71] These pipelines are currently operating well below their full capacities of 12 billion cubic meters per year for natural gas and 22 million metric tons per year of oil, which combined represent 6.6 percent of the liquified natural gas and 4 percent of the oil China imported in 2021.[72]

Like China's national tanker fleet, however, China's overland oil and gas pipelines lack the capacity required to replace China's overall seaborne energy imports. As stated earlier, China's inbound oil pipelines could only transport roughly 14 percent of China's total oil imports in 2021.[73] While China's inbound gas pipelines have the capacity to supply a larger portion of China's natural gas consumption, growth in China's demand for natural gas will likely outstrip growth in pipeline capacity this decade. China's gas pipelines have a collective capacity of 105 billion cubic meters per year, supplying over half of the 169 billion cubic meters of gas China imported in 2021.[74] The Power of Siberia 2 pipeline, scheduled to come online by the late 2020s, would likely add another 80 billion cubic meters to China's inbound gas pipeline capacity.[75] China's gas pipelines are limited by geography, primarily connecting to Russia and Central Asia. By 2030, the Central Asian countries currently supplying the majority of China's imported gas will likely be able to provide an additional 25 billion cubic meters of natural gas a year, bringing China's collective inbound gas pipeline capacity to 210 billion cubic meters per year.[76] An official from China Oil & Gas Pipeline Network Corporation (PipeChina), a Chinese state-owned oil and gas pipeline firm, however, projects China's gas consumption will reach 526 billion cubic meters per year by 2030 and continue growing to 650 billion cubic meters per year by 2035.[77] This growth in China's demand for natural gas would likely need to be resourced by Russian imports in addition to seaborne sources, the latter of which continue to exceed China's inbound pipeline capacity by 40 billion cubic meters per year and are projected to grow at a faster rate than pipeline capacity.[78]

China's Commercial Energy Strategy and Key Suppliers

In addition to conducting commercial energy trade, Chinese NOCs* bolster China's energy security by gaining access to foreign oil supplies via "equity oil" and resource-backed loans, often in authoritarian countries. The confluence of these activities extends the Chinese government's market-manipulating influence into other countries under the auspices of energy trade. Moreover, these activities expose recipient countries to financial risk while undermining international sanctions against rogue countries such as Russia and Iran.

Equity Oil: A Commercial Stockpile

Securing equity oil is a longstanding objective of China's NOCs. Dr. Meierding defines equity oil as "a share of resource output that [a purchaser] could book as reserves and sell wherever it chose" through gaining an ownership stake in foreign oil-producing assets.[79] While the complete network of China's equity oil agreements is not public, in 2020 PetroChina reported equity oil holdings equivalent to 76.4 million metric tons.[80] Similarly, a 2018 report by the China Petroleum Enterprises Association stated that the previous year China held 160 million metric tons of equity oil—roughly 24 percent of its consumption in 2017—and an additional 50 billion cubic meters of equity natural gas, representing a total of 201 million tons of oil equivalent across countries participating in the Belt and Road Initiative (BRI).[81]

As explained by an expert on China's National Energy Expert Advisory Committee, "equity oil is superior to oil traded on the market because the former would give Chinese NOCs additional security in time of market turbulence and supply disruptions."[82] Although China's NOCs generally sell their equity oil on international markets to maximize profit, China's government can require NOCs to ship equity oil to China for domestic consumption or stockpiling.[83] Currently, China's NOCs do not appear to be pursuing overseas energy engagements strictly to build China's energy stockpiles, and the oil produced overseas by Chinese companies is not typically shipped back to China, given prospects of greater profit in other markets.[84]

As early as 1993, China's NOCs pursued overseas acquisitions to obtain the oilfields, resources, and technologies a foreign company might hold.[85] Given the dominance of other multinational oil conglomerates over easily accessible sources of oil, Chinese NOCs were willing to pay a premium for oil assets, including riskier assets like unproven oil reserves in politically unstable countries.[86] Between 2005 and 2015, China's NOCs spent $134 billion on overseas oil as-

*These include China National Petroleum Corporation (CNPC), China Petroleum and Chemical Corporation (Sinopec), and the China National Offshore Oil Corporation (CNOOC).

sets, with the majority of purchases taking place between 2009 and 2013 following the global financial crisis.[87] Beginning in 2015, China's NOCs began rebalancing their acquisition strategies by making direct purchases of oil on international markets in addition to purchasing foreign oil-producing assets.[88] The collapse of oil prices in 2014–2016 almost certainly also contributed to this shift in China's oil security strategy, as the collapse drastically undercut the profitability of the many oil-producing assets China's NOCs had procured and began to disincentivize purchases of more such assets.[89]

Oil-Backed Loans: Driving Volatility and Funding Corruption

Chinese NOCs have also moved to secure control over oil flows from other countries' NOCs through the use of oil-backed loans supported by the China Development Bank and China Export-Import Bank.[90] Under an oil-backed loan agreement, a recipient government or NOC repays a loan from one of China's policy banks through oil sales to a Chinese NOC.[91] Oil-backed loans theoretically give China's government an option to claim some amount of other countries' oil production, ensuring supplementary oil supply secured against state-owned infrastructure.[92] Additionally, debtors holding oil-backed loans are vulnerable to price crashes that can force borrowers to devote greater volumes of oil to paying back the loan.[93]

China's government has used oil-backed loans to exert leverage over African and Latin American countries.[94] Between 2005 and 2010, Chinese aid to Angola, one of China's major oil suppliers and an early customer of Chinese oil-backed loans, coincided with Chinese NOC acquisition of exploitation rights to multiple oil blocks in Angola.[*][95] Similarly, Venezuela and Ecuador took advantage of Chinese policy bank financing at below-market rates secured by discounted oil. In part because Chinese oil-backed loans use revenue from daily oil sales as collateral for the loans,[†] both countries struggled with repayment terms when commodity prices crashed between 2014 and 2016.[96] In 2018, Ecuador's government committed 80 percent of its oil exports, negotiated down from 90 percent, to repay its oil-backed loans from China.[97] While China has used oil-backed loans as a strategic hedge against risk, oil-backed loans may conversely expose China to risk when oil prices rise, as countries would require smaller volumes of oil to pay off the value of the loan.

---

* China's government used oil-backed loans in concert with elite capture and corruption to extract maximum leverage in negotiations with Angola. For example, Isabel dos Santos, daughter of former Angolan president Jose Eduardo dos Santos and a former board member of Angolan NOC Sonangol, was accused by fraud authorities of funneling over $1 billion in funds linked to Chinese firms to accounts and companies under the control of Santos or her husband. Similarly, the China International Fund was implicated in a 2020 seizure of funds from corrupt Angolan officials. Emily de La Bruyere and Nathan Picarsic, "Two Markets, Two Resources: Documenting China's Engagement in Africa," *Horizon Advisory* (prepared for the U.S.-China Economic and Security Review Commission), November 2020, 18–19.

† China's loan agreements with Ecuador and Venezuela were predicated on daily oil transactions that were especially susceptible to price shocks. Both Ecuador and Venezuela paid for Chinese investment by committing their NOCs, Petroecuador and Petróleos de Venezuela, S.A., to ship oil to China on a daily basis through the life of the loan. Following the shipment, Chinese NOCs buy the oil in accordance with a pricing formula generally indexed to market prices with occasional discounts. The Chinese NOCs' payments for that oil become funds from which the China Development Bank can withdraw for loan repayment. As oil prices declined, Ecuador and Venezuela were obligated to sell larger volumes of oil to China's NOCs to meet their loan repayment obligations. Oil prices are currently rising, which carries the risk that China may receive smaller volumes of oil to repay loan obligations. Stephen B. Kaplan and Michael Penfold, "China-Venezuela Economic Relations: Hedging Venezuelan Bets with Chinese Characteristics," *Wilson Center*, 2019, 10; Michal Meidan, "China's Loans for Oil: Asset or Liability?" *Oxford Institute for Energy Studies*, 2016, 10.

China's government and NOCs demonstrate a pattern of engaging with oil-rich countries with low transparency and high levels of local corruption.[98] In oral testimony before the Commission, senior associate for the Center for Strategic and International Studies' Energy Security and Climate Change Program Edward Chow explained the corrosive nature of China's energy investments. According to Mr. Chow, Chinese NOCs seeking opportunities to invest in foreign oil-producing assets considered their indifference to corruption among host country officials to be a competitive advantage over major U.S. or European oil companies.[99] One study examining two decades of Chinese investment in 49 African countries found that China implements a policy of investing in resource-rich countries with high perceived corruption on the basis that "paying bribes is a faster way to secure a license and gain access to the natural resource deposit than following long bureaucratic processes that are mostly met with resistance from the locals."[100]

China's Authoritarian Energy Suppliers

China's energy strategy balances its sources of fossil fuels between its suppliers, many of which are authoritarian regimes, to avoid dependence on any individual country. By sourcing a significant portion of its fossil fuels from authoritarian regimes, China gives a lifeline to some countries sanctioned by the United States while granting China significant leverage over those countries.[101] Although the Chinese government has worked to diversify its energy import sources, it continues to source nearly one-third of its oil from Russia and Saudi Arabia, and it sources nearly 40 percent of its natural gas from Russia and Central Asia.[102]

China's energy trade with authoritarian regimes undermines international sanctions, particularly through its oil purchases and energy investments in Iran, Venezuela, and Russia.[103] China undermines international sanctions on Iran and Venezuela by rebranding* shipments of Iranian and Venezuelan crude oil as imported from Oman or Malaysia.[104] China's oil imports from Iran reached record highs in 2021, and according to Refinitiv Oil Research, 75 percent of the oil Iran moved to China between January 2020 and February 2021 was labeled as coming from Oman, the United Arab Emirates, or Malaysia.[105] China often provides capital and technology in exchange for Iranian oil and opportunities to invest in upstream† oil production.[106] In January 2022, Chinese Foreign Minister Wang Yi and Iranian Foreign Minister Hossein Amir-Abdollahian announced that the two countries would begin implementing a broad agreement on energy and infrastructure projects.[107] For Venezuela, Chi-

---

*To avoid detection when loading or transferring oil, ships will disable their automated identification system (AIS) transponders in a practice called "going dark." This practice is considered dangerous and an indication of violating sanctions compliance. In 2019, the U.S. Department of the Treasury's Office of Foreign Assets Control (OFAC) called this a "deceptive shipping practice" in an advisory warning against activity that violates sanctions on Iran and Syria. Irene Anastassiou, "'Going Dark' Is a Red Flag—AIS Tracking and Sanctions Compliance," *Gard*, May 29, 2019; U.S. Department of the Treasury, *OFAC Advisory to the Maritime Petroleum Shipping Community*, March 25, 2019.

†Upstream production refers to the processes of locating and extracting crude oil; another name for this is exploration and production (E&P). Midstream production includes transportation, storage, and marketing of oil, and downstream production occurs in distribution companies, refineries, petrochemical plants, and retail outlets such as a gas station. These three distinct sectors comprise the petroleum industry. BWAB Oil & Gas, "What Is Upstream Oil and Gas Production?" June 2, 2016.

na offers a market for its uniquely heavy, tar-like crude oil that requires a special refinery unit called a coker.[108] China has the world's second-largest coking capacity, and discounted Venezuelan crude oil has a large appeal for Chinese companies. According to a Bloomberg investigation into the now-sanctioned trading company Swissoil, shipping documents reveal that over 11.3 million barrels of Venezuelan oil arrived in China under disguised origins in 2020.[109] China's rising oil and gas purchases from Russia in the first half of 2022 have sustained Russian energy export revenues despite international sanctions against Russia for its unprovoked invasion of Ukraine.[110] New phases of international sanctions on Russian crude oil and petroleum products throughout 2022, however, will likely constrain China's flexibility to capitalize on Russia's cheap oil.[111] Chinese state-owned petrochemical companies such as China Petrochemical Corporation (Sinopec), China National Offshore Oil Corporation, PetroChina, and Sinochem have already demonstrated a reluctance to cooperate with directly sanctioned entities for fear of being hit by secondary sanctions.[112] With Iran, Venezuela, and Russia, China feigns compliance with international sanctions regimes while simultaneously ensuring a market for oil from these states.

The China-Russia energy relationship will likely remain aligned for the next decade, but China's efforts to transition to a less carbon-intensive economic model raises the possibility the two countries' energy relationship could potentially diverge in the long term. For years, China has maintained parity in the level of oil imports from Russia and Saudi Arabia, and through the end of 2021 China ensured that Saudi Arabia was its primary oil supplier by a small margin.[113] In 2022, China allowed Russian oil imports to surpass—at least temporarily—the amount of Saudi oil imports to take advantage of Russia's low prices after international demand for Russian oil waned in the wake of its unprovoked invasion of Ukraine.[114] China has also strengthened its gas trade with Central Asian states and uses the competition between Central Asian states and Russia to drive down gas prices.[115] (For more on China's relationship with Central Asian states and its competition with Russia in the region, see Chapter 3, Section 3, "China's Activities and Influence in South and Central Asia.") This confluence of interests will likely continue until China transitions to a less carbon-intensive economic model and reduces its dependence on fossil fuels. (For more on China's carbon transition, see the section below, "Economic Restructuring: A Prerequisite for Decarbonization"). Mr. Chow argued that "although China's and Russia's energy interests converge in the short run, they diverge in the long run as China seeks energy transition away from fossil fuels for both environmental and national security reasons. China's long-term energy interests are more compatible with those of other advanced economies."[116]

China remains heavily dependent on fossil fuels, particularly oil, and will almost certainly remain so for the next decade. This dependence could potentially decrease, however, over the course of decades as new energy technologies become available to assist China's efforts to transition away from carbon.

China's government ensures continued access to oil from the Persian Gulf by balancing steady state relationships with Iran and

Saudi Arabia. Although China imports significantly more energy resources from Saudi Arabia than Iran, it maintains a balanced approach to both countries in order to ensure a broadly permissive environment to expand its economic influence and military activities.[117] Demonstrating commitment to balancing its relationships with Iran and Saudi Arabia, China elevated its diplomatic ties with both countries in the same week to "comprehensive strategic partnership," the highest level in China's diplomatic hierarchy.[118] Maintaining positive relationships with the Gulf States is key for China's oil supply because the region, which already supplies nearly half of Chinese oil imports, is likely to double its exports to China by 2035.[119] This energy connection is likely a key motivator of Chinese commitments in development financing and the growing level of trade between China and the Gulf States, which exceeded $200 billion for the first time in 2021.[120]

Table 4: China's Current Fossil Fuel Dependence on Persian Gulf Countries and Russia, 2019

Country	Percent of China's Total Oil Imports, 2019	Percent of China's Total Natural Gas Imports, 2019
Iran	3	0
Iraq	10	0
Kuwait	4	0
Oman	7	0
Qatar	0	9
Russia	15	3
Saudi Arabia	16	0
United Arab Emirates	3	0
TOTAL	**58**	**12**

Source: U.S. Energy Information Administration, *Country Analysis Executive Summary: China*, September 30, 2020, 6.

China's Climate Liability

The Chinese economy's carbon intensity creates vulnerabilities for the CCP. Specifically, the country's economic boom, fueled primarily on coal, has come at a great cost to public health and environmental sustainability, generating both international condemnation and domestic discontent. Fundamental economic restructuring is required to realize Beijing's vision for sustainable economic growth, but Chinese policymakers have yet to make meaningful changes to China's energy-intensive economic model. When faced with crises like a severe economic downturn due to domestic novel coronavirus (COVID-19) lockdowns or policy-induced energy shortages, Chinese leaders preserve stability through short-term measures like encouraging infrastructure construction and expanding coal mining. These policies ultimately undercut long-term energy and climate-related goals. Deeply entrenched corporate and local government interests further delay China's realization of its stated decarbonization goals, as energy- and carbon- intensive industries form the backbone of many local economies throughout China. While political and institutional barriers drag on China's ability to decarbonize, policymakers envision China's domination of clean energy technologies providing the technical solutions for decarbonization, creating competitiveness challenges for the United States.

China's Carbon Footprint: An Economic and Reputational Liability

Chinese leaders have set unambitious public climate commitments and carbon reduction targets, yet China's ability to meet these targets is undermined by its accelerating coal infrastructure buildout. In September 2020, General Secretary Xi announced that China would peak its carbon emissions by 2030 and achieve net zero carbon emissions before 2060* (also known as the 30–60 goals) as its Nationally Determined Contribution under the Paris Climate Agreement.[121] Researchers from the New Climate Institute predict that China could peak its carbon emissions in 2025, making the target relatively unambitious in the absence of a "carbon cap."[122] Furthermore, in "peaking" its carbon emissions, China must only demonstrate a small decline or plateau of emissions by 2031 to meet the target, while carbon emissions can significantly increase before that time. By contrast, China's target to achieve net zero carbon emissions before 2060 is likely unachievable, as it would require policymakers to confront unprecedented logistical, technical, and institutional constraints to restructure China's energy system and its economy.[123] With China accounting for more than half of newly added global coal power capacity in 2021, only a large-scale investment in carbon capture, utilization, and sequestration (CCUS) technologies that remove carbon emissions from the atmosphere could allow China to achieve net zero carbon emissions before 2060.[124] Rather, CCUS investment and deployment are still in their nascent stages in China. Models predict that China could only achieve net zero before 2060 by significantly reducing energy intensity, replacing the role of fossil fuels with renewable energy, and by rebalancing the economy away from energy- and carbon-intensive heavy industries.[125] Despite the fact that China is unlikely to achieve its 2060 target without significant data manipulation, its sheer time frame also relieves current Chinese leadership of accountability should it not be achieved.[126]

China's rhetoric intends to position China as a global leader and a champion of climate concerns of developing countries, particularly those likely to be most impacted by climate change. This messaging constitutes part of its effort to build alignment against the United States at multilateral institutions like the UN while pursuing other objectives like diplomatically isolating Taiwan. China has leveraged this messaging strategy in its engagement with island nations prone to the environmental impacts of climate change, promising to pay attention to their climate-related "special concerns and legitimate

---

*Net zero carbon emissions means that for all carbon emissions released into the atmosphere, the same amount of emissions must be removed. Countries attempt to achieve net zero carbon emissions through a combination of policies to increase renewable energy and decrease use of fossil fuels and by implementing negative emissions technologies such as carbon capture, utilization, and sequestration systems.

demands."[127] In 2019, the Solomon Islands switched diplomatic recognition from Taiwan to Beijing, citing China's eagerness to help the country manage climate change through economic development opportunities.[128] Kiribati, another island in the South Pacific, reestablished its diplomatic relations with Beijing less than a week later, explicitly pointing to Chinese promises to help islands in the region mitigate climate change and implement the Paris Climate Accords.[129] The majority of the 14 countries that diplomatically recognize Taiwan* are either islands or located in low-lying coastal regions, making them likely targets for China's climate courtship strategy. While China capitalizes upon opportunities to cast itself as a responsible climate stakeholder, it simultaneously advocates for developing countries to be given a longer runway to develop economically before being expected to implement emissions mitigation measures. This strategy aims to court developing countries and cast the United States and other developed countries as responsible for climate change despite China's status as the world's top carbon dioxide emitter.

Domestically, Beijing's climate commitments are part of a broader effort to build legitimacy through alternative indicators to economic growth, an improved environment, and "human centered development." Lauri Myllyvirta, lead analyst at the Center for Research on Energy and Clean Air, similarly emphasized in his testimony that growing domestic concern about air pollution and environmental health threaten the CCP's legitimacy, thereby acting as a strong driver of China's climate policy.[130] Domestic calls to combat air pollution caused by burning coal further amplify international pressure, with the 2015 documentary *Under the Dome* revealing unprecedented air pollution levels in Chinese cities as well as regulatory failures to hold polluters accountable.† [131] The documentary catalyzed strong public debate on the issue in China, with small protests reportedly breaking out in the province of Shaanxi.[132] While the documentary was quickly banned by Chinese media censors and protesters were arrested, the film demonstrated to Chinese leadership that growing discontent over air quality and other environmental issues could easily foment domestic unrest.[133] A week after the film's release, General Secretary Xi promised to punish polluters "with an iron hand," while the former head of the Ministry of Environmental Protection‡ acknowledged the film's portrayal of "growing public concern over environmental protection and threats to human health."[134]

Beijing's economic goals consistently outweigh its climate concerns. Statements by Chinese leadership toward domestic energy

---

*Taiwan maintains diplomatic relations with Belize, Guatemala, Haiti, Honduras, Paraguay, St. Kitts and Nevis, Saint Lucia, St. Vincent and the Grenadines, eSwatini (formerly known as Swaziland), the Holy See (the central administration of the Roman Catholic Church), the Marshall Islands, Nauru, Palau, and Tuvalu.

†Carbon dioxide emissions and air pollution are closely related, as they are both caused by burning fossil fuels; however, air pollution broadly refers to air particles that have a detrimental impact on human health, while greenhouse gases like carbon dioxide have a warming effect on the earth's atmosphere. Institute for Advanced Sustainability Studies, "Air Pollution and Climate Change"; UN Environmental Program, "Air Pollution and Climate Change: Two Sides of the Same Coin," April 23, 2019.

‡The Ministry of Environmental Protection was folded into the Ministry of Environment and Ecology in March 2018. Jackson Ewing, "Tough Tasks for China's New Environment Ministry," *Diplomat*, March 17, 2018.

stakeholders continue to portray a belief that coal is central to China's immediate energy security and economic stability, with leaders stressing a "realistic" approach to decarbonization that leverages the "clean and efficient" use of coal.[135] Chinese energy policymakers therefore follow the maxim of "first building [new energy supplies] then breaking [old supplies]."[136] Under this guidance, China continues to ramp up coal-fired power plant development and coal mining domestically, thereby locking in coal-based infrastructure for years to come despite its climate targets. New energy supplies include not only renewable energy but also "clean" coal-fired power plants that emit fewer carbon emissions than the older generation plants being slowly phased out.[137] In 2021, China commissioned over three times as much new coal power capacity (38.4 gigawatts) as all other countries in the world combined.[138] China continued to build out its coal-fired power plant fleet in 2022 and accounted for 52 percent of globally operational coal-fired power capacity and 66 percent of newly announced and permitted coal projects.[139] China has also increased its support for domestic coal mining to feed its growing coal-fired power fleet, with domestic coal production reaching a new peak in March 2022 at 395.79 million tons.[140]

Chinese leaders also recognize that the carbon intensity of China's industries may become a threat to industries' role in international supply chains in an increasingly climate-conscious world.[141] Because Chinese industries like steel are more carbon intensive than their global competitors, any broad-based effort to incorporate the price of carbon into international trade would significantly reduce their cost competitiveness within global supply chains compared to competitors.[142] For example, in response to the EU's proposed carbon border adjustment mechanism (CBAM), which would act as an import tariff on the carbon dioxide emitted by producers of certain carbon-intensive goods like steel, Chinese leaders have criticized attempts to "extend the climate change issue to the trade sector."[143] In 2021, the United States and the EU also began a working group to combat carbon intensity and overcapacity within the steel and aluminum industries, marking a continuation of U.S. and EU efforts to counter Chinese dumping of steel and aluminum into their respective markets. Both sides indicated they would work to discourage the trade of high-carbon steel and aluminum that contribute to "global excess capacity from other countries" while supporting domestic efforts to reduce the carbon intensity of U.S. and EU industries.[144] In testimony before the Commission, Mr. Collins referenced such developments as emblematic of a broader shift toward "climate competition" in which countries no longer make concessions to cooperate on climate but instead pressure one another on climate issues based on their respective advantages.[145]

The rise of global investors interested in allocating investments according to environmental, social, and governance (ESG) standards may also point to a growing vulnerability for Chinese industries, as some ESG investors regard Chinese investments with a level of caution despite the Chinese government's public commitment to climate change and environmental sustainability. ESG investors must consider risks associated with China's lack of rule of law and respect for human rights (for discussion of the role forced labor in Xinjiang plays within the polysilicon industry, see "China Reaches for a Green Technology Solution and Geopolitical Leverage" later in this section). Moreover, the country's accelerating coal investments indicate that the Chinese government's support for green development is subject to reversal when it encounters threats to energy security and economic growth.[146] Observers also note that many Chinese firms do not provide quality data on their emissions or environmental footprints, creating additional hurdles for ESG investors interested in the Chinese market.[147] As ESG standards become a greater factor in investment decisions, these factors could generate greater vulnerabilities for industry in China.

Economic Restructuring: A Prerequisite for Decarbonization

China cannot significantly reduce emissions without transitioning its economy away from carbon-intensive industries, a long-held goal Chinese policymakers have failed to achieve. Chinese economic growth remains highly dependent on investment-led property and infrastructure development, which relies on carbon-emitting industries like steel, aluminum, and cement. As of 2019, these industries produced about 28 percent of China's total energy-related carbon emissions while accounting for 70 percent of China's energy consumption.[148] Any meaningful reduction in China's energy and carbon intensity would therefore require China to reduce the role of these industries within its economy. The Chinese central government has identified this as a goal within various campaigns, including "supply-side structural reform," which has sought to reduce the overcapacity in heavy industries like steel resulting from decades of subsidies and local government support. For example, between 2000 and 2015 China's share of global steel output rose from 15 percent to 50 percent while the U.S. share declined from 12 percent to 6 percent due to a precipitous fall in global prices from Chinese dumping.[149] Strategies to reduce overcapacity, including SOE consolidation, have largely failed to curtail China's steel output, which continued to produce excessively in 2020 when global demand had largely collapsed.[150] Furthermore, despite their desire to reduce overcapacity within heavy industries, Chinese policymakers relied on these industries to shore up short-term growth in 2020, making China the only major economy to report rising emissions in 2020.[151]

Chinese economic planning documents emphasize the need to cultivate new growth drivers but do not include meaningful constraints that would hold policymakers to these objectives. Like the 30–60 goals, energy intensity and emissions targets in Chinese economic planning documents allow China's policymakers to continue prioritizing economic growth over the major economic and energy reforms that are necessary for decarbonization. Key targets within the China's 14th Five-Year Plan (14th FYP) include an 18 percent reduction in carbon intensity and 13.5 percent reduction in energy intensity.[152] Importantly, the plan's energy and carbon targets are based on intensity rather than any absolute measure of energy use or carbon emissions, meaning that China's gross energy consumption and carbon emissions will continue to grow as long as the energy and carbon intensity of economic growth decrease. As such, these targets may encourage factories and power plants to operate more efficiently, but they stop short of forcing large-scale structural changes in energy composition or usage. China's 14th FYP targets do not represent any significant increase in ambition over 13th FYP targets, and they are purposefully set at achievable levels.[153] For example, China's carbon intensity fell by 18.8 percent from 2015 to 2020, while the 2025 target is set at only 18 percent. Similarly, the 14th FYP energy intensity reduction target of 13.5 percent falls below previous targets of 15 percent.[154]

Institutional and Technical Barriers Undermine China's Climate Goals

Energy-intensive and carbon-intensive industries are politically and economically entrenched within China's system, creating strong vested interests that obstruct China's decarbonization efforts. SOEs dominate the fossil fuel, power, and heavy industry sectors.[155] For example, China's three major oil companies, China National Petroleum Corporation, Sinopec, and China National Offshore Oil Corporation, collectively produce approximately 32 percent of China's domestic oil demand, while nearly 66 percent of China's coal power generation capacity is controlled by the "Big Five" state-owned power generators, Huaneng Group, Huadian Group, China Energy Investment Corp (CEIC), State Power Investment Corp (SPIC), and Datang Group.[156] China's electricity grid is primarily managed by two state-owned companies, State Grid Corporation and China Southern Power Grid Company, which are responsible for electricity retail and transmission within different geographies.[157] On the industry side, the world's top respective steel and aluminum producers, Baowu Steel and Aluminum Corporation of China, are both state owned with control over multiple subsidiaries.[158]

By virtue of their size, China's energy and industrial SOEs are significant providers of local employment and economic growth, with Sinopec and China National Petroleum Corporation alone employing at least 816,000 people in 2021.[159] According to Henry Lee, director of the Environment and Natural Resources Program at Harvard University, for every one million dollars of investment, China's coal industry produces 2.3 times as many jobs as renewables.*[160] Despite central government pressure to accelerate decarbonization, local governments dependent on fossil fuels and related industries are therefore unsure about how to mitigate the employment dislocation impacts of a carbon transition. With local cadres continually evaluated on their ability to stimulate economic growth, there are strong economic and political incentives for local governments to avoid "breaking the old" unless they see a compelling business case for "building the new," in spite of central government mandates. For example, in December 2021 Chinese environmental regulators found that the Shandong government had turned a blind eye to at least 19 companies that had illegally built approximately 60.4 million metric tons of annual oil refining capacity.[161]

---

*By contrast, research by the World Resources Institute suggests that renewable energy investments in the United States on average create more jobs than investments in fossil fuels. For example, for every million dollars invested in fossil fuels, U.S. investments in solar, wind, and hydro energy respectively produce 1.5, 1.2, and 1.2 times as many domestic jobs. Joel Jaeger et al., "The Green Jobs Advantage: How Climate-Friendly Investments Are Better Job Creators," *World Resources Institute*, October 18, 2021, 3.

Local autonomy to adjust and implement central government policy guidance has historically created ample space for entrenched fossil fuel interests to shape economic and energy policies in their favor. China's energy and industrial SOEs are powerful political actors that often coordinate closely with local governments to develop and implement planning targets, creating a forum for them to advocate their interests within critical government strategy and planning documents. The final targets included within Chinese planning documents thus represent the culmination of an opaque bargaining process between government planners, regulators, relevant SOEs, industry associations, and government think tanks (for more on China's economic policymaking process, see Chapter 1, "CCP Decision-Making and Xi Jinping's Centralization of Authority").[162] SOEs also indirectly influence policy through close relationships with local politicians, which are enhanced through a revolving door of employment between government offices and SOEs.[163] Given their mutual dependence with local governments, SOEs ultimately benefit from close access to policymakers and economic resources like bank loans. For example, provincial officials have historically supported their local power plants by refusing to purchase power produced in other provinces, thereby contributing to a trend of local energy system protectionism.[164] These trends further strengthen the political barriers to decarbonization while crowding out capital for investments in both renewable energy and alternative growth drivers.

A Chinese carbon transition has the potential to devalue SOE assets, pushing them to undermine decarbonization efforts while diversifying their investments. According to research by Jonas Nahm and Johannes Urpelainen of Johns Hopkins School of Advanced International Studies, about 55 percent of China's coal power units have both state and private investors, exposing the Chinese government to financial risk should coal infrastructure become obsolete.[165] SOEs are thus attempting to create a financial "off ramp" as their fossil fuel assets decline in value, with Michael Davidson, assistant professor at University of California at San Diego, arguing that Chinese SOEs are simultaneously diversifying their portfolios to include more renewable energy generation assets.[166] Consolidation has also been a key strategy to increase the efficiency and financial stability of incumbent SOEs, with mergers progressing in the coal, steel, cement, and rare earths industries.[*] [167] State domination will thus likely continue to be a key feature of China's energy system while SOEs enjoy increased market power and influence within their industries.[168]

The CCP's attempts to centralize authority and streamline policy implementation under General Secretary Xi have been ineffective in the energy sector,[†] further limiting the central government's ability

---

*For more on Chinese SOE mergers, see Sean O'Connor, "SOE Megamergers Signal New Direction in China's Economic Policy," *U.S.-China Economic and Security Review Commission*, May 24, 2018; and U.S.-China Economic and Security Review Commission, *Economics and Trade Bulletin*, January 28, 2022, 4–6.

†China's government expanded authorities of environmental regulation and climate policy by creating the Ministry of Ecology and Environment (MEE) in 2018 and increasing energy and environment-related legislation. Like its predecessor the Ministry of Environmental Protection, however, the Ministry of Ecology and Environment is constrained in its ability to enforce new laws. In an annual address at the ministry's work conference in January 2022, Minister Huang Runqiu noted that 7,020 environmental monitoring cases in 2021 resulted in total of roughly $134 million (renminbi [RMB] 900 million) in fines, or an average of just over $20,000 per case.

to combat strong localized interests of fossil fuel business and heavy industry. Energy policymaking in China remains structurally fragmented, with multiple agencies responsible for managing energy sector prices, competition, regulation, land use, and project approval. Weak oversight and regulatory enforcement creates additional space for policy distortions, as local governments and SOEs often have the power to exploit broad and general guidance to suit their interests.[169] Because the entities responsible for energy and climate policy respond to diverging incentives and interests, agency-level policies have not always been well coordinated, and bureaucratic competition can result in diluted policies with slow or distorted implementation. For example, the NDRC has authority over energy prices, while the Ministry of Ecology and Environment (MEE) and the National Energy Agency (NEA) respectively govern the emissions trading system and electricity market reform. Because energy prices are a key input to both the emissions trading system and electricity markets, the NDRC's upstream pricing policies can impact the outcomes of both the MEE and NEA's energy market initiatives.[170] Furthermore, the MEE and NEA, which are responsible for developing and implementing China's energy and climate policy, are relatively lean with low manpower and small budgets, thus forcing them to devolve significant enforcement responsibilities to their provincial and local branches and local SOEs.[171] China's NEA in particular suffers from limited capacity, as it has yet to be upgraded to a full ministry and must delegate project approval and regulatory enforcement responsibilities to the local level where fossil fuel interests are often strongest.[172]

China Reaches for a Green Technology Solution and Geopolitical Leverage

Chinese policymakers envision the country's rising leadership in clean energy technology* mitigating energy insecurity concerns arising from China's dependence on foreign oil, natural gas, and coal. Just as Chinese leaders see technological innovation as a solution to challenges in other areas like food security and healthcare, they intend for China to both domestically produce and export the technologies that will help to solve its enduring sense of energy insecurity. China has already become a key manufacturing hub for many of the technologies required to support decarbonization, including solar panels, wind turbines, and lithium-ion batteries (see Table 5 and Figures 4–6 below).† Furthermore, with global renewable electricity

---

Minister Huang also observed that environmental violations had increased over the previous year. Unless noted otherwise, this Report uses the following exchange rate from June 30, 2022 throughout: 1 U.S. dollar = 6.70 RMB. State Council of the People's Republic of China, *No Letup in Environmental Protection, Pledges Ministry*, January 18, 2022.

*Clean energy technologies are any technologies that reduce negative environmental consequences of energy usage. They encompass but extend beyond nonfossil fuel energy sources to include energy storage technologies such as batteries as well as carbon-reduction processes like carbon capture and storage and even LED lights, which require far less electricity to achieve the same brightness as incandescent bulbs. Such technologies trace their origins to industrial applications, such as batteries for storing energy within electrical grids. Today, they are increasingly manufactured for consumer markets (e.g., EV batteries and residential solar panels).

†While clean energy technologies produce far fewer carbon emissions than fossil fuels across their life cycle, manufacturing processes for technologies like wind turbines are still somewhat carbon intensive. For example, offshore wind turbines require approximately 500 tons of steel and 1000 tons of concrete per 1 megawatt of wind energy, with additional materials required to connect the turbines to electricity grids. Considering the carbon emissions released during the manufacturing process, in 2018 Chinese researchers estimated that Chinese-manufactured

capacity predicted to grow by at least 60 percent over 2020 levels by 2026, Chinese firms are poised to profit significantly from upcoming multitrillion-dollar clean energy investments around the world.[173] As China expands and solidifies its role within manufacturing supply chains for current and next-generation energy technologies, Chinese policymakers intend to benefit from "one-way globalization" in which foreign trade partners become increasingly dependent upon Chinese supply chains for new energy technologies. This exposes the United States and other countries to mounting supply chain risks, including exposure to China's alleged use of forced labor to produce polysilicon solar panels and EV batteries.[174] To address these concerns, Congress passed the Uyghur Forced Labor Prevention Act, which came into effect in June 2022, effectively placing a ban on the import of products including polysilicon and solar panels "mined, produced, or manufactured wholly or in part" from Xinjiang.[175] China has begun shifting its polysilicon industry in response to growing U.S. scrutiny of its labor practices, however, with Chinese companies establishing new polysilicon factories in Inner Mongolia and Sichuan Province.* [176]

Table 5: Chinese Capabilities within Clean Energy Technology Supply Chains

Technology	Definition	Chinese Capabilities
Wind	Turbines harness energy in wind through propeller-like blades connected to a rotor. The rotor is connected to a gearbox and main shaft that spins a generator, producing electricity. Wind turbines can contain as many as 8,000 parts, including blades that can span over 300 feet in length and towers that can exceed a height of 308 feet.	China is capable of producing all major land-based turbine components domestically and is a hub for offshore wind turbine manufacturing. China leads in labor-intensive operations like blade manufacturing and is a leading producer of subcomponents, including gearboxes and rare earth magnets. By 2020, Chinese firms accounted for 10 of the top 15 wind turbine manufacturers globally.

offshore wind turbines released about 25.5 grams of carbon dioxide per kilowatt hour of energy they produced. By comparison, natural gas power plants release about 437–758 grams of carbon dioxide per kilowatt hour, and coal fired power plants produce about 675–1,689 grams of carbon dioxide per kilowatt hour. Chinese manufacturing processes for raw materials like steel are also comparatively more carbon intensive, with China releasing approximately twice the amount of carbon dioxide per metric ton of steel it produces compared to the United States. Ali Hasanbeigi, "Steel Climate Impact," *Global Efficiency Intelligence*, April 2022, 3; Sara Peach, "What's the Carbon Footprint of a Wind Turbine?" *Yale Climate Connections*, June 30, 2021; Ariel Cohen, "As Global Energy Demands Grows, So Does Appetite for Offshore Wind," *Forbes*, March 26, 2019; Juhua Yang et al., "The Life-Cycle Energy and Environmental Emissions of a Typical Offshore Wind Farm in China," *Journal of Cleaner Production* 180 (April 10, 2018): 316–324.

*The Uyghur Forced Labor Prevention Act followed multiple actions from U.S. Customs and Border Patrol to detain imports of goods from Xinjiang suspected to have been produced using forced labor, including silica-based products from Hoshine Silicon Industry Co. Ltd. and Subsidiaries in June 2021. U.S. Customs and Border Protection, *Withhold Release Orders and Findings List*, 2022.

Table 5: Chinese Capabilities within Clean Energy Technology Supply Chains—*Continued*

Technology	Definition	Chinese Capabilities
Solar	Photovoltaic modules (also called solar panels) are made of thin cells that convert sunlight into electricity. The most common type of panel is crystalline silicon, which is made of polysilicon and known to be most efficient and heat resistant. Cadmium telluride panels are less common, but they can be produced at a lower cost with simpler production processes.	China controls the production of nearly every component used in crystalline silicon modules, controls supply chains for minerals used in their production, and now accounts for approximately 80 percent of global solar cell manufacturing. Chinese firms are cost competitive and can produce solar components for 30–40 percent less than the United States.
Energy Storage	Energy storage technologies capture energy for later deployment. While consumer-facing applications like the batteries in EVs may be best known, industrial applications, such as storing energy generated from renewables before it is deployed to the grid, are an important source of innovation and commercial potential. Like EVs, grid-scale batteries primarily use lithium-ion technologies.	China dominates the entire value chain for lithium-ion batteries, including raw and processed materials, subcomponents, and assembly. It also accounts for 80 percent of global capacity for cell manufacturing and battery recycling. China also accounts for about 61 percent of global production of vanadium, a key mineral used in vanadium flow batteries; however, most of China's vanadium is currently used to produce steel.
Carbon Capture Utilization and Sequestration (CCUS)	CCUS is a group of interconnected technologies used to reduce and store carbon emissions by: 1. Separating carbon dioxide from other gases; 2. Compressing them; 3. Transporting them to storage sites; and 4. Storing them permanently underground. Key technologies include solvent-based capture, carbon dioxide drying, steel pipeline transportation, and geologic storage technologies.	CCUS is not yet widely deployed in China, though China has ample domestic supply for raw materials used in CCUS, including rare earths, steel, cement, and aluminum.

Source: Various.[177]

State Support Builds the Chinese Clean Energy Technology Manufacturing Industry

China occupies a key "manufacturing node" along global clean energy technology supply chains due to a combination of supportive supply- and demand-side policies. Chinese government support for domestic clean energy technology manufacturing in the early 2000s was focused on developing indigenous innovation capabilities that could produce novel intellectual property.[178] Despite the government's emphasis on technological innovation, Chinese firms did not need to improve in this area given their sustained access to foreign innovation through direct technology transfers and licensing arrangements, training opportunities provided by foreign partners, and outright theft.[179] Rather than invent new technologies, Chinese firms leveraged government-provided research and development (R&D) support to innovate manufacturing processes that allowed them to scale up production and reduce manufacturing costs.[180] Local governments and their respective economies likewise benefited from supporting mass manufacturing operations through subsidies and preferential financing for local firms entering the market.[181] Over time, China's enormous manufacturing infrastructure has lowered the financial risks associated with commercial innovation, allowing Chinese firms to experiment with innovations in manufacturing processes and products and then pilot them with the support of local governments.* China's solar industry expansion demonstrates the outcome of state support coupled with China's commercialization abilities, as China's share of global solar manufacturing more than quadrupled between 2006 and 2013 following a flood of state subsidies meant to keep the industry afloat in the wake of the 2008 financial crisis.[182] As of 2022, China controls the production of nearly every component used for most solar modules due to significant cost advantages.[183]

China couples supply-side support like industrial subsidies with demand-side policies like tax credits and renewable energy subsidies called feed-in tariffs† to establish domestic markets for clean energy technologies. For example, the Chinese government began using feed-in tariffs in 2009 to secure a domestic market for solar energy after it collapsed in key export markets following the 2008 financial crisis.[184] By further subsidizing solar energy, the Chinese government created overcapacity within the solar industry rather than allow it to be conditioned by market forces. Only now that solar energy has become price competitive with fossil fuel energy has China announced plans to begin phasing out feed-in tariffs.[185] Like the solar energy market, China's domestic new electric vehicle (NEV) market was cultivated through both producer and consumer subsidies and tax credits, helping China to become the largest global market for NEVs with 3.3 million units sold in 2021.[186] By compar-

*China's multifaceted approach to stimulating supply and demand for renewable energy technologies has helped Chinese firms overcome what is known as the "valley of death." The "valley of death" refers to the period when basic research has established the potential viability of a new technology, but a lack of funding to take the technology from the laboratory to early stages of commercialization prevents further development of that technology. Timothy M. Persons et al., "Nanomanufacturing: Emergence and Implications for U.S. Competitiveness, the Environment, and Human Health," *U.S. Government Accountability Office*, GAO-14-181SP, January 2014, 25–27.

†Feed-in tariffs are subsidies paid by the Chinese government to renewable energy producers, which guarantee them above-market prices for the energy they deliver to the electricity grid.

ison, only 608,000 NEVs and hybrid NEVs were sold in the United States in 2021.[187] Domestic content requirements and support for national champions also helped ensure that equipment to feed the growing market was produced domestically, and in the case of NEVs, by 2019 Chinese companies held 85 percent of the domestic market.[188] Chinese manufacturers' success in NEVs may pave the way for China to become a leader in battery storage technologies for industrial applications,* like energy grid storage, as well as consumer-facing applications, like NEVs.[189] Given their wide-ranging applications, energy storage technologies have been a strategic focus for Chinese policymakers such that China now accounts for 80 percent of global capacity for lithium-ion battery cell manufacturing.[190]

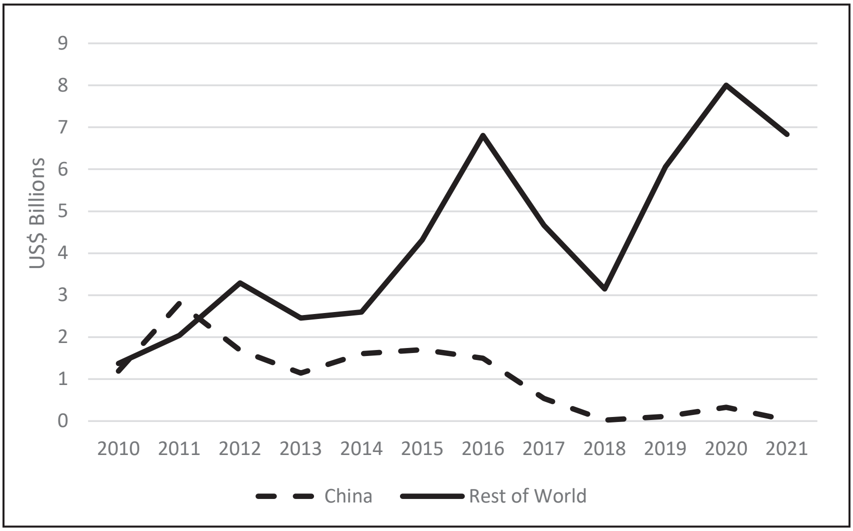
China's state support for domestic manufacturers of clean energy technologies undercuts U.S. producers and has contributed to erosion of the U.S. industrial base. China's supply- and demand-side support for its clean energy technology industry has generated harmful market distortions, including excess capacity among solar panel and wind turbine manufacturers.† As a result, the U.S. Department of Commerce and the International Trade Commission accused Chinese firms of dumping their products within foreign markets and eroding industries in competitor nations like the United States.[191] In response to requests from U.S. firms that have been harmed due to Chinese dumping of solar panels and wind turbines, the United States has used trade remedies, including antidumping and countervailing duties as well as safeguard tariffs, though with little success in regaining U.S. manufacturing capacity.[192] Dr. Nahm noted that rather than promote a reshoring or reorganization of the U.S. solar industry, tariffs have simply caused solar manufacturing capacity to relocate to other Asian countries like Vietnam and Malaysia, although according to a petition from U.S. company Auxin Solar, solar panels from these countries are still produced by Chinese companies circumventing tariffs.‡ [193] Ultimately, the United States requires a durable solution to counter the lasting damage to U.S. solar manufacturing caused by Chinese state subsidies and nonmarket practices.

* Chinese battery storage technologies, including those used for industrial applications, are not yet economically viable at scale due to high costs. Rising prices for inputs such as cobalt, lithium, nickel, copper, and magnesium supplies, as well as the need to compete for resources with EV producers, create challenges for China's energy storage industry. China's 14th FYP for New Energy Storage Technologies acknowledges these constraints and sets a goal for China to reduce the costs of battery storage technologies by 30 percent by 2025. Domestic demand for grid energy storage is currently concentrated within less energy-intensive industries desiring to reduce energy costs, while technological limitations prevent industrial energy storage systems from providing enough energy to power heavy industries. Michael Standaert, "China Ramping Up Ambitious Goals for Industrial Battery Storage," *Global Energy Monitor*, December 1, 2021; Ivy Yin, "China Targets to Cut Battery Storage Costs by 30% by 2025," *S&P Global*, March 22, 2022.

† For more on China's overcapacity in these industries, see Iacob Koch-Weser and Ethan Meick, "China's Wind and Solar Sectors: Trends in Deployment, Manufacturing, and Energy Policy," *U.S.-China Economic and Security Review Commission*, March 9, 2015.

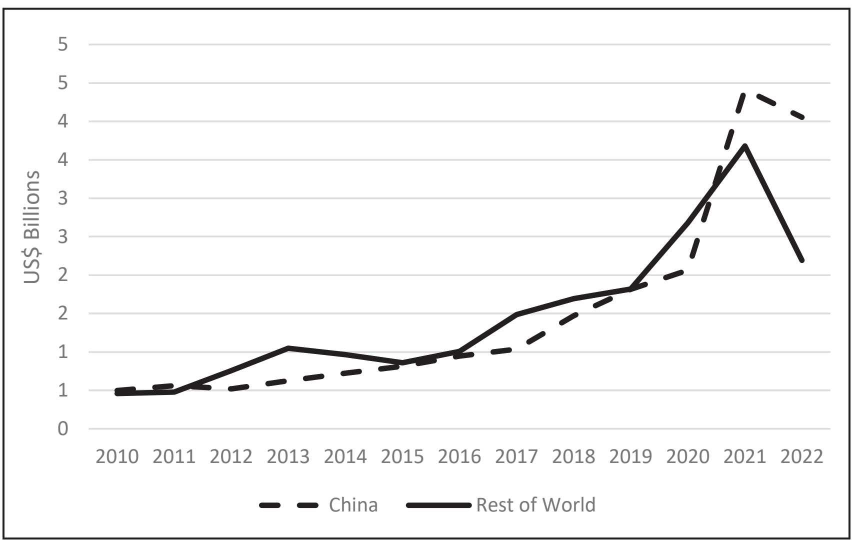
‡ On June 6, 2022, the Biden Administration invoked the Defense Production Act to support domestic manufacturing of solar panels and other clean energy technologies. It is not yet clear what tools the Department of Energy will use to support domestic manufacturing of these technologies. The Administration simultaneously announced that it would suspend tariffs on solar panels manufactured in Malaysia, Vietnam, Thailand, and Cambodia for two years pending the results of an investigation into whether these firms were using Chinese components and circumventing tariffs. Ethan Howland, "Biden Invokes Defense Production Act to Boost Domestic Manufacturing in Clean Energy, Grid Sectors," *Utility Dive*, June 7, 2022; Robert Delaney, "US Suspends Tariffs on Some Solar Panel Imports for Two Years, but Leaves China Out," *South China Morning Post*, June 7, 2022; White House, *FACT SHEET: President Biden Takes Bold Executive Action to Spur Domestic Clean Energy Manufacturing*, June 6, 2022.

Figure 4: U.S. Solar Panel Imports, 2010–2021



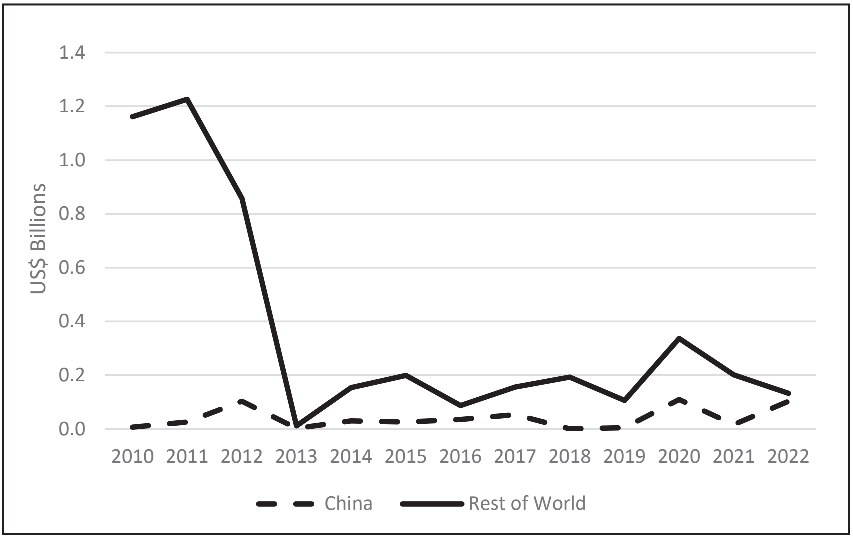
Note: The United States has maintained antidumping and countervailing duty tariffs on Chinese solar panel imports since 2012. Import data include the following HS Codes: 854140615, 854140620, 854140625, 854140630, and 854140635. U.S. International Trade Administration, *Commerce Finds Dumping and Subsidization of Crystalline Silicon Photovoltaic Cells, Whether or Not Assembled into Modules from the People's Republic of China*, October 10, 2012.
Source: U.S. Census Bureau.

Figure 5: U.S. Lithium-Ion Battery Imports, 2010–June 2022



Source: U.S. Census Bureau.

Figure 6: U.S. Imports of Wind Power Generating Equipment, 2010–June 2022



Note: The United States has maintained antidumping and countervailing duty tariffs on Chinese wind power generating equipment since 2012.
Source: U.S. Census Bureau.

Clean Energy Technology Competition with the United States and Other Economies

China outcompetes the United States in commercializing new technologies due to a combination of supportive policies, including government subsidies, low wages, and lax environmental regulations, all of which lower the costs associated with prototyping and scaling up new scientific breakthroughs.[194] By contrast, the United States has a competitive advantage in basic research, or research into foundational scientific questions, which is driven by private and federally funded research institutes, public and private R&D spending, and a strong university system to cultivate talent in critical disciplines. The United States also invests in applied research and technology commercialization through industry-university partnerships, direct government support for technology startups, and a healthy venture capital and private startup ecosystem.[195] With 17 national laboratories, the U.S. Department of Energy has developed one of the world's largest scientific research networks, connecting universities, industry, foundations, and public entities to develop both foundational and commercial research.[196] Between 2010 and 2019, U.S. companies filed about 20 percent of global low-carbon technology patents while China accounted for about 8 percent.[197] The United States is also competing with other countries in this area, as European countries and Japan respectively filed 28 and 25 percent of total low-carbon technology patents during the same time period.[198] The U.S. advantage in clean energy technology invention and basic research has not been accompanied by equally strong capabilities in commercialization, scaleup, and mass production.[199] U.S. leadership in basic research for clean energy technology implies that Chinese firms in the clean energy technology industry will continue to prioritize access to U.S. intellectual property through licit and illicit means. Like in the case of the U.S.-invented silicon solar cell, there is a continued risk that U.S. innovations will become commercialized in China, reducing the benefits to U.S. industry and ultimately eroding the economic foundation through which industry invests in innovation.[200]

Intellectual Property

Chinese firms continue to rely upon industrial economies like the United States and Germany for foundational research, intellectual property, and advanced components despite China's desire for self-sufficiency.[201] Between 2007 and 2013, U.S. firm Westinghouse* entered into a technology transfer agreement and joint venture with China's State Nuclear Power Technology Corp. (SNPTC) to use Westinghouse's technology in China's AP1000 nuclear reactor buildout.[202] China is now home to four AP1000 nuclear reactors, and it has also built out a fleet of CAP1000 nuclear reactors, which use a "licensed adaptation" of Westinghouse's technology.[203] While SNPTC acquired Westinghouse's AP1000 technology legally, in 2014 the U.S. Department of Justice indicted Chinese military officials for hacking Westinghouse's networks to steal its intellectual property, business plans, and negotiation strategies.[204] Additional cases have arisen in which U.S.-China clean energy partnerships resulted in illegal technology transfer from U.S. firms. In 2011, U.S. wind turbine designer American Superconductor (AMSC) filed a lawsuit against its Chinese R&D partner, Sinovel, after discovering that Sinovel was using AMSC technology in a Chinese wind turbine without purchasing or leasing such technology from AMSC.[205] Sinovel has since been forced to close operations after U.S. and Chinese courts convicted it of intellectual property theft and copyright infringement. China's track record of intellectual property theft has soured attempts to jumpstart bilateral clean energy R&D cooperation through programs like the U.S.-China Clean Energy Research Center, headquartered in Berkeley, California.†

Machine Tooling

Advanced economies like Germany are key suppliers of machine tools and robotics for China's clean energy technology industry. Germany is a world leader in producing and designing manufacturing equipment as well as core technologies, or the foundational hardware used to produce other technologies like solar modules, wind turbines, or chip wafers. According to Dr. Nahm, collaborations between German suppliers and Chinese manufacturers were at the heart of China's solar manufacturing boom, with German firms providing

*Toshiba purchased Westinghouse in 2006 for $5.4 billion amid a wider selloff by Westinghouse's parent company, British Nuclear Fuels Ltd. In 2018, Toshiba sold its stakes in Westinghouse to Bermuda-headquartered company Brookfield after Westinghouse declared bankruptcy. *World Nuclear News*, "Toshiba Sells Westinghouse-Related Assets in USA," April 6, 2018; *Reuters*, "Toshiba Buys Westinghouse for $5.4 Billion," March 8, 2006; Terry Macalister and Mark Milner, "Toshiba to Buy BNFL's Westinghouse," *Guardian*, January 23, 2006.

†The U.S.-China Clean Energy Research Center (CERC) was established by the U.S. and Chinese governments in 2011 to promote joint research between U.S. and Chinese clean energy research teams. For more information on attempts to establish U.S.-China clean energy technology cooperation, see U.S.-China Economic and Security Review Commission, Chapter 1, Section 4, "U.S.-China Energy Cooperation," in *2014 Annual Report to Congress*, November 2014, 183–226.

solar production equipment and retrofits for existing manufacturing lines.[206] Similar relationships support the Chinese wind turbine manufacturing industry, whereby German firms design and supply gearboxes, a core technology used to accelerate the rotation of wind turbines.[207] Chinese firms also remain dependent on foreign-produced lithography equipment for the semiconductors used within many clean energy technologies.[208] Recognizing the shortcomings of Chinese industry in core technologies and machine tooling, Chinese firms have prioritized accessing these resources and skills through trade, strategic acquisitions, localization requirements, and illicit activities. Illustrating this phenomenon, in the early 2000s the German wind turbine firm Vensys developed a new direct-drive technology for wind turbines that reduced cost and improved turbine reliability. Chinese turbine manufacturer Goldwind eventually acquired a majority stake in the company and now mass manufactures the technology in China, while upstream R&D is managed by Vensys in Germany.[209] By vertically integrating its R&D, Goldwind increases its ability to stay at the cutting edge of the industry and reduces the risk that more innovative firms will redirect the industry away from its core capabilities.[210]

Mass Manufacturing

China's global competitiveness in clean energy technologies derives from its ability to lower the costs of mass commercialization. With the support of subsidies and other industrial policy tools, China's mass production and assembly of technology components at scale has driven large-scale cost reductions, but these may ultimately harm consumers and undermine innovation. By creating "lock-in" to less innovative technologies that would not be commercially viable without extensive subsidization, the cost competitiveness of Chinese-manufactured technologies disincentivizes the commercialization of competing next-generation technologies.[211] This is an area where the United States possesses significant potential but continually struggles to commercialize new innovations.[212] For example, China's state-subsidized dominance over crystalline silicon solar cell manufacturing has contributed to their global proliferation, yet the U.S.-produced thin-film solar cells exhibit some technical advantages and could be produced at a lower cost.[213] Despite their potential advantages, thin-film solar cells accounted for only 5 percent of global market share in 2019, while crystalline silicon-based cells accounted for the other 95 percent.[214] As the world's solar manufacturing hub, China benefits from access to the innovation opportunities that occur during the production process and has thus continually made strides in reducing costs.

Market Size

China is also the fastest-growing market for clean energy technologies, creating additional opportunities for it to make technical innovations that improve upon existing technologies like wind turbines or solar modules and solve unique domestic energy problems. For example, China has built the world's longest and most powerful ultra-high-voltage (UHV) power lines to connect renewable energy sources in its northwest regions to the energy-hungry east coast.[215]

The challenges inherent in integrating China's geographically disparate renewable energy sources to energy consumers have incentivized China's major grid company, State Grid, to invest in developing smart grid technologies and advanced UHV power lines that it can commercialize and export.[216] State Grid has been a leading participant in BRI, where it has been involved in at least 16 grid development projects in countries around the world and claims to have exported equipment to over 80 countries.[217]

Given China's ongoing fossil fuel reliance, its anticipated domestic demand for CCUS technologies may represent another innovation opportunity for its clean energy technology industry. Because CCUS systems are designed to accommodate the unique infrastructure of individual power plants or other carbon-emitting factories, they are composed of numerous interconnected technologies and systems that can be customized or interchanged.[218] CCUS technologies therefore offer abundant opportunities for innovation. As the Chinese government attempts to reduce reliance on foreign oil imports, it also sees great promise in using the carbon dioxide captured from CCUS for enhanced oil recovery, a process that retrieves oil by injecting carbon dioxide into oil wells.[219] China's plan to double domestic CCUS capacity by 2025, coupled with investments by oil companies like Sinopec to develop CCUS technologies and use cases, mean China may be well positioned to develop the next generation of CCUS technologies.[220]

China's Critical Mineral Strategy Supports Its Technological Dominance

China's expanding role within global mineral supply chains complements its clean energy technology manufacturing ambitions while also increasing China's dependence on mineral imports to supply its industry. Chinese policymakers recognize that global demand for critical minerals will only increase as the "foundation for the green industrial economy" and have explicitly linked Chinese capabilities in the sector with energy security.[221] To support Chinese energy security through dominance over mineral supply chains, China seeks to establish influence through a multifaceted strategy combining (1) investments in foreign mineral extraction and transportation operations and (2) domestic dominance of raw material processing, separation, and refining (see Table 5).

Table 6: Refining Capacity for Key Minerals Used in Lithium-Ion Batteries, 2020

Mineral	China	United States	Japan
Lithium	61%	3%	0%
Cobalt	72%	0%	3%
Nickel	16%	0%	15%
Manganese	95%	0%	<5%

Source: U.S. Department of Energy, *Grid Energy Storage*, February 24, 2022, 20.

Investments across critical mineral value chains in regions like Africa and Latin America give China significant control over supply chains for key minerals used to produce clean energy technologies such as lithium, cobalt, copper, and rare earths. To gain access to mineral deposits in developing countries, Chinese SOEs have acquired ownership stakes in mines around the world and invested in mine exploration, processing and refining operations, and transport infrastructure. China's investments in global lithium mining and refining are well documented, with such investments occurring in Mexico as well as Latin America's "Lithium Triangle," encompassing Argentina, Bolivia, and Chile.[222] In August 2022, Chinese company Ganfeng Lithium paid approximately $253 million to complete its acquisition of British company Bacanora Lithium, which is currently building the world's biggest lithium mine (8.8 million metric tons) in Mexico's Sonoran Desert.[223] In 2022, Ganfeng also spent $962 million to acquire Argentine company Lithea, which owns the rights to two lithium salt lakes in Argentina.[224] Chinese companies acquired about 6.4 million metric tons of lithium reserves and resources in 2021, nearly as much as the amount acquired by all companies the year before.[225] Chinese companies have also outspent U.S. companies in this space, as they invested approximately $4.3 billion in lithium mining assets between 2018 and the first half of 2021, compared to the $1.4 billion invested by U.S. companies.[226] Chinese policy banks the China Development Bank and Export-Import Bank of China (China EXIM) further support China's mineral strategy by financing SOE investments around the world.[227] In 2007, China EXIM provided at least $6 billion in financing for Sinohydro and China Railway Group to carry out infrastructure and mining projects in the Democratic Republic of the Congo (DRC) in exchange for 68 percent ownership of one of Africa's largest copper and cobalt mines.[228] By specifically targeting debt-stressed mining operations in the DRC, Chinese firms were able to acquire ownership of or financial stakes in 15 of the country's 19 cobalt mines by 2020.[229]

China's role as the global hub for raw material refining and processing is a key component of its influence over critical mineral supply chains. Mineral refining processes intend to isolate and concentrate byproducts to increase mineral purity, often producing environmentally harmful toxic waste.[230] While the United States was once the world's leading supplier of rare earth minerals, environmental pressure and lower wages shifted the industry to China, which now controls about 85 percent of global rare earths processing.[231] Rare earth minerals are deposited across the globe; however, due to the financial and environmental costs of refining them domestically, most major miners of rare earths ship them to China for refining.[232] China's hold of raw material processing extends beyond rare earths to other minerals like lithium, cobalt, and graphite, which must be chemically processed to produce technologies like lithium-ion batteries. According to research by Benchmark Mineral Intelligence, by 2018 China produced 51 percent of the world's chemical lithium, 62 percent of the world's chemical cobalt, and 100 percent of the world's battery-grade graphite.[233]

Implications for the United States

The Chinese government sees itself as being in direct competition with the United States for influence and leadership across a broad array of policy areas affecting energy security. Although China's recent commercial energy shortages have largely been a result of its coal-dependent energy infrastructure and ineffective central government management, much of its policy is driven by considerations of the United States. China's government attempts to mitigate its perceived energy insecurity by attempting to diminish U.S. leadership in maritime security and clean energy technology. While China is currently experiencing relative stability in its energy security, recurring perceptions of insecurity among Chinese leaders indicate competition with the United States will likely intensify. Some of its actions suggest the CCP is preparing for a U.S. threat to China's energy supply.

Global energy prices and supply chains will continue to be susceptible to disruptions and shocks caused by Chinese government policy missteps. Chinese leaders' sense of energy insecurity combined with their reluctance to relinquish full control to private actors and free markets cause them to use prescriptive planning targets and energy price controls despite their contribution to numerous policy-induced energy crises. Despite loosening price controls to rectify the 2021 energy crisis, the Chinese government has simultaneously tightened its grip over the energy sector through SOE consolidation and state capture of renewable energy assets. Ultimately, the Chinese government sees markets as a tool for selective resource allocation rather than a guiding ethos for its energy sector.

With few alternative options to scale up new technologies and bring them to market, countries attempting to reduce the energy and carbon intensity of their industrial sectors will necessarily depend on Chinese supply chains. China is positioning itself to be the "central node" in a potentially "multi-trillion-dollar green economy" by coopting foreign innovation through subsidies, domestic production requirements, direct technology transfers, outright theft, and other policies. Despite making few breakthroughs in basic research, China has developed a decisive competitive advantage in commercializing clean energy technologies for mass manufacture. As a result, China now controls the majority of global solar panel production, leads in wind turbine manufacturing, and is increasing its control over the entire value chain for lithium-ion battery production.

The United States faces commercial and human rights risks stemming from China's intensifying influence over the clean energy industries. To achieve its nationally determined contribution under the Paris Climate Accords of reaching net zero carbon emissions by 2050, the United States will likely need to rely on China for a multitude of the technologies required for largescale decarbonization.[234] This reliance exacerbates existing U.S. dependencies on the Chinese economy and, as described by Nikos Tsafos, chief energy advisor to the Prime Minister of Greece, "ties U.S. energy priorities to Chinese industrial practices and location-specific shocks."[235] The solar industry continues to be illustrative of these risks. China's dominance within solar panel supply chains has forced U.S. policymakers to choose between environmental and human rights concerns, as the polysilicon for solar panels produced in China's Xinjiang Uyghur Autonomous Region (Xinjiang) was revealed to have been made using forced labor.* As Chinese producers expand and solidify their roles within clean energy technology supply chains, risks associated with market concentration and Chinese industrial practices will only become more pronounced.

In addition to growing its advantages in clean energy technologies and critical mineral supply chains, China's government is actively working to undermine U.S. advantages in maritime security. China's domestic tanker fleet and the PLA Navy's growing investment in Indian Ocean operations signal a coming challenge to the U.S. Navy's dominance of key sea lanes and may increase friction between the two navies as they operate with greater presence in closer quarters.

Climate competition may ultimately become a component of U.S.-China economic engagement. China's approach to decarbonization exposes leaders' concerns about economic and energy security, with a recognition that the Chinese economic model must eventually become more sustainable and less reliant on fossil fuels. While Chinese international climate commitments are relatively weak, China's leadership has identified decarbonization as critical to the CCP's domestic and international legitimacy. Clean energy technology competition with the United States is therefore likely to intensify because China views technological innovation as a silver bullet for its near-term climate liabilities. This is likely to perpetuate the same Chinese government industrial policies that have harmed U.S. industries for decades while locking out the clean energy innovations under development in the United States.

*While the U.S. government has intensified its efforts to crack down on solar panel components produced with forced labor in China's Xinjiang Uyghur Autonomous Region (Xinjiang), it has little visibility into conditions on the ground in Xinjiang and confronts challenges in discerning the origins of polysilicon once it reaches U.S. borders. The Uyghur Forced Labor Prevention Act, which was signed into law in December 2021, creates a rebuttable presumption that all goods produced in Xinjiang are produced with forced labor unless proven otherwise. The law went into effect on June 21, 2022. David Gelles, "Solar Industry 'Frozen' as Biden Administration Investigates China," *New York Times*, April 29, 2022; Thomas Kaplan, Chris Buckley, and Brad Plumer, "U.S. Bans Imports of Some Chinese Solar Materials Tied to Forced Labor," *New York Times*, June 24, 2021; Nikos Tsafos, "Addressing Forced Labor Concerns in Polysilicon Produced in Xinjiang," *Center for Strategic and International Studies*, June 7, 2021.

Appendix

Fossil Fuels: Coal, Petroleum, and Natural Gas

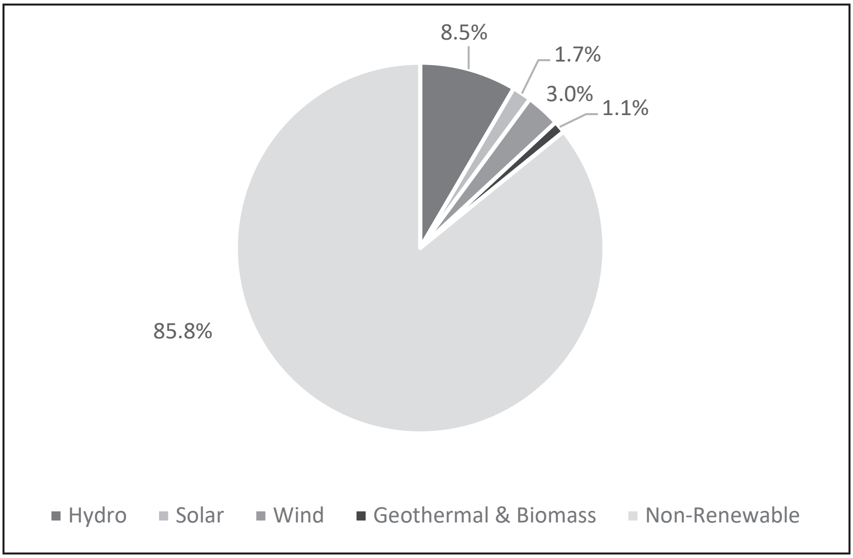
Coal, crude oil, and natural gas form from buried, fossilized remains of fauna and flora. These resources release energy when burned, emitting high concentrations of carbon into Earth's atmosphere in the process. The production method varies slightly depending on the fossil fuel type as well as where it is found, but generally the supply chain can be divided into three segments: exploration and extraction, refinement, and transmission and distribution.

- *Oil and natural gas:* China's oil and natural gas markets are dominated by three large state-owned companies: China National Petroleum Corporation, Sinopec, and China National Offshore Oil Corporation, the last of which has an external focus. Each is responsible for resource extraction, refining, pipeline development and management, investment, and maintaining national reserves, and all enjoy "administrative monopolies" or near-exclusive exploration rights from China's government. The companies occupy a quasi-ministerial rank within the central government and have significant influence over policymaking.[236] While monopoly rights exclude competitors in the upstream segment of the supply chain, China's midstream is dominated by excessive capacity in small "teapot refineries" known for lax environmental standards.[237]
- *Coal:* China's coal market is highly fragmented with thousands of local-level mines and power generators scattered throughout the country, though the largest and most productive mines are concentrated in central northern China.[238] China's southeastern coastal provinces typically import coal from overseas because much of China's coal is mined far from urban and industrial centers that require the most energy, and coal prices are largely determined by transportation costs. China's coal sector features mixed state and nonstate ownership, although the state maintains significant investments in nominally nonstate coal mines and power generators.[239]

Renewable Energy: Hydropower, Wind, Solar, Geothermal, and Biofuels

Renewable energy is power that comes from sources that are not depleted when used, such as sunlight or wind. It is narrower than "clean energy technology," which also includes energy storage and carbon sequestration technologies.

Figure 7: China Energy Consumption by Source, 2020 (Renewables Account for 14 Percent of China's Energy Mix)



Source: BP Statistical Review of World Energy Database.

- *Hydropower:* China is the world's leading hydropower producer, accounting for roughly 28 percent of global capacity in 2018.[240] The Three Gorges Dam in southwest China is the world's largest power station in terms of installed capacity, at 22.5 megawatts.[241] Construction of the dam took two decades and had an immense human and environmental toll, displacing some 1.4 million people and submerging two cities, 114 towns, and 1,680 villages.[242] Outside of largescale projects domestically, China's specialized construction SOEs like China Three Gorges Corporation are key entities in constructing BRI projects abroad.[243] Some of these projects have contributed to international backlash against BRI due to inadequate environmental impact assessment, such as SOE Sinohydro's Coca Codo Sinclair Dam in Ecuador, which was constructed on a fault line.[244] China's domestic hydropower system is vulnerable both to flooding, as occurred in the summers of 2020 and 2021 for much of central China, as well as droughts that occurred during the summer of 2021 (see the textbox "Drought and Heatwave Cause Second Summer Energy Crunch in a Row" above). The vast majority of some 98,000 dams and dikes on China's rivers date from the Mao era.[245] Many of these smaller dams are not structurally sound, creating unsecure reservoirs that could overflow or break through the dams, exacerbating downstream flooding.[246]
- *Wind:* China's wind energy market includes the wind farms that harvest wind energy and the manufacturers that produce wind turbines and turbine components. Both are primarily state owned, and the manufacturers serve the domestic market and are globally competitive in exporting turbines overseas.[247] Chi-

nese original equipment manufacturers (OEMs) accounted for ten of the top 15 OEMs in 2020, with China's largest manufacturer Goldwind* jumping from fourth place in 2019 to become second only to Dutch leader Vestas in 2020.[248]

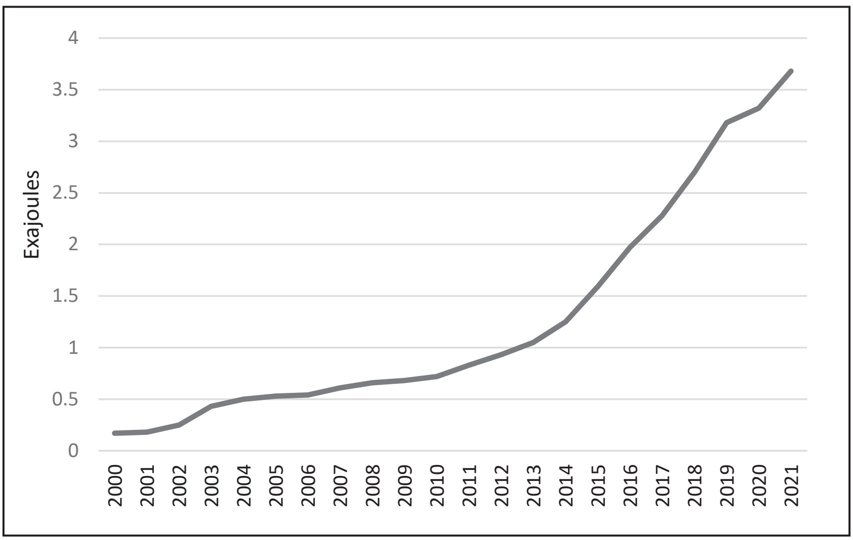
- *Solar:* China's solar component manufacturing industry features hundreds of firms that sprang up in response to local incentives and a strong export market.[249] The industry exhibits severe overcapacity and accounts for approximately 80 percent of global solar cell manufacturing.[250] Chinese firms are incredibly cost competitive and can produce solar components for 30–40 percent less than the United States.[251] Solar farms are concentrated in western China and are primarily state owned.[252]

Nuclear Energy

Nuclear energy is generated by either splitting or fusing atoms through a process of nuclear fission or fusion. This process creates heat that transforms water into steam, which turns a turbine to generate electricity.[253]

Market Structure

Figure 8: China Nuclear Energy Consumption Growth, 2000–2021



Note: While China's consumption of nuclear energy in 2021 was nearly 22 times greater than in 2000, nuclear still only accounts for about 2.2 percent of China's total energy consumption. BP, "Statistical Review of World Energy 2021."
Source: BP Statistical Review of World Energy Database.

- China's nuclear power generators are primarily state owned, while state-owned companies such as China General Nuclear Power Group (CGN) and China National Nuclear Corporation (CNNC) are heavily involved in developing nuclear equipment and components through subsidiaries and joint ventures.[254]

* Goldwind started as an SOE and still has a high minority share of state owners.

Foreign firms are also involved in China's civil nuclear industry, with U.S. firm Westinghouse selling the technology for its AP1000 reactor and entering into a joint venture with State Nuclear Power Technology Corporation to build out China's AP1000 supply chain.[255]

- CGN and CNNC both have distinct ties to the PLA. In August 2017, a nuclear engineer consulting for CGN was found guilty of corporate espionage in the United States after attempting to obtain unauthorized assistance to develop nuclear technologies with military applications.[256] As a result, the Commerce Department placed CGN on its Entity List, banning U.S. companies from supplying the company, and the Department of Energy announced a "presumption of denial" of any new licenses or extensions for technology exports to CGN.[257] Similarly, CNNC is the dominant Chinese institution responsible for processing and producing nuclear fuel for both civilian and military purposes, creating an explicit link between China's civilian nuclear power research and military application.[258] In 2020, the Department of Defense designated CNNC as a Communist Chinese Military Company associated with the PLA.[*] [259]
- China hopes to become a leading exporter of nuclear energy technology, but to date has only exported its commercial Hualong One reactor to Pakistan and is in talks to build one each in the UK and Argentina.[260] China has also sold smaller reactors to Ghana, Iran, and Syria, and it engages in research partnerships and cooperative arrangements with other developing countries, including Egypt, Kenya, Algeria, Ghana, Morocco, Sudan, Tunisia, Uganda, Cambodia, Kazakhstan, and Thailand.[261] China still lags behind major nuclear exporters, including Russia, Sweden, Germany, the United States, and France.[262]

Nuclear Safety

- China's civil nuclear industry has expanded rapidly over the past two decades; however, its safety culture and regulatory regime have not developed with equal speed and robustness. Lack of regulatory capacity and highly skilled personnel and the presence of counterfeit or substandard components all contribute to safety risks within China's civil nuclear industry.[263]
- Following the 2011 Fukushima disaster, China increased its scrutiny over its civil nuclear industry and required domestic regulations to fully incorporate International Atomic Energy Association safety standards.[264] Despite incorporating precautions, a 2021 radiation leak at China's Taishan nuclear power plant led to accusations that Chinese regulators increased acceptable radiation limits at the plant to avoid shutting it down.[265]

---

[*] Similarly, in December 2021 the U.S. Department of the Treasury included CNNC on its Non-Specially Designated Nationals and Blocked Persons Chinese Military-Industrial Complex Companies (NS-CMIC) list, identifying it as a company associated with the PLA and subject to certain sanctions. U.S. Department of the Treasury, *Non-SDN Chinese Military-Industrial Complex Companies List*, December 16, 2021, 7.

- China's own nuclear scientists admit that the reliability of Chinese-developed software products for nuclear plant design, operation, and safety evaluation are lacking, while fines for safety standard noncompliance were too low to act as an effective deterrent.[266] Poor supervision, manufacturing defects, insufficient testing of equipment, poor quality assurance, inadequate analysis of inspection results, lack of process control, poor skills in personnel, and failure to check installed equipment against design specifications have also been cited by China's National Nuclear Safety Administration as chronic deficits within China's civil nuclear safety culture.[267]
- China aims to develop and maintain a strong nuclear safety track record for its credibility as an exporter, and it partners with foreign companies and governments to achieve this objective.*[268] In expanding its role as a global exporter of nuclear technologies and building the largest reactor fleet, China may eventually have an outsized influence in setting future standards for the industry within the 21st century.[269]

Key Policy Goals

- *Economic:* Chinese policymakers hope to become fully self-sufficient in nuclear reactor technology to make China a leading exporter of nuclear energy technology.[270] In March 2018, CNNC China Nuclear Power Engineering Co., Ltd. President Liu Wei announced a goal to build 30 nuclear reactors in BRI countries by 2030.[271] In order to accomplish this, Chinese nuclear companies have been pursuing training and research partnerships.
- *Emissions:* Nuclear energy does not produce carbon emissions and is therefore expected to play a significant role in China's decarbonization. China's 14th FYP a Modern Energy System sets a target for installed operating capacity of nuclear power to reach 70 gigawatts by 2025.[272] As of May 2022, China's nuclear generation capacity is reportedly approximately 54.5 gigawatts.[273]
- *Security:* China's ongoing technological development of nuclear power will plausibly support buildup of its nuclear arsenal. China's options to produce nuclear weapon materials involve technology already being used or under development for nuclear reactors.[274] Because China's fleet of nuclear reactors is primarily located on its eastern seaboard, greater nuclear power in China's energy mix will also help reduce dependence on imported fossil fuel sources.

Challenges

- *Public opposition:* Nuclear disasters like Chernobyl, Three Mile Island, and Fukushima have generated public wariness and even opposition to nuclear energy projects. Since the Fukushima nuclear meltdown, Chinese policymakers have largely confined construction of nuclear reactors to coastal sites where

---

*For more on U.S.-China nuclear safety cooperation, see U.S.-China Economic and Security Review Commission, Chapter 1, Section 4, "U.S.-China Clean Energy Cooperation," in *2014 Annual Report to Congress*, November 2014.

seawater can more easily dilute and dissipate heat from the reactor should a meltdown occur. Concentrating China's civil nuclear buildup on the coast where population density is highest may generate resistance on economic, capacity, and political grounds.[275]

- *Commercial risks:* Nuclear reactor exports create long-term commitments between buyer and seller, as initial contractual discussions and construction take about ten years, operation lasts about 60 years, and decommission requires additional technical support.[276] Throughout this process, innumerable challenges can arise, creating risks for both the Chinese seller and the foreign buyer. Financially sound and politically stable countries are therefore ideal candidates for nuclear exports.
- *Innovation:* China's nuclear reactor technology is primarily replicated from designs developed in other countries.[277] To compete with industry leaders, China will need to improve foundational nuclear research if it is to develop more advanced nuclear technologies.[278]

ENDNOTES FOR SECTION 3

1. Enerdata, “Energy Intensity,” 2022.
2. Enerdata, “World Energy & Climate Statistics—Yearbook 2022.”
3. China National Bureau of Statistics via CEIC Database; World Bank, “Industry (Including Construction), Value Added (% of GDP)—China.”
4. China’s National Bureau of Statistics via CEIC Database.
5. Madhumitha Jaganmohan, “Leading Countries in Installed Renewable Energy Capacity Worldwide in 2021,” *Statista*, April 13, 2022; International Renewable Energy Agency, “Renewables Take Lion’s Share of Global Power Additions in 2021,” April 11, 2022; Center for Strategic and International Studies, “How Is China’s Energy Footprint Changing?” February 7, 2022; International Energy Agency, “Coal 2021,” December 2021; Mining Technology, “Countries with the Biggest Coal Reserves,” January 6, 2020; Global Carbon Project, “Global Carbon Atlas.”
6. BP Statistical Review of World Energy Database; BP, “Energy Outlook 2020-China,” 2020.
7. Gabriel Collins, written response to question for the record, U.S.-China Economic and Security Review Commission, *Hearing on China’s Energy Plans and Practices*, March 17, 2022, 1.
8. Gabriel Collins, written testimony for U.S.-China Economic and Security Review Commission, *Hearing on China’s Energy Plans and Practices*, March 17, 2022, 6.
9. Huaxia, “China Registers 18.71 Million Motor Vehicles in H1,” *Xinhua*, July 6, 2021.
10. Ping Huang and Ying Liu, “Renewable Energy Development in China: Spatial Clustering and Socio-Spatial Embeddedness,” *Current Sustainable/Renewable Energy Reports*, April 17, 2017.
11. Ding Yongbin, “The Persistence of Flexible Coal in a Deeply Decarbonizing Energy System,” *Environmental Research*, May 26, 2021; International Renewable Energy Agency, “Flexibility in Conventional Power Plants: Innovation Landscape Brief,” 2019.
12. Jinqiang Chen, “The Challenges and Promises of Greening China’s Economy,” *Harvard Belfer Center*, January 2017.
13. China State Council Information Office, *White Paper on Energy in China’s New Era* (《新时代的中国能源发展》白皮书), December 21, 2020. Translation; *People’s Daily*, “Xi Jinping: Actively Promote the Revolution of Energy Production and Consumption in China” (习近平：积极推动我国能源生产和消费革命), June 14, 2014. Translation.
14. *People’s Daily*, “Xi Jinping: Actively Promote the Revolution of Energy Production and Consumption in China” (习近平：积极推动我国能源生产和消费革命), June 14, 2014. Translation.
15. Enerdata, “World Energy & Climate Statistics—Yearbook 2022.”
16. Echo Xie, “A Reprieve for Coal? Xi Jinping Urges ‘Realism’ on China’s Road to Carbon Goals,” *South China Morning Post*, March 6, 2022.
17. International Energy Agency, “Oil, Gas and Coal Import Dependency in China, 2007–2019.”
18. Michal Meidan, written testimony for U.S.-China Economic and Security Review Commission, *Hearing on China’s Energy Plans and Practices*, March 17, 2022, 10.
19. Michal Meidan, written testimony for U.S.-China Economic and Security Review Commission, *Hearing on China’s Energy Plans and Practices*, March 17, 2022, 9; Energy Voice, “China’s Oil Demand to Peak by 2030 Says CNPC,” December 28, 2021.
20. Michal Meidan, written testimony for U.S.-China Economic and Security Review Commission, *Hearing on China’s Energy Plans and Practices*, March 17, 2022, 8–10; Kenji Kawase, “China’s Big Oil to Pour Cash into Boosting Domestic Output,” *Nikkei Asia*, April 6, 2022; Michal Meidan, “China’s Oil Demand in the Wake of COVID-19,” *Oxford Institute for Energy Studies*, September 2020; David Fickling, “How Will Oil Markets Cope without China’s Demand?” *Washington Post*, March 30, 2022.
21. China Petroleum and Chemical Industry Federation via CEIC Database; Institute for Energy Research, “China Is Investing in Its Domestic Oil and Gas Industry,” October 5, 2021.
22. Bertrand Rioux et al., “How Do Price Caps in China’s Electricity Sector Impact the Economics of Coal, Power and Wind? Potential Gains from Reforms,” *Energy Journal* 28, 65.
23. Bertrand Rioux et al., “How do Price Caps in China’s Electricity Sector Impact the Economics of Coal, Power and Wind? Potential Gains from Reforms,” *Energy Journal* 28, 65.
24. Michal Meidan, written testimony for U.S.-China Economic and Security Review Commission, *Hearing on China’s Energy Plans and Practices*, March 17, 2022, 11.

25. Ouyang Shijia, "NDRC Studying Ways to Stabilize Coal Prices over the Long Run," *China Daily*, October 26, 2021.
26. Keith Bradsher, "Power Outages Hit China, Threatening the Economy and Christmas," *New York Times*, September 27, 2021.
27. Alice Su, "Traffic Lights Gone Dark. Factories Shut Down. What Caused China's Power Crisis?" *Los Angeles Times*, October 2, 2021; Umesh Ellichipuram, "China Limits Power in at Least 20 Provinces amid Energy Crisis," *Power Technology*, September 29, 2021.
28. National Bureau of Statistics via CEIC Database. (Indicator is CN: Value Added of Industry YoY (Real))
29. Trading Economics, "Steel," 2022.
30. *Reuters*, "China's Scorching Southwest Extends Power Curbs as Drought, Heatwave Continue," August 22, 2022.
31. Primrose Riordan, Gloria Li, and Andy Lin, "China Drought Highlights Economic Damage Wrought by Global Warming," *Financial Times*, August 30, 2022.
32. *Reuters*, "The Power Crunch in China's Sichuan and Why It Matters," August 26, 2022.
33. BP Statistical Review of World Energy Database; *Reuters*, "The Power Crunch in China's Sichuan and Why It Matters," August 26, 2022.
34. Trivium China, "China Runs Dry," *One Thing from Beijing*, August 26, 2022; Primrose Riordan, Gloria Li, and Andy Lin, "China Drought Highlights Economic Damage Wrought by Global Warming," *Financial Times*, August 30, 2022.
35. Whet Moser, "Your Monday Briefing: Record Heat Disrupts China," *New York Times*, August 28, 2022; Weather Spark, "Climate and Average Weather Year Round in Chongqing."
36. Trivium China, "Well and Truly Blunted," *Trivium Markets*, August 24, 2022; Su-Lin Tan, "China Is Facing Another Power Crunch. But This Time It's Likely to Be Different," *CNBC*, August 23, 2022; *Reuters*, "China's Scorching Southwest Extends Power Curbs as Drought, Heatwave Continue," August 22, 2022.
37. Michal Meidan, written testimony for U.S.-China Economic and Security Review Commission, *Hearing on China's Energy Plans and Practices*, March 17, 2022, 10.
38. Michal Meidan, written testimony for U.S.-China Economic and Security Review Commission, *Hearing on China's Energy Plans and Practices*, March 17, 2022, 11.
39. Michal Meidan, written testimony for U.S.-China Economic and Security Review Commission, *Hearing on China's Energy Plans and Practices*, March 17, 2022, 11; Edmund Downie, "Gatekeepers of the Transition: How Provinces Are Adapting to China's National Decarbonization Pledges," *Columbia SIPA Center for Global Energy Policy*, November 22, 2021; Charlie Campbell, "Will China's Energy Crisis Make It More Reluctant to Fight Climate Change?" *Time*, September 30, 2021.
40. Charlie Campbell, "Will China's Energy Crisis Make It More Reluctant to Fight Climate Change?" *Time*, September 30, 2021.
41. International Energy Agency, "Coal Power's Sharp Rebound Is Taking It to a New Record in 2021, Threatening Net Zero Goals," December 17, 2021.
42. John Kemp, "Column: China's Widening Electricity Crisis Caused by Coal Shortage," *Reuters*, September 28, 2021.
43. Lucas Myers, "Internal Politics, Instability, and China's Frustrated Efforts to Escape the 'Malacca Dilemma,'" *Wilson Center*, July 20, 2021.
44. Ian Storey, "China's 'Malacca Dilemma,'" *China Brief*, April 12, 2006.
45. Jeffrey Becker, "China Maritime Report No. 11: Securing China's Lifelines across the Indian Ocean," *China Maritime Studies Institute*, December 2020, 2.
46. Jeffrey Becker, "China Maritime Report No. 11: Securing China's Lifelines across the Indian Ocean," *China Maritime Studies Institute*, December 2020, 4; Naval Research Academy Office of Political Affairs, "Hundreds of Jobs! The Naval Research Academy Turns to the Public to Recruit for Civilian Posts! What Are You Waiting For!" (百余岗位！海军研究院面向社会公开招聘文职，你还在等什么！), *PLA Navy Daily*, March 15, 2019. Translation.
47. Xiao Tianliang, ed., *The Science of Military Strategy* (Revised in 2020), PLA National Defense University Press, 2020, 295.
48. Gabriel Collins, written testimony for U.S.-China Economic and Security Review Commission, *Hearing on China's Energy Plans and Practices*, March 17, 2022, 9.
49. Emily Meierding, written response to question for the record, U.S.-China Economic and Security Review Commission, *Hearing on China's Energy Plans and Practices*, March 17, 2022, 7; Liz McCarthy, "12.2 Knots: The Secret to Efficient VLCC Chartering," *Lloyd's List*, April 11, 2013.
50. Sharon Cho, "More Russian Oil than Ever Before Is Heading for China and India," *Bloomberg*, May 26, 2022; Serene Cheong, "Rare Ship-to-Ship Transfers Keep

Oil Moving from Russia to China," *Bloomberg*, May 25, 2022; Christopher Helman, "Rerouting Russian Oil Would Require Dozens Of Supertankers—That Don't Exist," *Forbes*, April 11, 2022; S&P Global, "Analysis: Asia May Favor Russian Crude as Freight Rates Jump Post COSCO Dalian Sanctions," October 10, 2019.

51. Daniel Workman, "Top 15 Crude Oil Suppliers to China," *World's Top Exports*; Hannah Reale, Emma Bingham, and Kara Greenberg, "Where Does China Get Its Oil?" *Wire*, July 12, 2020.

52. Hannah Reale, Emma Bingham, and Kara Greenberg, "Where Does China Get Its Oil?" *Wire*, July 12, 2020.

53. Emily Meierding, written response to question for the record, U.S.-China Economic and Security Review Commission, *Hearing on China's Energy Plans and Practices*, March 17, 2022, 6.

54. Christopher Colley, written testimony for the U.S.-China Economic and Security Review Commission, *Hearing on China's Activities and Influence in South and Central Asia*, May 12, 2022, 1–2; Hu Bo, "The Global Maritime Multipolar Pattern and Rise of China's Navy" (全球海上多极格局与中国海军的崛起), *Academy of Ocean of China*, November 22, 2021.

55. Emily Meierding, written testimony for U.S.-China Economic and Security Review Commission, *Hearing on China's Energy Plans and Practices*, March 17, 2022, 8; Gabriel B. Collins and Andrew Erickson, "Chinese Efforts to Create a National Tanker Fleet," in Gabriel B. Collins et al., eds., *China's Energy Strategy: The Impact on Beijing's Maritime Policies*, China Maritime Studies Institute, 2008, 83.

56. Emily Meierding, written response to question for the record, U.S.-China Economic and Security Review Commission, *Hearing on China's Energy Plans and Practices*, March 17, 2022, 7–8.

57. Emily Meierding, written response to question for the record, U.S.-China Economic and Security Review Commission, *Hearing on China's Energy Plans and Practices*, March 17, 2022, 7–8.

58. Emily Meierding, written testimony for U.S.-China Economic and Security Review Commission, *Hearing on China's Energy Plans and Practices*, March 17, 2022, 8.

59. Xiao Tianliang, ed., *The Science of Military Strategy* (Revised in 2020), PLA National Defense University Press, 2020, 295.

60. Collin Koh (@CollinSLKoh), "New table reflecting latest counter-piracy deployment by PLA Navy's 40th Escort Task Force in Gulf of Aden. Southern Theater Command contributes forces this time, and Type-052D destroyer Hohhot debuts in this deployment. H/t: @supbrow for the heads-up. http://english.chinamil.com.cn/view/2022-01/16/content_10123678.htm," Twitter, January 15, 2022, 9:10 p.m; Tyler Headley, "China's Djibouti Base: A One Year Update," *Diplomat*, December 4, 2018; Jerome Henry, "China's Military Deployments in the Gulf of Aden: Anti-Piracy and Beyond," *Asie.Visions*, November 2016, 24–25.

61. U.S. Department of Defense, *Annual Report to Congress: Military Power of the People's Republic of China 2021*, November 3, 2021, X.

62. Gordon Lubold and Warren P. Strobel, "Secret Chinese Port Project in Persian Gulf Rattles U.S. Relations with U.A.E." *Wall Street Journal*, November 19, 2021.

63. U.S. Department of Defense, *Annual Report to Congress: Military and Security Developments Involving the People's Republic of China 2016*, April 26, 2016, 47.

64. Gabriel Collins, written testimony for U.S.-China Economic and Security Review Commission, *Hearing on China's Energy Plans and Practices*, March 17, 2022, 10.

65. China Power Project, "How Is China's Energy Footprint Changing?" *Center for Strategic and International* Studies, February 7, 2022; Stephen O'Sullivan, "China: Growing Import Volumes of LNG Highlight China's Rising Energy Import Dependency," *Oxford Institute*, June 2019, 3.

66. Chen Aizhu, "Russia, China Agree 30-Year Gas Deal via New Pipeline, to Settle in Euros," *Reuters*, February 4, 2022; N. Sönnichsen, "Natural Gas Consumption in China 1998–2021," *Statista*, July 13, 2022.

67. Iacob Koch-Weser and Craig Murray, "The China-Russia Gas Deal: Background and Implications for the Broader Relationship," *U.S.-China Economic and Security Review Commission,* June 9, 2014, 3, 10–11; Evelyn Cheng, "This Map Shows the Massive Gas Pipeline That Russia and China Are Building," *CNBC*, July 26, 2022; Chen Aizhu, "Russia, China Agree 30-Year Gas Deal via New Pipeline, to Settle in Euros," *Reuters*, February 4, 2022.

68. Gabriel Collins, written testimony for U.S.-China Economic and Security Review Commission, Hearing on China's Energy Plans and Practices, March 17, 2022, 11; N. Sönnichsen, "Natural Gas Consumption in China 1998–2021," Statista, July 13, 2022; N. Sönnichsen, "Oil Consumption in China 2005–2021," Statista, July 26, 2022; Anna Galtsova and Tianshi Huang, "'New' Gas from Russia to China via Power of

Siberia-2 Pipeline: New Route and New Strategic Opportunities," *IHS Market*, July 16, 2020; Statistical Review of World Energy—2021; China's Energy Market 2020.
69. Toru Takahashi, "Thai 'Land Bridge' Project Caught in Sino-U.S. Tug of War," *Nikkei Asia*, February 20, 2022; Rhea Menon, "Thailand's Kra Canal: China's Way around the Malacca Strait," *Diplomat*, April 6, 2018.
70. Toru Takahashi, "Thai 'Land Bridge' Project Caught in Sino-U.S. Tug of War," *Nikkei Asia*, February 20, 2022; Rhea Menon, "Thailand's Kra Canal: China's Way around the Malacca Strait," *Diplomat*, April 6, 2018.
71. Dipanjan Roy Chaudhury, "Myanmar Junta Expedites Work on China Funded Kyaukphyu Port," *Economic Times*, August 9, 2021; China Research Center, "A Relationship on a Pipeline: China and Myanmar," October 12, 2020.
72. Neslihan Topcu, "A Relationship on a Pipeline: China and Myanmar," *China Research Center*, October 12, 2020.
73. Gabriel Collins, written testimony for U.S.-China Economic and Security Review Commission, *Hearing on China's Energy Plans and Practices*, March 17, 2022, 10.
74. Gabriel Collins, written testimony for U.S.-China Economic and Security Review Commission, *Hearing on China's Energy Plans and Practices*, March 17, 2022, 10.
75. Gabriel Collins, written testimony for U.S.-China Economic and Security Review Commission, *Hearing on China's Energy Plans and Practices*, March 17, 2022, 10.
76. Gabriel Collins, written testimony for U.S.-China Economic and Security Review Commission, *Hearing on China's Energy Plans and Practices*, March 17, 2022, 13.
77. Argus Media, "China's Gas Consumption Seen Peaking by 2035," June 25, 2021.
78. Gabriel Collins, written testimony for U.S.-China Economic and Security Review Commission, *Hearing on China's Energy Plans and Practices*, March 17, 2022, 10.
79. Emily Meierding, written testimony for U.S.-China Economic and Security Review Commission, *Hearing on China's Energy Plans and Practices*, March 17, 2022, 4.
80. *China Petroleum News*, "For the First Time, PetroChina Achieves Three '100 Million Tons' of Domestic Annual Oil and Gas Equivalent Production, and Overseas Oil and Gas Equivalent Equity Production" (中国石油首次实现国内年产油、气当量和海外油气权益产量当量3个 "1亿吨"), January 25, 2021. Translation.
81. BP Statistical Review of World Energy 2021, 22; Li Hengyuan, "China's Overseas Oil and Gas Equity Production Increases" (我国海外油气权益产量上升), *China Mining News*, March 26, 2019. Translation.
82. Bo Kong, *China's International Petroleum Policy*, ABC-CLIO, 2010, 93.
83. Emily Meierding, written testimony for U.S.-China Economic and Security Review Commission, *Hearing on China's Energy Plans and Practices*, March 17, 2022, 4.
84. Guy C.K. Leung et al., "Securitization of Energy Supply Chains in China," *Applied Energy* 123 (June 15, 2014): 322.
85. Susana Moreira, "Learning from Failure: China's Overseas Oil Investments," *Journal of Current Chinese Affairs* 42:1 (March 2013): 131–165.
86. Edward Chow, oral testimony before the U.S.-China Economic and Security Review Commission, *Hearing on China's Energy Plans and Practices*, March 17, 2022, 154.
87. Monique Taylore, "China's Evolving Energy Security Strategy," *Asian Affairs* 52:4 (2021): 890–913, 898.
88. Samantha Gross, "The Global Energy Trade's New Center of Gravity," *Brookings Institution*, September 14, 2020.
89. Samantha Gross, "The Global Energy Trade's New Center of Gravity," *Brookings Institution*, September 14, 2020; Francesco Grigoli, Alexander Herman, and Andrew J Swiston, "A Crude Shock: Explaining the Impact of the 2014–2016 Oil Price Decline Across Exporters," *International Monetary Fund*, July 18, 2017, 3.
90. Monique Taylore, "China's Evolving Energy Security Strategy," *Asian Affairs* 52:4 (2021): 890–913, 898, 906.
91. Emily Meierding, written testimony for U.S.-China Economic and Security Review Commission, *Hearing on China's Energy Plans and Practices*, March 17, 2022, 6.
92. Monique Taylore, "China's Evolving Energy Security Strategy," *Asian Affairs* 52:4 (2021): 890–913, 898.
93. Jevans Nyabiage, "Angola Seeks to Rethink Debt Deal with China as Oil Revenue Slumps," *South China Morning Post*, June 7, 2020.
94. Monique Taylore, "China's Evolving Energy Security Strategy," *Asian Affairs* 52:4 (2021): 890–913, 898.
95. Yun Sun, "China's Aid to Africa: Monster or Messiah?" *Brookings Institution*, February 7, 2014.

96. David Mihalyi, Aisha Adam, and Jyhjong Hwang, “Resource-Backed Loans: Pitfalls and Potential,” *Natural Resource Governance Institute*, February 2020, 32.
97. Nicholas Casey and Clifford Krauss, “It Doesn’t Matter if Ecuador Can Afford This Dam. China Still Gets Paid,” *New York Times*, December 24, 2018.
98. Patricia I. Vasquez, “China’s Oil and Gas Footprint in Latin America and Africa,” *International Development Policy* 11:1 (2019): Paragraph 61.
99. Edward Chow, oral testimony before the U.S.-China Economic and Security Review Commission, *Hearing on China’s Energy Plans and Practices*, March 17, 2022, 161–162.
100. Vincent Tawiah, Jeleta Kebede, and Anthony Kyiu, “Corruption, Chinese Investment, and Trade: Evidence from Africa,” *Journal of Emerging Market Finance*, February 8, 2022.
101. Will Green and Taylore Roth, “China-Iran Relations: A Limited but Enduring Strategic Partnership,” U.S.-China Economic and Security Review Commission, June 28, 2021, 3; U.S.-China Economic and Security Review Commission, *Annual Report to Congress 2019*, November 2019, 315.
102. U.S. Energy Information Agency, *Country Analysis Executive Summary: China*, September 30, 2020, 6, 10.
103. Emily Meierding, oral testimony before the U.S.-China Economic and Security Review Commission, *Hearing on China’s Energy Plans and Practices*, March 17, 2022, 105.
104. Sharon Cho and Sarah Chen, “China Gorges on Cheap, Sanctioned Oil from Iran, Venezuela,” *Bloomberg*, January 11, 2022.
105. Nidhi Verma and Shu Zhang, “Analysis: Iran Slips Record Volume of Oil into China, Reaches out to Asian Clients for Trade Resumption,” *Reuters*, March 8, 2021.
106. Marybeth Davis et al., “China-Iran: A Limited Partnership,” *CENTRA Technology* (prepared for the U.S.-China Economic and Security Review Commission), April 2013, 5.
107. *Agence France-Presse*, “China, Iran Begin Implementation of Sweeping Strategic Agreement,” January 15, 2022; Nidhi Verma and Shu Zhang, “Analysis: Iran Slips Record Volume of Oil into China, Reaches out to Asian Clients for Trade Resumption,” *Reuters*, March 8, 2021.
108. Lucia Kassai, “Doctored and Rebranded Oil Blacklisted by U.S. Winds Up in China,” *Bloomberg*, January 21, 2021.
109. Lucia Kassai, “Doctored and Rebranded Oil Blacklisted by U.S. Winds Up in China,” *Bloomberg*, January 21, 2021; U.S. Department of the Treasury, *Teasury Targets Venezuelan Oil Sector Sanctions Evasion Network*, January 19, 2021.
110. Lauri Myllyvirta, Hubert Thieriot and Adrei Ilas, “Financing Putin’s War: Fossil Fuel Imports from Russia in the First 100 Days of the Invasion,” *Center for Research on Energy and Clean Air*, June 12, 2022.
111. Council of the European Union, “EU Sanctions against Russia Explained,” August 11, 2022.
112. Chen Aizhu and Florence Tan, “Exclusive: China State Refiners Shun New Russian Oil Trades, Teapots Fly under Radar,” *Reuters*, April 6, 2022; *Financial Times*, “Chinese Smartphone Shipments to Russia Plunge as Ruble Collapses,” March 9, 2022.
113. General Administration of Customs via CEIC.
114. Chen Aizhu, “China May Oil Imports from Russia Soar to a Record, Surpass Top Supplier Saudi,” *Reuters*, July 6, 2022.
115. Edward Chow, written testimony for U.S.-China Economic and Security Review Commission, *Hearing on China’s Energy Plans and Practices*, March 17, 2022, 3.
116. Edward Chow, oral testimony before the U.S.-China Economic and Security Review Commission, *Hearing on China’s Energy Plans and Practices*, March 17, 2022, 114.
117. Julia Gurol and Jacopo Scita, “China’s Persian Gulf Strategy: Keep Tehran and Riyadh Content,” *Atlantic Council*, January 24, 2020.
118. Jonathan Fulton, written testimony for U.S.-China Economic and Security Review Commission, *Hearing on U.S.-China Relations in 2020: Enduring Problems and Emerging Challenges*, September 9, 2020, 2; China’s Ministry of Foreign Affairs, *Xi Jinping Meets with Speaker of the Islamic Consultative Assembly Ali Larijani of Iran*, January 24, 2016; China Ministry of Foreign Affairs, “Xi Jinping Holds Talks with King Salman bin Abdulaziz Al Saud of Saudi Arabia,” January 19, 2016.
119. China Power Project, “How Is China’s Energy Footprint Changing?” *Center for Strategic and International Studies*, February 7, 2022.
120. Ben Hubbard and Amy Qin, “As the U.S. Pulls Back from the Mideast, China Leans In,” *New York Times*, February 2, 2022.

121. *CGTN*, "Full Text: Xi Jinping's Speech at the General Debate of the 7th Session of the United Nations General Assembly," September 23, 2020.
122. Swithin Lui, "Why China Is Set to Significantly Overachieve Its 2030 Climate Goals," *Carbon Brief*, May 19, 2022.
123. Michael Davidson, oral testimony for U.S.-China Economic and Security Review Commission, *Hearing on China's Energy Plans and Practices*, March 17, 2022, 53.
124. Lili Sun, Huijuan Cui, and Quansheng Ge, "Will China Achieve Its 2060 Carbon Neutral Commitment from the Provincial Perspective?" *Advances in Climate Change Research* 13:2 (April 2020): 169–178; Adam Vaughan, "China Is Building More than Half of the World's New Coal Power Plants," *New Scientist*, April 26, 2022.
125. Lili Sun, Huijuan Cui, and Quansheng Ge, "Will China Achieve Its 2060 Carbon Neutral Commitment from the Provincial Perspective?" *Advances in Climate Change Research* 13:2 (April 2020): 169–178.
126. Michael Davidson, oral testimony for U.S.-China Economic and Security Review Commission, *Hearing on China's Energy Plans and Practices*, March 17, 2022.
127. Rob Harris, "China's Pacific Climate Pitch Angers Australia, US," *Sydney Morning Herald*, August 16, 2019.
128. Ashley Westerman, "Some Pacific Island Nations Are Turning to China. Climate Change Is a Factor," *NPR*, November 23, 2019.
129. Ashley Westerman, "Some Pacific Island Nations Are Turning to China. Climate Change Is a Factor," *NPR*, November 23, 2019.
130. Lauri Myllyvirta, written testimony for U.S.-China Economic and Security Review Commission, *Hearing on China's Energy Plans and Practices*, March 17, 2022, 7.
131. Jane Golley, "China's Environmental Challenges: Under the Dome with No Way Out?" *Asia Pacific Journal* 14:22.3 (April 15, 2016).
132. Danielle Cave, "Under the Dome and India's Daughter: Documentaries Stir Powerful Online Reaction in Asia," *Lowy Institute*, March 11, 2015.
133. Tom Phillips, "China Arrests Anti-Smog Campaigners," *Telegraph*, March 9, 2015.
134. CK Yong, "Under the Dome: Is This China's Version of Silent Spring?" *Climate Home News*, September 3, 2015; Danielle Cave, "Under the Dome and India's Daughter: Documentaries Stir Powerful Online Reaction in Asia," *Lowy Institute*, March 11, 2015; Zheng Jinran, "Smog Documentary Goes Viral with 100m Viewers," *China Daily*, March 2, 2015.
135. Echo Xie, "A Reprieve for Coal? Xi Jinping Urges 'Realism' on China's Road to Carbon Goals," *South China Morning Post*, March 6, 2022.
136. Michal Meidan, written testimony for U.S.-China Economic and Security Review Commission, *Hearing on China's Energy Plans and Practices*, March 17, 2022, 12.
137. Trivium China, "The Good, the Bad, and the TBD," *Trivium China Net Zero*, March 10, 2022.
138. Global Energy Monitor, "China Dominates 2020 Coal Plant Development," February 2021, 2.
139. Global Energy Monitor, "Coal-Fired Power Capacity by Country (MW)," *Global Coal Plant Tracker*, July 2022; Global Energy Monitor, "New Coal-Fired Power Capacity by Country (MW)," *Global Coal Plant Tracker*, July 2022.
140. China's National Bureau of Statistics via CEIC Database.
141. Michal Meidan, oral testimony for U.S.-China Economic and Security Review Commission, *Hearing on China's Energy Plans and Practices*, March 17, 2022, 15.
142. Cecilia Han Springer, oral testimony for U.S.-China Economic and Security Review Commission, *Hearing on China's Energy Plans and Practices*, March 17, 2022, 221.
143. *Reuters*, "China Says EU's Planned Carbon Border Tax Violates Trade Principles," July 26, 2021.
144. White House, *Joint US-EU Statement on Trade in Steel and Aluminum*, October 31, 2021.
145. Gabriel Collins, oral testimony for U.S.-China Economic and Security Review Commission, *Hearing on China's Energy Plans and Practices*, March 17, 2022, 142.
146. Hudson Lockett and Thomas Hale, "Sustainable Investors Ponder Chinese Opportunities," *Financial Times*, October 17, 2021.
147. Eric Ng, "Climate Change: More Chinese and Asian Firms Disclose Greenhouse-Gas Emissions, but Lag in Reduction Commitments, Data Quality," *South China Morning Post*, May 22, 2022; Michal Meidan, oral testimony for U.S.-China Economic and Security Review Commission, *Hearing on China's Energy Plans and Practices*, March 17, 2022; Hudson Lockett and Thomas Hale, "Sustainable Investors Ponder Chinese Opportunities," *Financial Times*, October 17, 2021; Anna Zimmer-

mann Jin, "Supply Chain Transparency and Climate Mitigation in China," *Skoll*, September 21, 2017.
148. China's National Bureau of Statistics via CEIC database; Center for Strategic and International Studies, "How Is China's Energy Footprint Changing?" *China Power*, March 17, 2022.
149. Stephen Ezell, "China-Induced Global Overcapacity an Increasing Threat to High-Tech Industries," *Information Technology and Innovation Foundation*, February 27, 2018.
150. Sam Angell, "OECD Warns against Steel Overcapacity," *Argus Media*, September 29, 2020.
151. Mikhail Grant, Hannah Pitt, and Kate Larsen, "Mikhail Grant, Hannah Pitt, and Kate Larsen," *Rhodium Group*, March 4, 2021.
152. State Council of the People's Republic of China, *The Fourteenth Five-Year Plan for National Economic and Social Development of the People's Republic of China and the Outline of Long-Term Goals for 2035* (中华人民共和国国民经济和社会发展第十四个五年规划 和 2035 年远景目标纲要), March 12, 2021. Translation.
153. Lauri Myllyvirta, "China's Five-Year Plan: Baby Steps towards Carbon Neutrality," *Centre for Research on Energy and Clean Air*, March 5, 2021.
154. Lauri Myllyvirta, "China's Five-Year Plan: Baby Steps towards Carbon Neutrality," *Centre for Research on Energy and Clean Air*, March 5, 2021.
155. University of Alberta China Institute, "State-Owned Enterprises in the Chinese Economy Today: Role, Reform, and Revolution," 2018.
156. Jonas Nahm and Johannes Urpelainen, "The Enemy Within? Green Industrial Policy and Stranded Assets in China's Power Sector," *Global Environmental Politics*, November 2021; Ben Cahill and Ryan McNamara, "Chinese National Oil Companies Face the Energy Transition," *Center for Strategic and International Studies*, August 26, 2021.
157. Henry Lee, written testimony for U.S.-China Economic and Security Review Commission, Hearing on China's Energy Plans and Practices, March 17, 2022, 1; Ivy Yin, "China's State Power Grids to Prioritize Residential Supply, Boost Fuel Stocks," *S&P Global*, September 28, 2021.
158. Aluminum Corporation of China Limited, U.S. Securities and Exchange Commission Form 20-F/A, August 31, 2022; Fitch Ratings, "Aluminum Corporation of China," April 6, 2022; Fitch Ratings, "China Baowu Steel Group Corporation Limited," March 5, 2022; S&P Global, "China's Steel Industry Consolidation Speeds Up as Baowu Takes Over Xinyu Steel," April 25, 2022.
159. Ben Cahill and Ryan McNamara, "Chinese National Oil Companies Face the Energy Transition," *Center for Strategic and International Studies*, August 26, 2021.
160. Henry Lee, written testimony for U.S.-China Economic and Security Review Commission, *Hearing on China's Energy Plans and Practices,* March 17, 2022, 3.
161. Muyu Xu, Min Zhang, and Dominique Patton, "China Oil Hub Shandong Slammed over Illegal Capacity," *Nasdaq*, December 14, 2021.
162. Anders Hove, Michal Meidan, and Philip Andrews-Speed, "Software Versus Hardware: How China's Institutional Setting Helps and Hinders the Clean Energy Transition," *Oxford Institute for Energy Studies*, December 2021, 26.
163. Wendy Leutert, "The Political Mobility of China's Central State-Owned Enterprise Leaders," *Cambridge University*, January 8, 2018; Anders Hove, Michal Meidan, and Philip Andrews-Speed, "Software Versus Hardware: How China's Institutional Setting Helps and Hinders the Clean Energy Transition," *Oxford Institute for Energy Studies*, December 2021, 20.
164. Jinqiang Chen, "The Challenges and Promises of Greening China's Economy," *Harvard Belfer Center*, January 2017.
165. Jonas Nahm and Johannes Urpelainen, "The Enemy Within? Green Industrial Policy and Stranded Assets in China's Power Sector," *Global Environmental Politics*, November 2021, 89.
166. Michael Davidson, oral testimony for U.S.-China Economic and Security Review Commission, *Hearing on China's Energy Plans and Practices*, March 17, 2022, 48; Jonas Nahm and Johannes Urpelainen, "The Enemy Within? Green Industrial Policy and Stranded Assets in China's Power Sector," *Global Environmental Politics*, November 2021, 89.
167. Jenny Huang and Duncan Innes-Ker, "Chinese Coal, Steel and Cement Firms to See Further Consolidation," *Fitch Ratings*, September 16, 2021; Felix Chang, "China's Rare Earth Metals Consolidation and Market Power," *Foreign Policy Research Institute*, March 2, 2022.
168. Henry Lee, oral testimony for U.S.-China Economic and Security Review Commission, *Hearing on China's Energy Plans and Practices*, March 17, 2022, 7.

169. Anders Hove, Michal Meidan, and Philip Andrews-Speed, "Software Versus Hardware: How China's Institutional Setting Helps and Hinders the Clean Energy Transition," *Oxford Institute for Energy Studies*, December 2021, 8.
170. Anders Hove, Michal Meidan, and Philip Andrews-Speed, "Software Versus Hardware: How China's Institutional Setting Helps and Hinders the Clean Energy Transition," *Oxford Institute for Energy Studies*, December 2021, 19.
171. Anders Hove, Michal Meidan, and Philip Andrews-Speed, "Software Versus Hardware: How China's Institutional Setting Helps and Hinders the Clean Energy Transition," *Oxford Institute for Energy Studies*, December 2021, 19.
172. Anders Hove, Michal Meidan, and Philip Andrews-Speed, "Software Versus Hardware: How China's Institutional Setting Helps and Hinders the Clean Energy Transition," *Oxford Institute for Energy Studies*, December 2021.
173. International Energy Agency, "Renewable Electricity Growth Is Accelerating Faster than Ever Worldwide, Supporting the Emergence of the New Global Energy Economy," December 1, 2021; Daniel Gleeson, "Green Is Good: Playing to Win in a Multi-Trillion-Dollar Green-Tech Game," *International Mining*, November 29, 2021.
174. Ana Swanson and Chris Buckley, "Red Flags for Forced Labor Found in China's Car Battery Supply Chain," *New York Times*, June 20, 2022.
175. Uyghur Forced Labor Prevention Act, Pub. L. No. 117–78, 2021.
176. *Bloomberg*, "China's Solar Industry Is Slowly Shifting Away from Xinjiang," December 21, 2021.
177. U.S. Department of Energy, *Solar Photovoltaics Energy Supply Chain Deep Dive Assessment*, February 24, 2022; U.S. Department of Energy, *Wind Energy Supply Chain Deep Dive Assessment*, February 24, 2022, 10, 17–21; U.S. Department of Energy, *Grid Energy Storage*, February 24, 2022, 21; U.S. Department of Energy, *Achieving American Leadership in the Carbon Capture, Transport, and Storage Supply Chain*, February 24, 2022; U.S. Department of Energy, *Carbon Capture Technologies Supply Chain Deep Dive Assessment*, February 24, 2022; Sinopec, "Sinopec Completes China's First Megaton Scale Carbon Capture Project," *Cision PR Newswire*, January 29, 2022; *Argus Media*, "China's 2022 Vanadium Demand from VRFB Forecast to Rise," October 21, 2021; U.S. Department of Energy, *How Does Solar Work?*; Emiliano Bellini, "Future of Cadmium Telluride PV Tech," *PV Magazine*, May 13, 2021; Wood Mackenzie, "Global Wind Turbine Market: State of Play," April 14, 2021; U.S. Energy Information Administration, *Wind Explained*, March 17, 2021; Shishi Barla, "Extract: Global Wind Turbine OEMs 2020 Market Share," *Wood Mackenzie*, March 31, 2021, 3; Thomas Bowen et al., "Grid-Scale Battery Storage," *National Renewable Energy Laboratory*, 2019; Mat Dirjish, "What's the Difference between Thin-Film and Crystalline-Silicon Solar Panels?" *Electronic Design*, May 16, 2012; U.S. Department of Energy, *Wind Manufacturing and Supply Chain*.
178. State Council of the People's Republic of China, *Medium- and Long-Term Strategic Plan for the Development of Science and Technology* (国家中长期科学和技术发展规划纲要（2006—2020年)), 2006. Translation.
179. Jonas Nahm, *Collaborative Advantage: Forging Green Industries in the New Global Economy*, Oxford University Press, 2021, 115; Sherisse Pham, "Chinese Wind Turbine Firm Found Guilty of Stealing U.S. Secrets," *CNN*, January 25, 2018.
180. Jonas Nahm, *Collaborative Advantage: Forging Green Industries in the New Global Economy*, Oxford University Press, 2021, 112–113.
181. Sarah Ladislaw et al., "Industrial Policy, Trade, and Clean Energy Supply Chains," *Center for Strategic and International Studies*, February 2021, 11–13.
182. David M. Hart, "The Impact of China's Production Surge on Innovation in the Global Solar Photovoltaics Industry," *Information Technology and Innovation Foundation*, October 5, 2020, 1; Huizhong Tan, "Solar Energy in China: The Past, Present, and Future," *China Focus*, February 16, 2021.
183. U.S. Department of Energy, *Solar Photovoltaics Energy Supply Chain Deep Dive Assessment*, February 24, 2022, 17–21.
184. Huizhong Tan, "Solar Energy in China: The Past, Present, and Future," *China Focus*, February 16, 2021.
185. Yujie Xue, "China to Remain Renewable Energy Leader with Strong Capacity Growth in 2022, despite Subsidies Phase-Out," *South China Morning Post*, January 2, 2022.
186. Eamon Barrett, "China Electric Vehicle Sales Surged 154% Last Year, with Warren Buffett–Backed BYD Topping Tesla," *Fortune*, January 7, 2022; Clemens Dabelstein et al., "Winning the Chinese BEV Market: How Leading International OEMs Compete," *McKinsey & Company*, May 4, 2021; Jack Perkowski, "What China's Shifting Subsidies Could Mean for Its Electric Vehicle Industry," *Forbes*, July 13, 2018.
187. Scott Minos, "New Plug-in Electric Vehicle Sales in the United States Nearly Doubled from 2020 to 2021," U.S. Department of Energy, March 1, 2022.

188. Clemens Dabelstein et al., "Winning the Chinese BEV Market: How Leading International OEMs Compete," *McKinsey & Company*, May 4, 2021.
189. Vincent Shaw, "The Weekend Read: China's Battery Storage Awakening," *PV Magazine*, August 21, 2021.
190. U.S. Department of Energy, *Grid Energy Storage: Supply Chain Deep Dive Assessment*, February 24, 2022, x.
191. *Reuters*, "U.S. Solar Producer Asks Biden Administration for New Tariff Probe," February 9, 2022; Diane Cardwell, "U.S. Raises Tariffs on Chinese Wind-Turbine Makers," *New York Times*, July 27, 2012.
192. David Feldman, "To Understand Why Biden Extended Tariffs on Solar Panels, Take a Closer Look at Their Historical Impact," *The Conversation,* April 6, 2022; *Reuters*, "U.S. Solar Producer Asks Biden Administration for New Tariff Probe," February 9, 2022; Diane Cardwell, "U.S. Raises Tariffs on Chinese Wind-Turbine Makers," *New York Times*, July 27, 2012.
193. Jonas Nahm, written testimony for U.S.-China Economic and Security Review Commission, *Hearing on China's Energy Plans and Practices*, March 17, 2022, 6; Thomas Beline et al., "Crystalline Silicon Photovoltaic Cells, Whether or Not Assembled into Modules from the People's Republic of China," *Cassidy Levy Kent*, February 8, 2022, 1.
194. U.S. Department of Energy, *America's Strategy to Secure the Supply Chain for a Robust Clean Energy Transition*, February 24, 2022, 5, 9; David Hart, "Clean-Energy Technology Often Faces a 'Valley of Death'—This Idea Would Change That," *Market Watch*, October 9, 2020.
195. Jonas Nahm, *Collaborative Advantage: Forging Green Industries in the New Global Economy*, Oxford University Press, 2021, 151–183.
196. U.S. Department of Energy, "National Laboratories."
197. International Energy Agency, "Patents and the Energy Transition," April 2021, 6.
198. International Energy Agency, "Patents and the Energy Transition," April 2021, 6.
199. Jetta Wong and David M. Hart, "Mind the Gap: A Design for a New Energy Technology Commercialization Foundation," *Information Technology Innovation Foundation*, May 11, 2020.
200. American Physical Society, "This Month in Physics History," *APS News* 18:4 (April 2009).
201. Jonas Nahm, *Collaborative Advantage: Forging Green Industries in the New Global Economy*, Oxford, 2021; Jost Wübbeke and Björn Conrad, "'Industrie 4.0': Will German Technology Help China Catch Up with the West?" *Mercator Institute for China Studies*, April 14, 2015; Cora Jungbluth, "Is China Systematically Buying Up Key Technologies?" *Global Economic Dynamics*, 2018; Continental, "Belts Instead of Gearbox: Continental Equips Goldwind Wind Turbines with Efficient Drive Belts," May 25, 2020.
202. World Nuclear Association, "Nuclear Organisations in China," September 2020; Tai Ming Cheung et al., "Planning for Innovation: Understanding China's Plans for Technological, Energy, Industrial, and Defense Development," *University of California Institute on Global Conflict and Cooperation* (prepared for the U.S.-China Economic and Security Review Commission), July 28, 2016, 100; Kenneth Rapoza, "Westinghouse Electric's Chinese 'Trojan Horse,'" *Forbes*, May 17, 2016.
203. *Nuclear Newswire*, "China Greenlights Four Additional AP1000 Reactors," May 4, 2022; *Neutron Bytes*, "China Greenlights Six New Nuclear Reactors," April 28, 2022.
204. U.S. Department of Justice, *U.S. Charges Five Chinese Military Hackers for Cyber Espionage against U.S. Corporations and a Labor Organization for Commercial Advantage*, May 19, 2014.
205. Joanna I. Lewis, "A Better Approach to Intellectual Property?: Lessons from the US-China Clean Energy Research Center," *Paulson Center*, June 2015, 5–6.
206. Jonas Nahm, *Collaborative Advantage: Forging Green Industries in the New Global Economy*, Oxford University Press, 2021, 92–93.
207. Jonas Nahm, *Collaborative Advantage: Forging Green Industries in the New Global Economy*, Oxford University Press, 2021, 94–96; U.S. Department of Energy, *Advanced Wind Turbine Drivetrain Trends and Opportunities*, July 3, 2019.
208. Stu Wu and Yang Jie, "China Wants a Chip Machine from the Dutch. The U.S. Said No," *Wall Street Journal*, July 17, 2021.
209. Jonas Nahm, *Collaborative Advantage: Forging Green Industries in the New Global Economy*, Oxford University Press, 2021, 96–97.
210. Lin Ping et al., "Vertical Integration and Disruptive Cross-Market RD," *Munich Personal RePEc Archine*, 2017, 4.

211. Jonas Nahm, written testimony for U.S.-China Economic and Security Review Commission, *Hearing on China's Energy Plans and Practices*, March 17, 2022, 2.
212. Jonas Nahm, written testimony for U.S.-China Economic and Security Review Commission, *Hearing on China's Energy Plans and Practices*, March 17, 2022, 2.
213. *Global Newswire*, "Global Thin-Film Module Market (2020 to 2025) - Players Include United Solar Ovonic, TS Solar and NanoPV Solar among Others," November 27, 2020; 1st Sunflower, "The Difference between Thin Film and Crystalline Silicon Solar Panels," September 18, 2020; Mat Dirjish, "What's the Difference between Thin-Film and Crystalline-Silicon Solar Panels?" *Electronic Design*, May 16, 2020.
214. *Global Newswire*, "Global Thin-Film Module Market (2020 to 2025) - Players Include United Solar Ovonic, TS Solar and NanoPV Solar among Others," November 27, 2020.
215. *Bloomberg*, "World's Biggest Ultra-High Voltage Line Powers Up across China," *T&D World*, January 2, 2019.
216. REG Global, "China Focuses on Innovation to Revolutionise Its Power Sector," November 4, 2020.
217. State Grid Corporation of China, "State Grid, a Contributor to the Belt and Road Initiative," October 9, 2019; American Enterprise Institute, "China Global Investment Tracker," 2022.
218. U.S. Department of Energy, *Carbon Capture Technologies Supply Chain Deep Dive Assessment*, February 24, 2022, 3–4.
219. L. Bruce Hill, Xiaochun Li, and Ning Wei, "CO2-EOR in China: A Comparative Review," *International Journal of Greenhouse Gas Control* 103:103173 (November 2020): 1.
220. Eric Ng, "China's Plan to Double Carbon Capture Capacity by 2025 Hinges on Securing Funding for Projects," *South China Morning Post*, June 14, 2021; Sinopec, "Sinopec Completes China's First Megaton Scale Carbon Capture Project," *Cision PR Newswire*, January 29, 2022.
221. Nikos Tsafos, written testimony for U.S.-China Economic and Security Review Commission, *Hearing on China's Energy Plans and Practices*, March 17, 2022, 4.
222. Sarah Morland and Noe Torres, "Analysis: Lithium Experts Skeptical on Success of Mexico's State-Run Miner," *Reuters*, August 226, 2022; Ryan Berg, "South America's Lithium Triangle: Opportunities for the Biden Administration," *Center for Strategic and International Studies*, August 17, 2021.
223. Sen Ning, "Ganfeng Pays USD253 Million for UK's Bacanora to Acquire World's Biggest Lithium Mine Project," *Yicai Global*, August 11, 2022.
224. *Pandaily*, "Ganfeng Lithium Acquires Argentina-Focused Lithea for $962M," July 12, 2022.
225. Kip Keen and Camille Erickson, "China Mining, Battery Companies Sweep Up Lithium Supplies in Acquisition Blitz," *S&P Global*, November 1, 2021.
226. Kip Keen and Camille Erickson, "China Mining, Battery Companies Sweep Up Lithium Supplies in Acquisition Blitz," *S&P Global*, November 1, 2021.
227. *Foreign Policy*, "Mining the Future," May 1, 2019, 4; Friends of the Earth, "China Development Bank's Overseas Investments: An Assessment of Environmental and Social Policies and Practices," July 2012, 13–33.
228. *Foreign Policy*, "Mining the Future," May 1, 2019, 4.
229. Eric Lipton and Dionne Searcey, "Chinese Company Removed as Operator of Cobalt Mine in Congo," *New York Times*, February 28, 2022; *Foreign Policy*, "Mining the Future," May 1, 2019, 4.
230. Massachusetts Institute of Technology, "Environmental Costs of Refineries," 2016.
231. Samantha Subin, "The New U.S. Plan to Rival China and End Cornering of Market in Rare Earth Metals," *CNBC*, April 17, 2021; *Reuters*, "U.S. Dependence on China's Rare Earth: Trade War Vulnerability," June 27, 2019.
232. Sun Yu and Demetri Sevastopulo, "China Targets Rare Earth Export Curbs to Hobble US Defence Industry," *Financial Times*, February 16, 2021.
233. Christian Roselund, "State Department Issues Strategy on Diversifying Clean Energy, Storage Supply Chains," *PV Magazine*, June 14, 2019; Ecograf, "Graphite."
234. Josh Lederman and Denise Chow, "Biden Commits to Cutting U.S. Emissions in Half by 2030 as Part of Paris Climate Pact," *NBC News*, April 22, 2021.
235. Nikos Tsafos written testimony for U.S.-China Economic and Security Review Commission, *Hearing on China's Energy Plans and Practices*, March 17, 2022, 2.
236. Jonas Nahm, "The Energy Politics of China," in Kathleen Hancock and Juliann Allison, eds., *Oxford Handbook of Energy Politics*, April 2019, 15.
237. John Calabrese, "Something's Brewing: China's 'Teapot' Refineries and Middle East Oil Producers," *Middle East Institute,* May 19, 2022.
238. GlobalData, "China: Five Largest Coal Mines in 2021," July 2, 2022.

239. Jonas Nahm and Johannes Urpelainen, "The Enemy Within? Green Industrial Policy and Stranded Assets in China's Power Sector," *Global Environmental Politics*, November 2021.
240. Columbia University SIPA Center on Energy Policy Guide to Chinese Climate Policy, "Hydropower."
241. Walter Science School, "Three Gorges Dam, China Is the World's Largest Hydro Facility," *U.S. Geological Survey*.
242. Nectar Gan, "China's Three Gorges Dam Is One of the Largest Ever Created. Was It Worth It?" *CNN*, July 31, 2020.
243. Belt and Road Energy Cooperation, "China Three Gorges Corporation," April 27, 2020; Henrik Bergsager and Anna Korppoo, "China's State-Owned Enterprises as Climate Policy Actors," *Nordic Council of Ministers*, 2013.
244. Matthew Crittenden et al., "China's BRI in Latin America: Case Study—Hydropower in Bolivia," *National Geospatial-Intelligence Agency*, June 1, 2021; Nicholas Casey and Clifford Krauss, "It Doesn't Matter if Ecuador Can Afford This Dam. China Still Gets Paid," *New York Times*, December 24, 2018.
245. Rosa de Acosta and Max Rust, "China's Mighty Yangtze Is Heaving from Rain and the Three Gorges Will Be Tested," *Wall Street Journal*, July 25, 2020.
246. Rosa de Acosta and Max Rust, "China's Mighty Yangtze Is Heaving from Rain and the Three Gorges Will Be Tested," *Wall Street Journal*, July 25, 2020.
247. Blueweave Consulting and Research, "China Wind Energy Market Poised for Continued Growth- Projected to Grow at a CAGR of 10.2% during the Forecast Period (2022–2028)," January 19, 2022.
248. Shashi Barla, "Global Wind Turbine Market: State of Play," *Wood Mackenzie*, April 14, 2021, 3.
249. Matthew Hopkins and Yin Li, "The Rise of the Chinese Solar Photovoltaic Industry: Firms, Governments, and Global Competition," draft chapter for Yu Zhou, William Lazonick, and Yifei Sun, eds. *China as an Innovation Nation*, January 2015, 3–6; Henrik Bergsager and Anna Korppoo, "China's State-Owned Enterprises as Climate Policy Actors," *Nordic Council of Ministers*, 2013.
250. Kenneth Rapoza, "How China's Solar Industry Is Set Up to Be the New Green OPEC," *Forbes*, March 14, 2021.
251. U.S. Department of Energy, *Solar Photovoltaics Energy Supply Chain Deep Dive Assessment*, February 24, 2022, iv, 37.
252. U.S. Department of Energy, *Solar Photovoltaics Energy Supply Chain Deep Dive Assessment*, February 24, 2022, 8.
253. Nuclear Energy Institute, "What Is Nuclear Energy?"; U.S. Department of Energy, *Fission and Fusion: What Is the Difference?* April 1, 2021.
254. World Nuclear Association, "Nuclear Organisations in China," September 2020; Tai Ming Cheung et al., "Planning for Innovation: Understanding China's Plans for Technological, Energy, Industrial, and Defense Development," *University of California Institute on Global Conflict and Cooperation* (prepared for the U.S.-China Economic and Security Review Commission), July 28, 2016, 84.
255. Tai Ming Cheung et al., "Planning for Innovation: Understanding China's Plans for Technological, Energy, Industrial, and Defense Development," *University of California Institute on Global Conflict and Cooperation* (prepared for the U.S.-China Economic and Security Review Commission), July 28, 2016, 92–101.
256. U.S. Department of Justice, *U.S. Nuclear Engineer Sentenced to 24 Months in Prison for Violating the Atomic Energy Act*, August 31, 2017.
257. U.S. Department of Energy, *U.S. Policy Framework on Civil Nuclear Cooperation with China*; Christian Shepherd, "US Blacklists Chinese Nuclear Company over Theft of Military Tech," *Financial Times*, August 15, 2019.
258. World Nuclear Association, "Nuclear Organisations in China," September 2020.
259. Mark Hibbs, written testimony to the U.S.-China Economic and Security Review Commission, *Hearing on China's Nuclear Forces*, June 10, 2021, 3.
260. Echo Xie, "China Is Building a Nuclear Power Plant in Argentina as It Looks to Latin America," *South China Morning Post*, February 13, 2022; Chad Bray, "UK Regulators Sign Off on Chinese Nuclear Reactor Design," *South China Morning Post*, February 7, 2022; *Nuclear Newswire*, "First Hualong One Unit outside China Enters Commercial Operation," June 1, 2021; Jane Nakano, "China's Nuclear Power Sector: What It Is and What It Is Not (Yet)," *Center for Strategic and International Studies*, February 19, 2019.
261. World Nuclear Association, "Nuclear Power in Egypt," July 2022; World Nuclear Association, "Emerging Nuclear Energy Countries," May 2022; Dan Murtaugh and Krystal Chia, "China's Climate Goals Hinge on a $440 Billion Nuclear Buildout," *Bloomberg Green*, November 2, 2021.

262. Observatory of Economic Complexity, "Nuclear Reactors," 2021.

263. Mark Hibbs "The Future of Nuclear Power in China," *Carnegie Endowment for International Peace*, 2018, 85–89.

264. Darius Izad, "Cautious Optimism: China's Nuclear Energy Safety Measures Improving," *New Security Beat*, October 6, 2014.

265. David Stanway, "Explainer: What Happened at China's Taishan Nuclear Reactor?" *Reuters*, June 15, 2021.

266. Stephen Chen, "China's Nuclear Safety Queried over Taishan Reactor, but It Wants to Lead World by 2050," *South China Morning Post*, June 21, 2021.

267. Mark Hibbs, "The Future of Nuclear Power in China," *Carnegie Endowment for International Peace*, 2018, 87–89.

268. China National Nuclear Safety Administration, *2020 Annual Report*, May 19, 2021, 104–107; Adam Vaughan and Lily Kuo, "China's Long Game to Dominate Nuclear Power Relies on the UK," *Guardian*, July 26, 2018.

269. Jessica Lovering, written testimony for U.S.-China Economic and Security Review Commission, *Hearing on Technology, Trade, and Military-Civil Fusion: China's Pursuit of Artificial Intelligence, New Materials, and New Energy*, June 7, 2019, 1.

270. Tai Ming Cheung et al., "Planning for Innovation: Understanding China's Plans for Technological, Energy, Industrial, and Defense Development," *University of California Institute on Global Conflict and Cooperation* (prepared for the U.S.-China Economic and Security Review Commission), July 28, 2016, 92.

271. Chen Bing-Ming, "China's 'Nuclear Dragon' Goes Abroad: Exporting Nuclear Power Infrastructure through the Belt and Road Initiative," *Center for International Private Enterprise*, May 18, 2021, 4.

272. State Council of the People's Republic of China, *The Fourteenth Five-Year Plan for National Economic and Social Development of the People's Republic of China and the Outline of Long-Term Goals for 2035* (中华人民共和国国民经济和社会发展第十四个五年规划 和 2035 年远景目标纲要), March 12, 2021. Translation.

273. John S. Van Oudenaren, "Beijing Makes a Big Long-Term Bet on Nuclear Power," *Jamestown Foundation*, August 12, 2022.

274. Mark Hibbs, written testimony for U.S.-China Economic and Security Review Commission, *Hearing on China's Nuclear Forces*, June 10, 2021, 9.

275. Mark Hibbs, "The Future of Nuclear Power in China," *Carnegie Endowment for International Peace*, 2018, 2.

276. Chen Bing-Ming, "China's 'Nuclear Dragon' Goes Abroad: Exporting Nuclear Power Infrastructure through the Belt and Road Initiative," *Center for International Private Enterprise*, May 18, 2021, 5.

277. Mark Hibbs, "The Future of Nuclear Power in China," *Carnegie Endowment for International Peace*, 2018, 84–85.

278. Mark Hibbs, "The Future of Nuclear Power in China," *Carnegie Endowment for International Peace*, 2018, 84–85.